

## ■ Research Paper

# Time Management by Living Systems: Time Modularity, Rhythms and Conics Running Calendars. Methodology, Theory and Applications

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No system can be defined as an independent closed space but as an independent, autonomous closed 'time'. Its time modularity is evidenced by rhythms at different scales. Endogenous rhythms are built as a result of past interactive responses (time delays, entrainments and breakages) between its endophysiotope of functioning (ENDO) and its ecoexotope of survival (EXO). Modelling has to take into account the concepts of temporal window, 'Before the time has come, it's too soon. Once the time has passed, it's too late.'; time latency and time shifting, 'It is necessary to give some time to the time.'; compartmentation of the time, 'There is a time for each event. And each event is located into its time place.'; nonlinearity and non-summation, 'The temporal Whole is both more and less than the sum of its Parts.'; and interactions between time and space, 'The time arrow structures the space functionalities of living systems. But, the systems compartments structure back the arrow of their time.' Time knowledge requires skills and tools to be designed by the system so as to manage time when accomplishing specific tasks to survive. It appears that timelines are designed as ellipses projected on a plan or a Moebius strip and labelled alongside with dates and events on points where they absolutely have to happen. The emergence of a new blueprint runs through the juxtaposition and embedment of previous systems. The new time of the whole emerges through the simultaneous metamorphoses of the parts into their whole. Each subsystem maintains its space–time identity into the whole with which it is a partner, a *Parcener*.<sup>1</sup> The partial autonomy of each partner is allowed through the maintenance of individual or collective spatial and temporal boundaries. These interfaces structure the

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<sup>1</sup> Old French *parçonier*, from *parçon*, from Latin *partitio* a sharing, from *partire* to divide. A person who takes an equal share with another or others, who inherits an estate as coheir with others. <http://www.memidex.com/parcener>

spatiotemporal integration of the parts into the ENDO of their whole and of the whole into its EXO of survival. The transition from one level of organization to a superior one results from the building of a new spatiotemporal network. In this new orderly spaced-timed system, many braces are allowed, but each partner owns a special place, both through the time and into the space. The whole emerges with the building of an Association for the Reciprocal and Mutual Sharing of Advantages and DisAdvantages (<http://armsada.eu>). That allows—in a no-change EXO—the maintenance of both a requisite variety of partners and the unity of the whole. If the ENDO or EXO ever changes, that is the only way to set a new networking mode of organization and integration. These associations emerge through the interactive fitness between ‘the capacity to welcome’ of the EXO and ‘the capacity to be welcome’ of the ENDO of each parcener. Failures of medical treatments and pathological processes can be explained in terms of breakages of time architectures. Inside a system, time can stop, move with different speeds and jump from one step to another but will never turn back. When a step is in the past, a complete new cycle is needed to reach it again. Copyright © 2013 John Wiley & Sons, Ltd.

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INTRODUCTION

The *holistic approach* of the description of a living system is based on the concept that that system (Figure 1) is a participant not only to its own

evolution but also to that of all the subsystems it contains and of all the systems in which it is a subsystem (Nikolaeva-Hubenova, 2001). Thus, no system must be defined as an independent, autonomous closed space, but it can be described

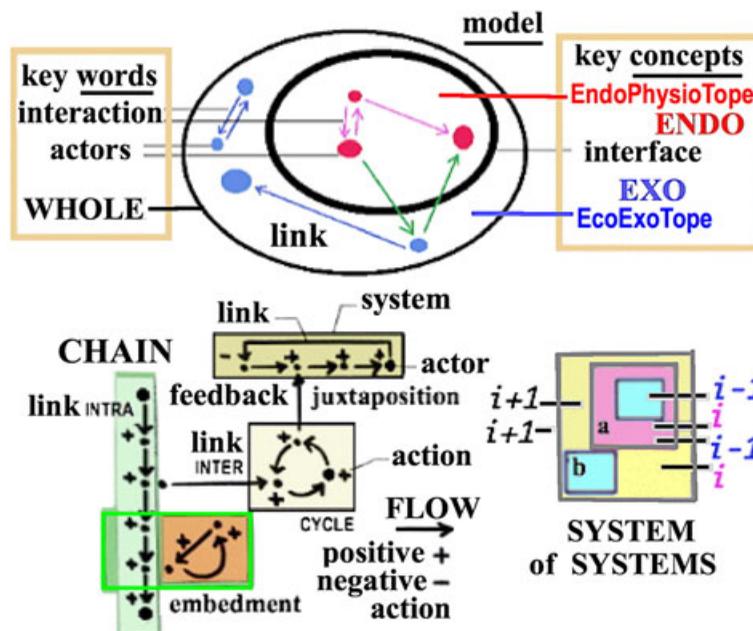


Figure 1 Spatial organization of a system: ecoexotope and endophysiotope. Every living system is first a wholeness but made of actors that are juxtaposed and embedded in subsystems and in interactions: links (indicated with arrows). So the ENDO of a system  $i$  is always the EXO of survival of the subsystems  $i - 1$  it is hosting and its EXO is the ENDO of a system  $i + 1$  in which it is hosted (Bricage, 2002, 2010a)

as an independent, autonomous closed time! Whatever its organization, a living system is integrated into an ecoexotope (EXO)—from Greek, exo: external, tope: space–time, eco: of inhabitation—from which it cannot be separated and into which it is welcome ('hosting capacity' of the EXO). The mutual interactions between this EXO and the system's endophysiotope (ENDO)—from Greek, endo: internal, tope: space–time, physio: of functioning—shape their mutual morphogenesis (Bricage, 2005c). The 'capacity to be welcome' of the ENDO results from its spatial and temporal modular organization. Its survival and ontogeny result from interactions between the EXO and ENDO (Bricage, 2002). These spatial interactions are represented by conics graphs (Bricage, 2010a) meaning that the space of a whole system is both more and less than the sum of the spaces of its subsystems parts (Figure 1). But the

EXO and ENDO temporal structures are usually different. Is the time of a system made of juxtaposed and embedded times of its subsystems, such as the space is (Bricage, 2009)?

THE TIME ARROW IS AN ORIENTED ELLIPSE

**Ecoexotope and Endophysiotope: The Artificial Time of the Observer is not the Intrinsic Time of the Observed Subject**

Usually, the evolution of a system is represented using the time of the observer: looking at the glycaemia of somebody we say the glycaemia and insulinaemia runs in parallel and the insulinaemia and glucagonaemia in opposite (Figure 2 (left)). Using the simplest (first order) adjustment, we can say the correlation is a line (Figure 8 (top)).

