

Aging and Dynamics of Information: The Deeper Side of Biology (An Interdisciplinary Commentary)

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Abstract

The relationship between the evolution of the basal metabolic rate (BMR) and the evolution of mass estimated as body weight in complex organisms such as human beings show the association between dissipated energy and information recovered as material structure. In such a context, it is necessary to highlight that the metabolic rate estimated as the energy dissipated per unit of mass presents the same rate of change as the mechanical speed estimated as distance traveled per unit of time. We describe this as a logical equivalence that has consequences on the geometry of the system. Our study proposes to describe the relationships between BMR, body weight, and the geometry of these systems in the same way that relativistic mechanics describes the relationships between matter, speed, and the geometry of the space in which the variables of a physical system are defined. It is exactly the same mechanical description, but considering five dimensions instead of four. The concept of information density limit is decisive in this theoretical framework since it contributes to explaining the changes in the geometry of these systems, their order-chaos transitions, and their general holographic description.

Keywords

Margalef's Principle, Hologram, Metabolic Rate, Bekenstein Boundary, Temporal Perimeter, Size and Dimension

1. Introduction

Given the general characteristics of this article (a commentary on previous publications), we will not develop a special section on methodology. However, we will provide details on the methodology used in previous works published by the authors.

In previous publications, we have raised the need for a general theory of aging. [1] [2] We consider that current biological theories explain the aging process in a partial and therefore incomplete manner. [3]-[6]

It is clear that genetic theories cannot explain why the randomness of accumulated mutations always generates the same changes associated with aging in all living beings and at the same time in their lives. If, instead, we assume that these are precise sequential activation programs and not linked to coincidental, we must ask ourselves about the general reasons that lead to their expression.

In any case, whether we think of random mutations or of a supposed genetically programmed aging, they cannot explain the results of cloning, in which cell nuclei that have already accumulated mutations or triggered their aging programs, reverse the changes and develop a new individual. [7]-[10]

Cellular metabolic theories, including oxidative damage by oxygen free radicals [11] [12], also cannot explain the results of nuclear transplants in fibroblast cultures. Neuroendocrine and immunological theories can only explain the alterations associated with aging at the organizational level of such systems, but cannot explain the genetic, metabolic, and cellular alterations associated with the process. [13]-[15]

To understand the process of aging, we must first define it. Aging is defined as the gradual loss of homeostasis and self-organization that occurs over the course of a lifetime. To understand this, we must begin by understanding the general conditions that lead to the development of homeostasis and self-organization. [16]-[18]

This requires considering living beings as systems beyond their level of organization. Margalef's Principle defines living beings as complex physical systems made up of an energy-dissipating system, associated and complementary to a self-organizing system that recovers the dissipated energy as information.

A less precise but simpler way of defining living beings is that they are systems that use the energy they dissipate to generate their own structure. Therefore, since the structure is the set of relationships between the parts of a system, it is valid to say that the information of the system is found in the structure. [19]

This leads us to observe that living beings dissipate energy through their surface. Let us consider the simplest case, that of a cell, which allows us to easily observe the relationship between size (which we estimate as volume) and surface area.

Previous studies by the authors have contributed to the understanding that energy dissipation in living organisms is more closely related to their surface area than to their volume (holographic principle).

When comparing the total BMR/day with the dry BMR/Kg, R^2 has a value of 0.96 ($p < 0.02$), which is statistically significant, as can be seen in **Figure 1**.

But, when comparing the total BMR/day with the total body mass, R^2 has a value of 0.84 (NS), showing that there is no statistically significant association, as can be seen in **Figure 2**.

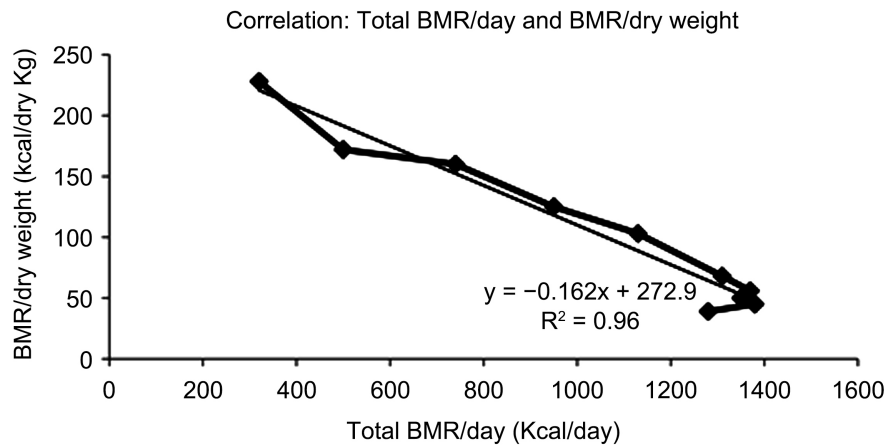


Figure 1. Relationship between dissipated energy and relative surface área ($R^2 = 0.96$, $p < 0.02$).