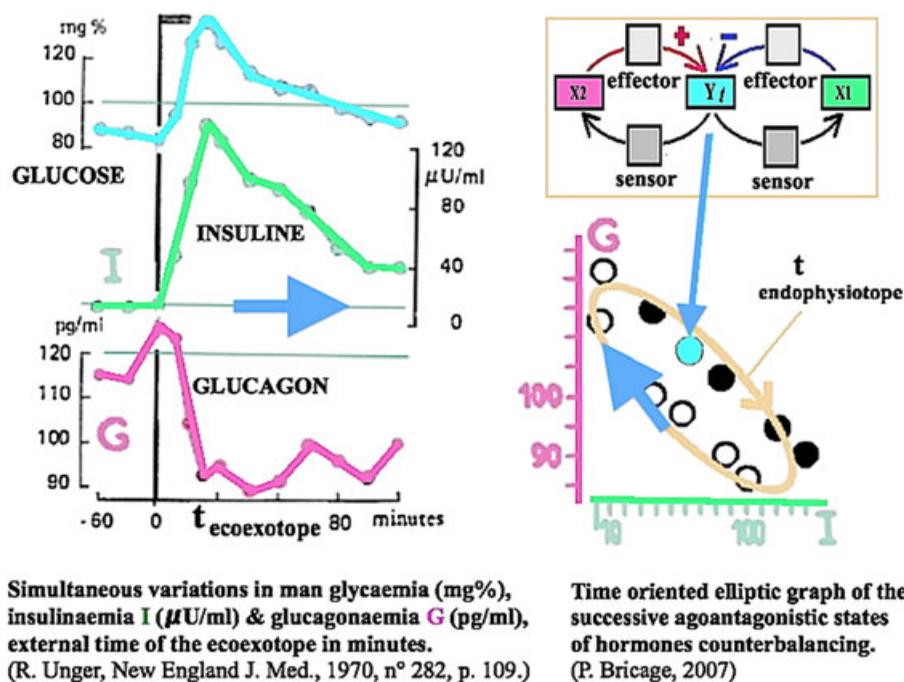


Figure 2 Glycaemia calendar: a systemic constructal law with two actors. On the left, the real two phases process: first, a rapid change then a long slow return, with glycaemia (glucose concentration) and insulinaemia (insulin concentration) running in parallel and insulinaemia and glucagonaemia (glucagon concentration) running in opposite. Antagonist local interactive actors: insulin (hypoglycaemic hormone) secreting cells or glucagon (hyperglycaemic hormone) secreting cells. On the right, the whole agoantagonistic process: model: X1, X2 antagonistic local (cell level) controlling actors (Figure 10), + or – positive (increasing) or negative (decreasing) effect, Y global controlled variable: glucose (organism level, adjacent superior level of the cell level) at time t, reality: I insulinaemia, G glucagonaemia, agoantagonistic emergent process of a controlling clock t, the endophysiotope of the organism is the ecoexotope of survival of the cells (Bricage, 2007)

But looking at the sequence of the values, we see that the evolution is different depending on which phase we are focusing on among the two phases of the process. The real time clock is an ellipse calendar (*second order cybernetics*), and the time of the ENDO is running along it, always in a unique way, without turning back (Figure 2 (right)).

### Different Endophysiotope Calendars Run Simultaneously

Looking at an asthma crisis (Figure 3), using the EXO time of the observer (in which the day is longer than the night), we see the histaminaemia and adrenalinaemia run in opposite. With the

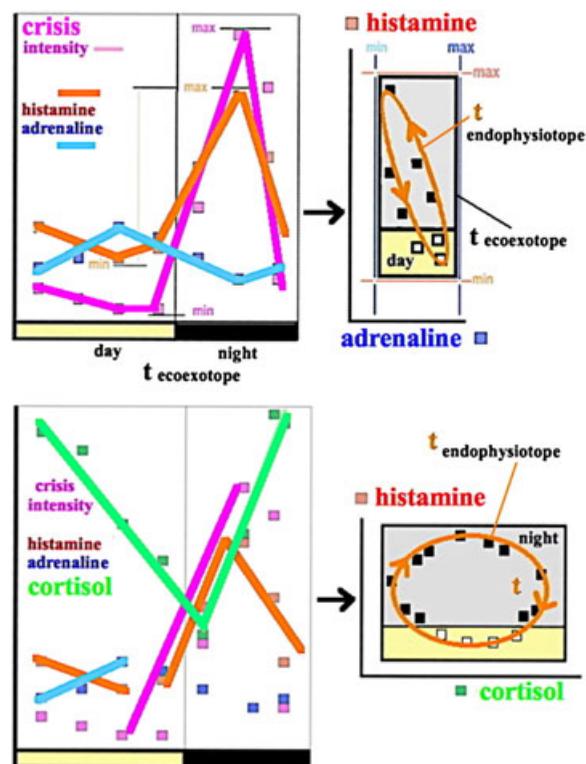


Figure 3 Asthma crisis control calendars. Three actors: A, adrenaline; C, cortisol; and H, histamine. On the left: their relative amounts running (reference time is that of the observer: ecoexotope), in per cent of their respective maximum (adapted from Barnes *et al.*, 1980). On the right: the two corresponding endophysiotope conics running calendars (Bricage, 2012a), with opposite time moves (real internal times of functioning), depending on agoantagonistic interactions

simplest (first order) adjustment, the correlation is a line (Barnes *et al.*, 1980). But with the sequence of the values, we see that the ENDO time calendar is an ellipse too. Yet, the time is moving along two different ellipses; in a unique way, without turning back, but with opposite directions, depending on the interaction. The night phase in that calendar is relatively three times greater than the day one that explains why the crisis is so stressful for the patient.

### Entrainment of Metabolic Chains of the Endophysiotope by the Temperature Changes of the Ecoexotope

Looking at the anthocyanin pigments in *Lathyrus* leaves (Bricage, 1985), we see that from one day (of the time of the observer) to another, the trisubstituted products (which are synthesized from the disubstituted ones) are increasing with the increase of the temperature daily difference (Tdd). After a first order adjustment of the cloud of values, the correlation is a line (Figure 4). But with the values sequencing, we see that the ENDO time calendar is an ellipse too. The line is its axis. The temperature evolution within the EXO structures the ENDO time way and speed of running. The time is irregular; within a no-change EXO, it can stop but never turns back.

### SPACE STRUCTURES TIME AND RECIPROCALLY

#### Various Ecoexotope Zeitgebers, Different Alarms and Watching Systems but Only One Endophysiotope Clock

From one day to another, the maximum enzyme capacities of the isoperoxidase activities in *Pedilanthus* leaves (Bricage, 1986) (Figure 5 (left)) are timed—either by the light on (whatever the temperature and the day length): family M (Figure 5 (right)), by the temperature peak (whatever the day length): family R, or by the Tdd: family L. The daily metabolic expression of the peroxidases activities—with the synthesis of anthocyanins such as in *Lathyrus* (Figure 4)—is fixed by the thermoperiod:

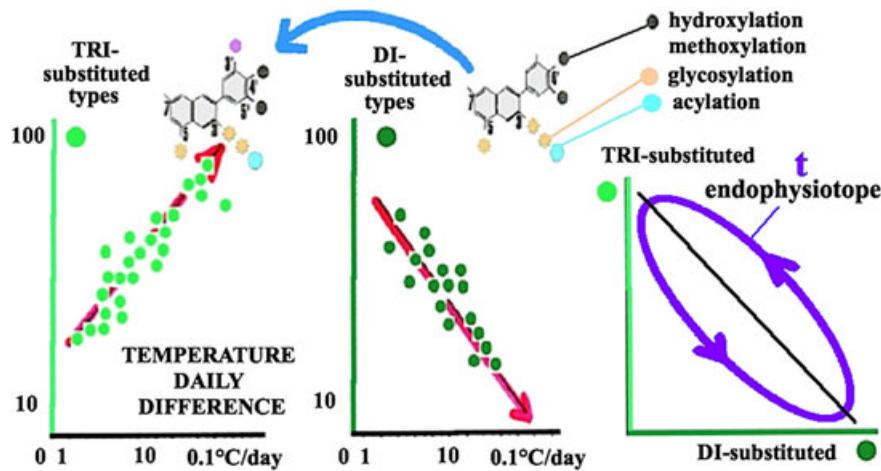


Figure 4 The temperature of the ecoexotope structures the endophysiotope time. Enzymes' substrates: D-substituted anthocyanin pigments, enzymes' products: TRI-substituted anthocyanin pigments in per cent, temperature daily differences (TdD) in 0.1°C/day (Bricage, 1985), t endophysiotope time calendar.

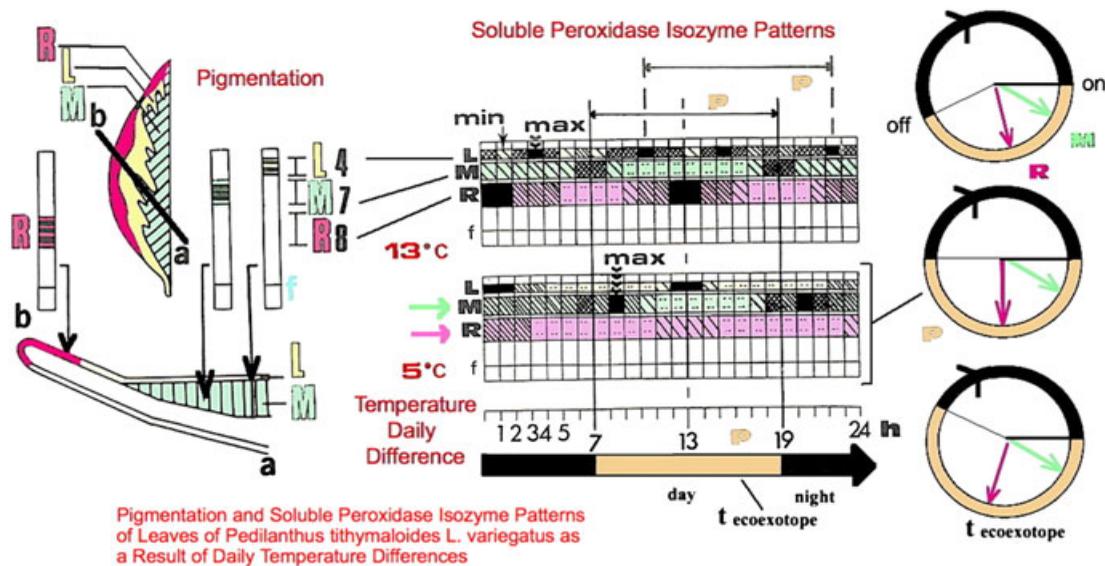


Figure 5 Peroxidases daily timing: three actors, three spaces, three zeitgebers and one clock. On the left: half-leaf section ab of *Pedilanthus tithymaloides* L. variegatus, with the palisade layer (M) and the epidermis (L). Tissue associated peroxidases families (three actors in three different spaces): M family (seven isozymes) in palisade layer cells (chloroplasts linked), L family (four isozymes) in yellow (expressed at low temperature daily differences) then white epidermis cells, R family (eight isozymes) in epidermis red (anthocyanins synthesis only at high temperature daily differences) sectors cells—acrylamide gel electrophoresis separations. On the middle: daily patterns of peroxidase capacities (optimum conditions), min minimum, max maximum, at 13°C or 5°C constant temperature daily differences. P photoperiod (constant light—here 12 h—night in black), t time of the ecoexotope (night/day). On the right: 24h watch. Zeitgebers: constant temperature daily difference (TdD), light: constant intensity, on/off light on/off, P light duration (different photoperiods). A same endophysiotope clock but different hours of the ecoexotope (Bricage, 1986): first arrow: a 'fixed timed' event (M) and second arrow: a 'variable timed' event (R)

the hourly position of the maximum intensity depends on the TdD (Fig. 5 (middle)). Everything takes place as if the number of possible events within the ENDO—the graduation of the timetable (family L) and the intensity of an event, that is the number of rung knocks indicating the hour (family R)—depended on the temperature of the EXO. The EXO zeitgebers structure the ENDO clock (clock making), and its hours of enzymes bursts (wake making). Time is irregular but never turns back. The plant is a pericline chimera, so the growth of leaf tissues is directly linked to the changes of light and temperature and indirectly to the enzymes activities. The spaces of the ENDO structure the local ENDO times and *reciprocally*.

### Ecosystem Evolution: Timing of a Run Through the Time

Look at the spatial and temporal organization of the food chains (Figure 6 (middle top)) into a forest

(bois de Pau, France) (Bricage *et al.*, 1989). The forest health is evaluated with four parameters NIV, DIV, DEN and ENV (Figure 6 (middle)). They are markers of the local structure and functioning of the food chains. Where the plants variety is too low ( $ENV < 4$ ) or too high ( $ENV > 6$ ), the forest is endangered because the deciduous trees are the keystone species (Bricage, 2010b, 2010c) of the ecosystem. There are two metastable steady state equilibria ( $ENV = 4$  and  $ENV = 6$ ) at which NIV is the lowest, allowing the *mutual* survival of the preys (the trees) and their predators (the insects) and the best survival for the whole. ‘To survive that is first to eat and not to be eaten.’ (Bricage, 2005b), ‘For the one to survive, the other one must survive first.’, ‘At the end, soon or late, every being is eaten’ (Bricage, 2010b).

The global survival of the forest is allowed only if a minimal area of healthy potential reproductive trees will survive: *a threshold* number of local spaces where the trees biodiversity *remains between* 3 and 7. We can follow year by year, place to place,

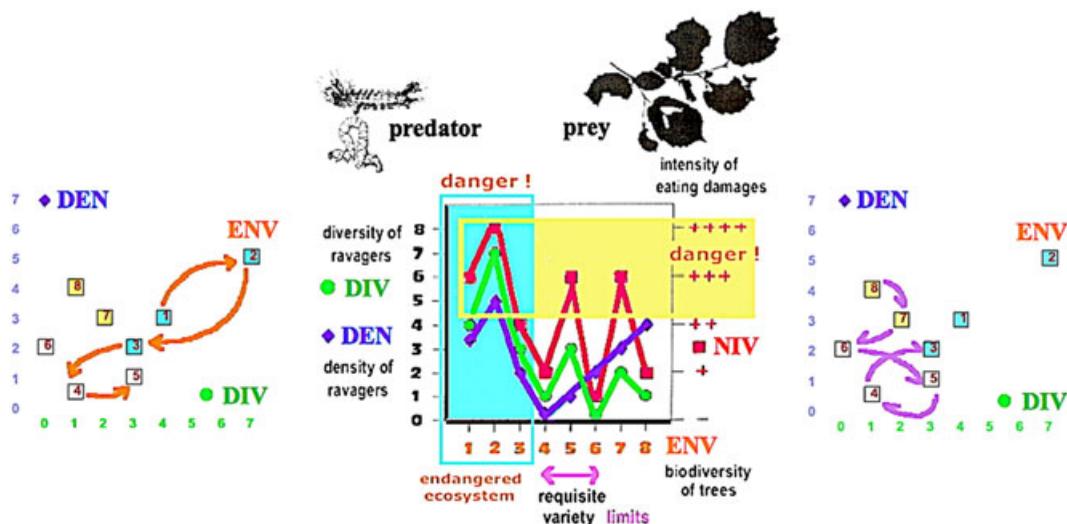


Figure 6 Towards the equilibrium (climax) of a forest ecosystem. Middle top: prey example: leaves of hazel tree; predator examples: *Lymantria dispar* and *Erannis defoliaria* caterpillars. Middle graph: NIV intensity of eating damages (−5%, +20%, ++40%, +++ +80% foliar area reduction), ravagers caterpillars species diversity DIV (1, 2, 3...) and density DEN (1x, 2x, 3x ...), diversity of local plant species ENV (Bricage *et al.*, 1989), requisite variety: nothing in excess (meden agan), ‘variété indispensable présente au préalable, ni trop grande, ni trop petite suivant les moyens disponibles pour un but précis’ (Vallée, 2003). Left: the step by step story from a place where the diversity of the local actors ( $ENV = 1, 2, 3$ ) is not sufficient for the survival of the whole (the forest), unless a new ACTOR is integrated (the arrow indicates the developmental way) in order the forest to reach ‘as quickly as possible’ an equilibrium (climax), the zone of metastable states ( $ENV = 4, 5, 6$ ) where the differentiated forest survival is allowed without change or with a moderated one (one actor). Right: the opposite supposed step by step way from a planted forest running downwards the equilibrium, the calendar of retrogression of the system if the actors (ENV) dissociated gradually (1 by 1), whatever is the order of elimination of a previous actor (Bricage, 2010c, 2012a)

the changes of the number (ENV and DIV) of the local actors. If the system is balanced, we can observe no change for several years. We can observe a system's answer, but that is to an aggression from the outside; only when a human intervention has taken place (deforestations, plantations or both). Let us suppose that the actors (ENV) joined gradually (1 by 1)—to establish a forest through colonization of a naked space, whatever the order of integration of each new actor—or as the opposite dissociated gradually (1 by 1 too)—if the diversity of the local actors is too high (ENV = 7, 8) for the survival of the whole, previous actors must be eliminated (retrogression). The actor's constraints of survival, the story of the development or the retrogression of the whole (Bricage, 1986, 2005b)—evidenced by ENV changes and represented by the relation between the DEN and DIV of the ravagers' populations—is not an ellipse but an analemma. Why?

### Endophysiotope Timing in a Through Space Run

In a fixed place on Earth, the annual graph of the time equation is a curve called a solar analemma. Every point of this curve represents a position of the sun but photographed every day at the same

hour. Its shape depends on that same hour of recording (<http://fr.wikipedia.org/wiki/Analemma>).

The duration changes of the longest and shortest night cycles of a man's daily sleep follow lunar calendars (Bricage, 1993) with the shape of analemmas (Figure 7 (middle)). They are evidenced by factorial analysis of correspondences (Figure 7) between the durations of the cycles and the dates of the lunar cycles (moving in perigee or apogee, moving in ascent and descent). Everything fits as if the sleeper was a fixed point looking to the Moon and following with his or her eyes the lunar trajectory (lunar analemma) as an Earth fixed camera follows the visible trajectory of the sun during the course of the Earth around it (solar analemma). In the factorial plans, the intersection point of the axes and the stacked or juxtaposed analemmas fits with all the other days of the timetable (Figure 7 (middle, right)). Everything runs as if the ENDO physiological time, at that point, stops, whereas the time of the EXO runs ahead regularly. During the moving from ascent to descent—or reversely—and on apogee or perigee, for few days before and after, the local ENDO time restarts, accelerates and then stops again. The ENDO time exists only when the EXO time is changing. The movements of outside actors in the EXO space are what create the inside (Kampis, 1994) ENDO time. The interactions

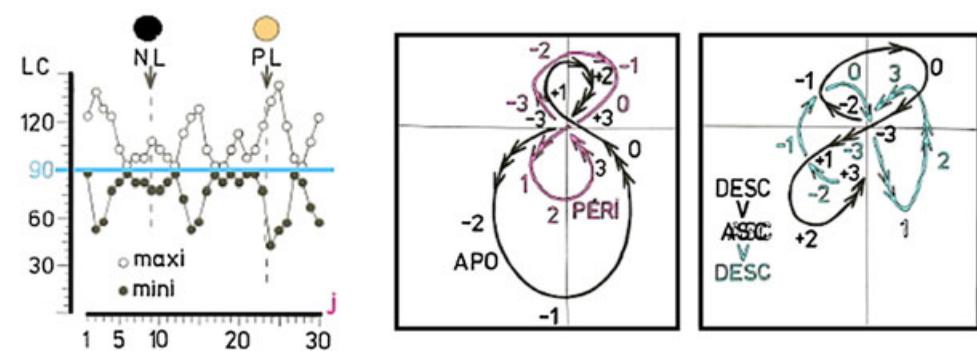


Figure 7 Sleep night cycles daily durations calendars are lunar analemmas. Left: LC the shortest (mini) and longest (maxi) durations (in minutes) of all the cycles of a night sleep—LC mean: 90 min; during a 30-day J period; with a lunar cycle (NL new moon, PL full moon); without change of location of the sleeper. Middle: multifactorial analysis of correspondences projection map, with the times of the lunar cycle APO/PERI,  $-3, -2, -1$  the 3 days before,  $+1, +2, +3$  the 3 days after, 0 day of apogee APO or perigee PERI. All the other days are fused together in the plan of projection at the axes intersection point. Right: projection map with the times of the descendant phase/ascendant phase lunar cycle DESC/ASC,  $-3, -2, -1$  the 3 days before the change,  $+1, +2, +3$  the 3 days after, 0 from DESC to ASC change or ASC to DESC change. All the other days are fused together in the plan of projection at the axes intersection point (Bricage, 1993, 1997)

between the EXO and ENDO spaces create the internal time into the ENDO. Why is the trajectory *an analemma* just like the one of the forest running towards its climax (Figure 6 (left))?

ENDO moving in its ECO is a conic ( $Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0$ ); a calendar according to which forecasted events are ordered (Figures 2 (right), 3 and 4).

## MODELLING OF THEIR TIME TEMPLATE BY LIVING SYSTEMS

The time whole is both more and less than the sum of its time parts (Table 1). What is true for the space (Bricage, 2012a) is true for the time (Bricage, 2012b)! The usual time trajectory—on a plan of projection ( $x, y$ )—of a living system

## Why Is the Timeline an Ellipse?

1-sine waves—sinusoids—are graphs of the repetitive oscillations occurring in biological processes (such as glycaemia under regulation) and in signal processing. In the affine plan, with orthonormal axes, the resultant of two oscillations (Table 2)—whose variations are antagonist—

Table 1 The simplest fields of interaction are graphed as conics. The whole time is  $Y = T$  and its  $i$  ( $i = 1$  to  $n$ ) Parts are  $X_i = t_i$ ,  $Y = f(X)$  representative graph of interaction of two systems  $X_1$  and  $X_2$  (Figure 12)

### **The WHOLE is both more and the less than the sum of its PARTS.**

$$\begin{aligned} \mathbf{T} = \mathbf{K} \text{ or } \mathbf{t_i} = \mathbf{K_i} & \text{ independence of the parts } \mathbf{t_i} \text{ and the whole } \mathbf{T} \\ \mathbf{T} = \sum (\mathbf{k_i \cdot t_i}) & \text{ the WHOLE is limited by the PARTS,} \\ & \text{ limiting factors of the whole, or} \\ \mathbf{t_i} = \mathbf{k'_i \cdot T} & \text{ the PARTS are limited by the WHOLE,} \\ & \text{ limiting factor of the parts.} \end{aligned}$$

The *welcome capacity* is limited by the *to be welcomed capacity*, reciprocally the *capacity to be welcomed* is limited by the *welcome capacity*.

$\mathbf{bT} = \sum (\mathbf{a_i \cdot t_i}) + \mathbf{K}$  "The whole is bigger than the sum of the parts." (Confucius)  
but it can also be the sum of its parts,  
sometimes it is smaller, but mostly "it is different"!

**Line in 2D ( $n = 2$ )**  $\mathbf{a_1 \cdot X_1 + a_2 \cdot X_2 = K}$  (which is a conic)  
 $\mathbf{X_1, X_2}$  are the building actors, ENDO  $\mathbf{T}$  is running in a unique way along the line.

### **The WHOLE is more and less than the product of its PARTS.**

The simplest graphic 2D representations are always conics or assembly of conics. The usual space trajectory of a mobile in a field of gravity, is a conic. The same for "the time trajectory" of a living system ENDO moving in its ECO. Its projection on the plan ( $x, y$ ) is a **CONIC**:  $Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0$   
 $x, y$  are the building actors, ENDO  $T$  is running in a unique way along the ellipse.

$$\begin{aligned} \text{Circle} & \quad \mathbf{X_i^2 + X_j^2 = K^2} \text{ (in the plan of projection } \mathbf{X_i, X_j}) \\ \text{Parabola} & \quad \mathbf{X_i = k \cdot X_j^2 + K} \\ \text{Hyperbola} & \quad \mathbf{X_i \cdot X_j = K} \text{ the WHOLE is the product of the parts} \\ & \quad \text{(welcome capacity) x (capacity to be welcomed) = K,} \\ & \quad \mathbf{(X_1 + X_2) \cdot (X_1 - X_2) = X_1^2 - X_2^2 = K} \text{ in 2D (n=2)} \\ & \quad \text{the WHOLE is the product of the sum and the difference of the parts} \\ \text{Ellipse} & \quad \mathbf{(X_1 + X_2) \cdot (X_2 + X_1) = X_1^2 + X_2^2 + 2X_1X_2 = K} \text{ in 2D (n=2)} \\ & \quad \text{the WHOLE is the square product of the sum of the parts.} \end{aligned}$$

Table 2 Emergence of the whole time from its time parts. Juxtaposed and embedded oscillations: time whole  $Y$ , time parts  $X_i$

- graph of a **repetitive oscillation X** (1 actor):

**sine wave or sinusoid**

$$X(t) = A \cdot \sin(\omega t + \phi)$$

**A amplitude**

**What** is the peak deviation of the function from its centre position.

**$\omega$  angular frequency**

**How Many** oscillations occur in a unit **time interval t**.

**$\phi$  phase**

**Where** in its cycle,  $t = 0$ , the oscillation begins.

- parametrising of **2 antagonistic juxtaposed running oscillations X1, X2** (2 actors):

$$X1(t) = a1 + A1 \cdot \cos(\omega_1 t + \phi_1),$$

$$X2(t) = a2 + A2 \cdot \sin(\omega_2 t + \phi_2)$$

**ellipse** if a **same EXO zeitgeber** is synchronising the 2 ENDO waves:

$$\omega_1 = \omega_2$$

- parametrising of **3 agoantagonistic juxtaposed and embedded running oscillations X1, X2, X3** (3 actors):

**Moebius strip**

$$X1(t) = (a + A \cdot \cos(\omega t / 2)) \cdot \cos(\omega t),$$

$$X2(t) = (a + A \cdot \cos(\omega t / 2)) \cdot \sin(\omega t),$$

$$X3(t) = A \cdot \sin(\omega t / 2)$$

gives an ellipse as a periodic configuration (Figure 2 (right) and 3): the ellipse<sup>2</sup> is the simplest Lissajous curve formed when the horizontal and vertical motions are sinusoids with the same frequency. A circle is an ellipse. In Euclidean geometry, ellipses arise as images of a circle under parallel projection and the bounded case of perspective projection, which are intersections of the projective cone with the *plan of projection*. An ellipse is defined as the bounded case of a conic section or as the set of all points of the plan such that the sum of the distances to two fixed points is constant. Each focus of the ellipse is associated with a *line* parallel to the minor axis

<sup>2</sup> <http://en.wikipedia.org/wiki/Sinusoid> and <http://en.wikipedia.org/wiki/Ellipse>

called a directrix. In geometry, by projective duality, an ellipse is also defined as the envelope of all lines that connect corresponding points of two lines that are related by a projective map. This definition also generates hyperbolas and parabolas. However, in projective geometry, every conic section is equivalent to an ellipse. A parabola is an ellipse that is tangent to the line at infinity, and the hyperbola is an ellipse that crosses it. An ellipse may be defined with a circle or a composition of two circles as directrix. It is a special case of hypotrochoid. The image of an ellipse by any affine map is an ellipse and so is the image of an ellipse *by any projective map* such that the line does not touch nor cross the ellipse. The result from the projection of a circle, ellipse or sphere (3D) on a plan (2D), by parallel lines,

is also an ellipse. An ellipse has 5 degrees of freedom, defining its position (where the calendar is), orientation (the way the arrow of the time is oriented), shape (the strength of the link between the actors) and scale (depending on the level of organization). Circles or parabolas have less degrees of freedom. The general solution for a harmonic oscillator in two or more dimensions is *an ellipse*. As it is the case for any object that moves under the influence of an attractive force that is directly proportional to its distance from

a fixed attractor (Figure 8), time is running under the influence of an attractive field.

### What Is the Timeline—an Ellipse or an Analemme?

A conic section is the intersection of a plan and a cone. The observed conic depends on both the plan of projection and the position of the observer. By changing the angle and location of

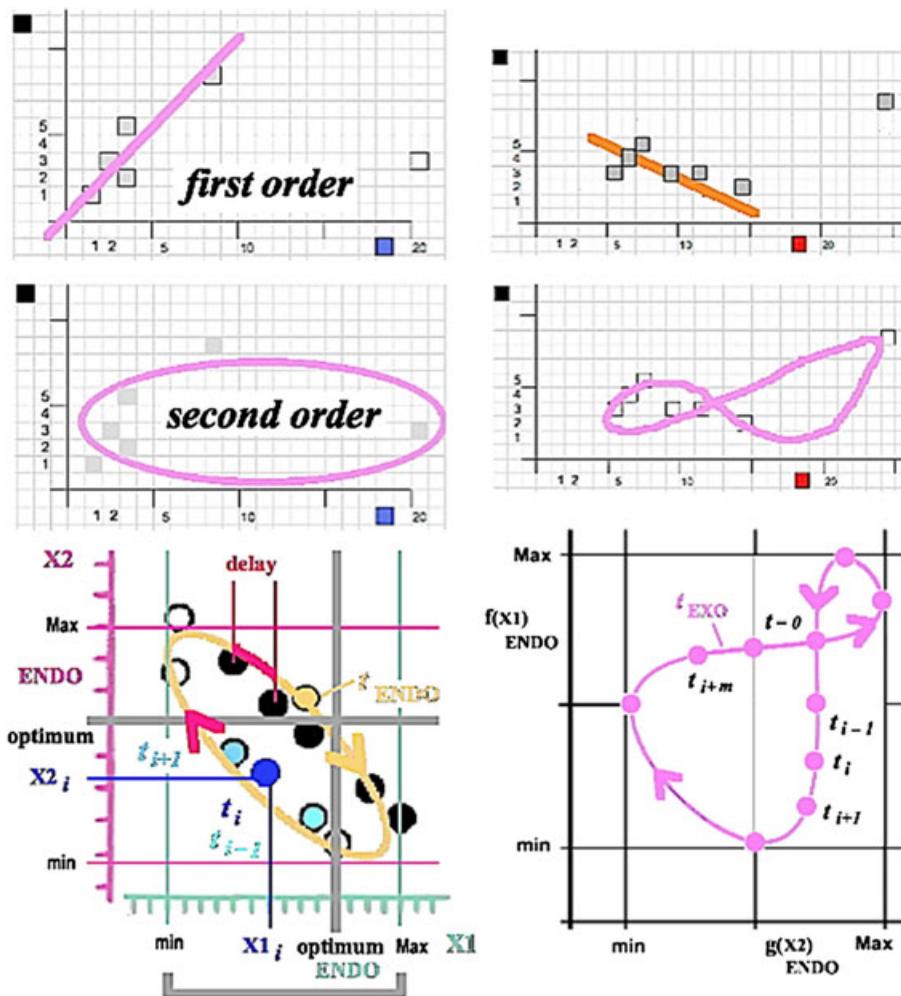


Figure 8 From first order to second order cybernetics (Bricage, 2010a, 2012b). Top: line (linear adjustment), first order relationship; agonism, amplification or positive feedback (left) for example FSH and LH in menstrual cycle; antagonism, negative feedback (right) for example FSH and oestrogens in menstrual cycle. Middle: agoantagonism, ellipse (left), analemme (right)—second order timelines. Down: ellipse ENDO timeline built by two antagonist ENDO actors, for example glycaemia—(left); control of the functioning of two ENDO actors by a recalled analemme EXO timeline, for example man sleep—(right) (Bricage, 1997)

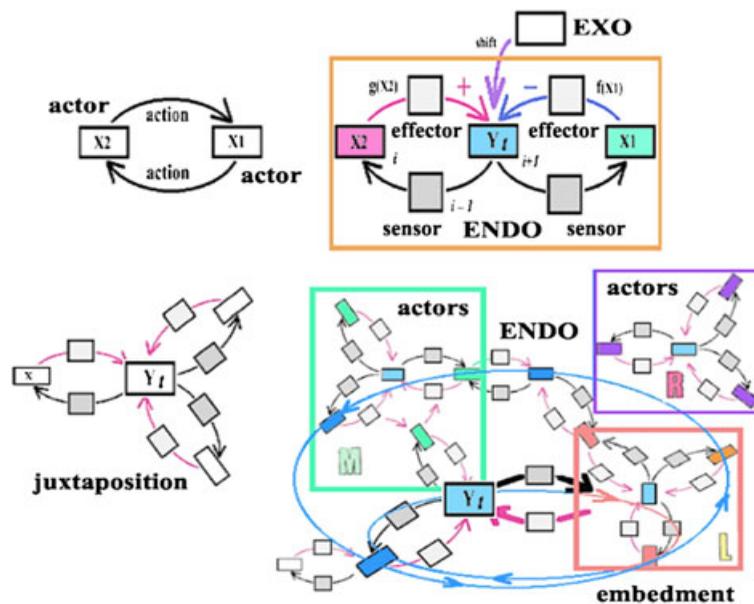


Figure 9 Timeline building by juxtaposed and embedded actors (Bricage, 2001). Actors (top left):  $X_1$ ,  $X_2$  actors, systemic constructal law:  $X_1$  action causes on  $X_2$  an effect that is at the origin of an  $X_2$  action that is the cause of an effect on  $X_1$  and so on (Bricage, 2007, 2010a). Top right: before an  $X$  action of an effector a signal must be sensed by a sensor that is usually at an inferior level of organization (e.g.  $i - 1$  molecular level, if  $i$  cell level of the actor and  $i + 1$  organism ENDO level): example of two antagonist actors (+ hyper, - hypo),  $Y$  controlled factor at  $t$ , shift  $Y$  change as result of an EXO action (e.g. glycaemia: Figure 2). Down left: juxtaposed actors  $X$ ,  $Y$  controlled factor at  $t$  (e.g. asthma: Figure 3). Down right: juxtaposed and embedded actors (e.g. L, M, R cell peroxidases: Figure 5)

the intersection, we produce a circle, an ellipse, a parabola, a hyperbola or, in special cases—when the plan touches the vertex—a point, a line or two intersecting lines (Figure 12).<sup>3</sup> In the projective plan, with the directrix in the infinity, a conic is always an ellipse—whatever it might be in the affine plan (ellipse, parabola or hyperbola). The equidistant curves between two internal circles are ellipses. Depending on the juxtaposition or encasement of the times, we look either at an ellipse or an analemme (Figure 8 and 9) in projection on a Moebius strip (Table 2). If you reflect an ellipse in a circle you obtain an egg curve. Two juxtaposed egg curves look like an analemme.

The shape of an analemme, as that of a conic, depends on the point of view of the observer (Schwarzenbach, 1983). Temporal series may be created by longitudinal cuttings of the Moebius

strip.<sup>4</sup> A line drawn starting from the seam down the middle of a Moebius strip will meet back with the seam but at the other side. If continued, the line will meet the starting point and will be double the length of the original strip. This single continuous curve by projection looks like an ellipse or an analemme (Bricage, 1997). The loci of the centres of circles tangent to two circles with different radius are conics. A circle seen in perspective is a conic. It is an ellipse, a parabola or a hyperbola as the observer is outside or inside the circle. An observer who looks at a parabola can see an ellipse!

### Times Are Juxtaposed and Embedded Like Spaces Are

The constant time of a physical watch is different from the variable time of a living clock (Robert,

<sup>3</sup> [http://en.wikipedia.org/wiki/Conic\\_section](http://en.wikipedia.org/wiki/Conic_section), <http://www.mathcurve.com/courbes2d/conic/conic.shtml> and <http://math2.org/math/algebra/conics.htm>

<sup>4</sup> The Moebius strip is a surface with only one side and only one boundary component. It has the property of being nonorientable. It can be realized as a ruled surface. [http://en.wikipedia.org/wiki/Möbius\\_strip](http://en.wikipedia.org/wiki/Möbius_strip)

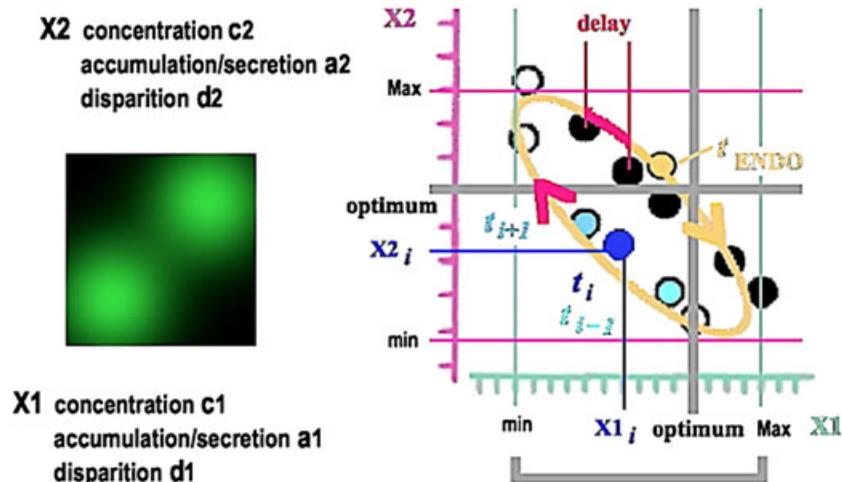


Figure 10 Timeline building by two antagonist juxtaposed actors? Using different times of latency for X1 and X2 responses, different half-times of duration for H1 and H2 actions, can we model with a system of modules of GPU (left image) a real living TIME system (graph of Figure 8 (down)), as it has been performed for example for gradient diffusion mechanisms (Zhang et al., 2012) that are responsible for SPACE system morphogenesis (Nahmad and Lander, 2011)? Left: graphing processing unit (GPU) actors: X1, X2, each one is supposed to be involved in the secretion of at least one hormone, hormones H1 or H2 from X1 and X2 have opposite effects (such as in Figures 2 and 3), which concentrations  $c$  are simultaneously increasing (accumulation rate  $a$ ) and decreasing (disappearance rate  $d$ ), systemic constructal law: 'interaction is construction, construction is interaction.' Right: adjacent successive times:  $0, \dots, i-1, i, i+1$  of the timeline  $t$  (ellipse) of the system controlled by these two actors (at a defined level of organization)

1989) that is contingent both to the genetic and epigenetic contexts (Bricage, 2002). When the functional state of the ENDO does not change, time does not flow (Figure 7). A model in which the time flows faster or slower depending on the speed of changes was proposed by Robert Vallée<sup>5</sup> (Vallée 2001, 2002). When time is running in a second order manner (Figure 8b), phenomena of explosion or implosion can be described by conics: hyperbola or parabola. Time can thus be modelled (Winfrey, 1994) in the same way as space: as the space, time can be both more and less than the sum of its parts (Table 1) (Bricage, 2010a).

Whatever the level of organization within the ENDO (Figures 2 and 3) or within the EXO (Figures 5 and 7), time waves (Figure 10 and Table 2) structure space volumes, and spatial waves (Figure 9) structure timelines (systemic constructal law) (Bricage, 2002, 2009). Time and space are not *a priori*; they result from interactive processes; they are built by interactive systems and for their *mutual* organization (Bricage,

2005a, 2005b). They are, from emergent scales to emergent scales, emergent properties of systems of systems (Figures 1 and 9). At all scales, as well as for the physiological ENDO time as for the cosmological EXO time, we have to distinguish the artificial reference time that allows to write the equation of evolution of a system (Vallée, 2001)—that is its possible ENDO adaptation to random EXO changes, either achieved or undergoing changes from what it was originally—and its internal ENDO time, which does not flow if the state of the system does not change. As long as it did not feel it, nothing comes real for a system. The general solution for a harmonic oscillator is an ellipse (Table 2).

## CONCLUSIONS

Whatever its level of organization, any alive system is defined by inseparable and continuously interactive internal space–time (ENDO) and external space–time (EXO). Both within

<sup>5</sup> Thank so much to Robert Vallée for comments.

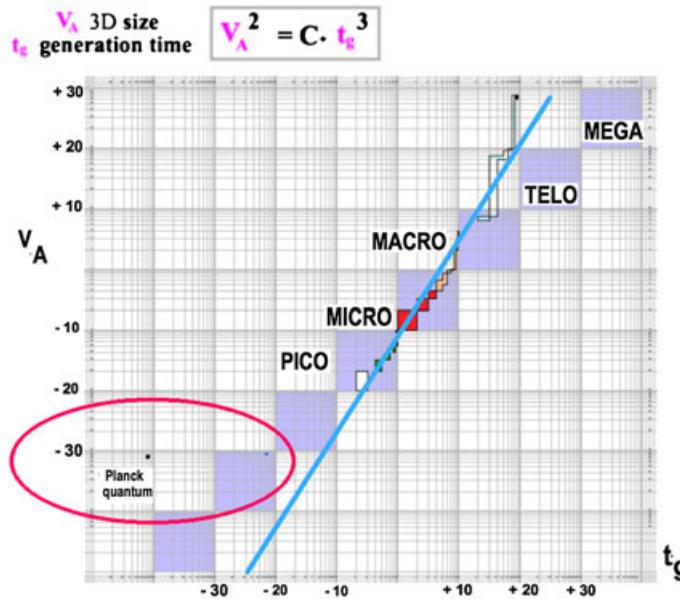


Figure 11 A Kepler’s third law like equation for the Universe (Bricage, 2009). An empirically found law, for living systems, expresses a relationship between the time scale  $t_g$  ‘the generation time’ (in 10x), that is the period of a revolution (a cycle of acquisition of the sexual maturity), that is the time spacing from a generation to the next one—and the spatial scale  $V_A$ —‘the 3D size’ (in 10y), that is the volume of the grown-up stage (of a ‘moving’ growing system) at the end of its growth phase, C constant, y and x axes:  $V_A$  et  $t_g$ ,  $\log_{10}(\ ) / \log_{10}(\ )$ . <http://hal.archives-ouvertes.fr/hal-00423730/fr>

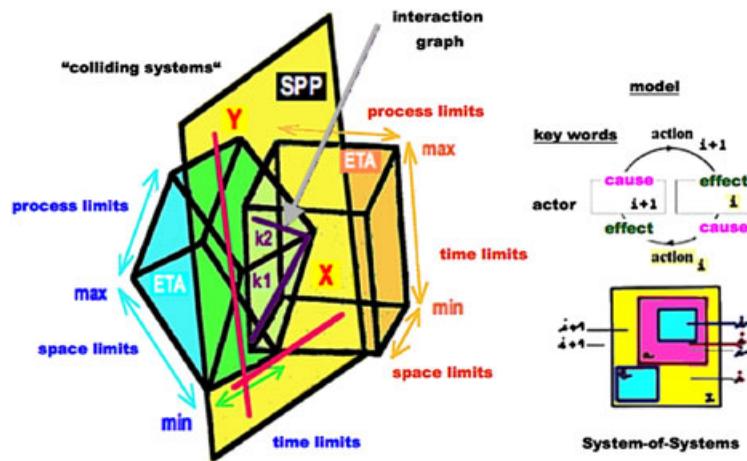


Figure 12 Timeline building by two agoantagonist ‘colliding’ systems? The two hyper–time–space interacting systems (ETA) are systems of systems with  $n$  dimensions  $D$  (for space: 3D, for process controls: at least 3D, for time: at least 2D, ENDO/EXO). They are viewed as (computing) intersecting ‘volumes’ ETA or multilayered GPU (each one, e.g. is supposed to be involved in the secretion of at least one hormone, hormones H1 or H2 with opposite effects, such as in Figures 3 and 10), SPP is the simplest plan of projection (of a multifactorial analysis) in which the representative graph of their interaction  $Y=f(X)$  can be one line (the simplest curve) or two—with  $k1$  or  $k2$  as slope—or a circle or an analemma..., depending on the agoantagonistic phenomenon we are looking for (by changing the angle and location of the intersection, we produce a circle, an ellipse, a parabola, a hyperbola or in the special case when the plan touches the vertex a point, a line or two intersecting lines). Right up: the circular arrow is the timeline, from one instant  $i$  to next one  $i+1$ , each cause is at the origin of an effect on another actor that becomes a cause and so on: systemic structural law ‘interaction is construction, construction is interaction’, juxtaposed and embedded levels of time or space organization:  $i-1, i, i+1$

the ENDO and within the EXO, temporal waves structure the space, and, reversely, simultaneous spatial waves structure the time (systemic constructal law). Time and space are not *a priori* categories of physics, but they result from interactive processes; they are constructions of systems of systems produced in interaction by, and for their organization, they are emergent dimensions. Whatever the spatiotemporal scale of a system, and as well for the representation of the physiological time as of the cosmological time, we have to distinguish a *reference time*—the artificial time that allows us to write the equation of evolution of any system (Vallée, 2002), that is its possible internal adaptation in response to external changes, external changes of which it is at the origin or undergoes—from an internal, *endogenous (or intrinsic) time* that does not flow if the state of the system—in the absence of any influence of the environment—does not change. Whatever the level of organization of the alive, any system, is simultaneously space and time, wave and corpuscle (Bricage, 2009). At different scales, ENDO rhythms (Figure 10) display oscillations along cycles of finite duration. They are driven by or composed of at least one calendar: the ‘timing’; one watch: the ‘timer’; and one clock: the ‘timed’ alarm. All of them are self-sustained, adjusted to the local EXO (entrained) by zeitgebers (the most important are the daylight and TdD) and irregular—that is made up of ‘sounds’ (tic-tac) when time runs and of ‘silences’ when time stops. The ENDO time builds itself ‘by walking’ into the ENDO space; space and time are cocreating themselves (Bricage, 2005c, 2009, 2012a). From a projective point of view, there is only one conic because the conics are images by homography. With elliptic timelines, the geometry of the time is gauge-invariant.

As the Egyptians anticipated it 3000 years ago, the time is a whole made of two complementary aspects—‘eternal durations’, *global* embedding times (hyperbola, parabola or line) to be run only once and *local* ‘cyclic times’ (ellipse or circle) that are finite, juxtaposed and locally repeating—both being able to contain other juxtaposed and embedded cyclic times for which they constitute emergent ‘eternal’ times—depending on the scale, but all linked together globally (Bricage,

2012b). An empirically found law (Bricage, 2009) expresses this relation between the *time scale*  $t_g$  ‘the generation time’, that is the period of a revolution (a cycle of acquisition of the sexual maturity), that is the time between two generations and the *spatial scale*  $V_A$  ‘the 3D size’, that is the volume of the grown-up stage (of a ‘moving’ system, at the end of its growth), Figure 11.

$$\frac{V_A \text{ 3D size}}{t_g \text{ generation time}} = V_A^2 = C \cdot t_g^3$$

Whatever the level of organization, a system is both a manufacturer (a watchmaker) and a user of calendars for the functioning (Sarrazin *et al.*, 2012; Vandeginste, 2012) of its emergent ENDO. It contains, maintains and uses a set of watches (which measure different times), a set of juxtaposed and fitted clocks (which indicate hours for change) and a set of juxtaposed and fitted calendars (which contain time ordered programmes)—all at the same time.

To build its own time allows the system to forecast the next events to come in its space-time. This ‘implementation’ is made without any *a priori* project, without other purpose than a single constraint ‘to live on for life to keep going on’.

Is it the time that allows to channel random events towards a reproducible global behavior? Is it the global randomness that, thanks to the local *requisite variety* (Figure 6), creates the arrow of a unique, local and global time? Time is an emergent concept. What we perceive as being the time reflects only the relations that the various subsystems (Figure 1) of the Universe (Figure 10) maintain between each other (Bricage, 2009); *time* is the order and the causality, and *space* is all the possible times (Bricage, 2010a). Just like the causalities do, times are *in loops* too. Time—as space—is a macroscopic arrangement of *ergodic and fractal* microstates (Bricage, 2001) (Figure 12). Whatever the scale, a referent *quantum* is needed: a quantum of space, time and action (Bricage, 2010a). The quantum laws apply to all scales, even if their appearances are unnoticed. Space and time are one: space creates time and conversely time creates space (Bricage, 2009). *Timelines are ellipses*: trajectories of an object moving under the influence of an attractive force that is directly

proportional to its distance from a fixed attractor. Timeline's orbits have centres of attraction—with a fairly simple equation of time motion—due to 'a time force field' (Bricage, 2012a).

ENDO-physics or EXO-physics are fundamentally different forms of reality description. They correspond to different philosophy of sciences and epistemological attitudes (Kampis, 1994, 1995). A biological reality can be defined without reference to a temporally situated observer! We must decouple the observer (with respect to the system's own time variables) from the observed system (Bricage, 2012a).

There is no time but the right time. There is a time and a place for everything.

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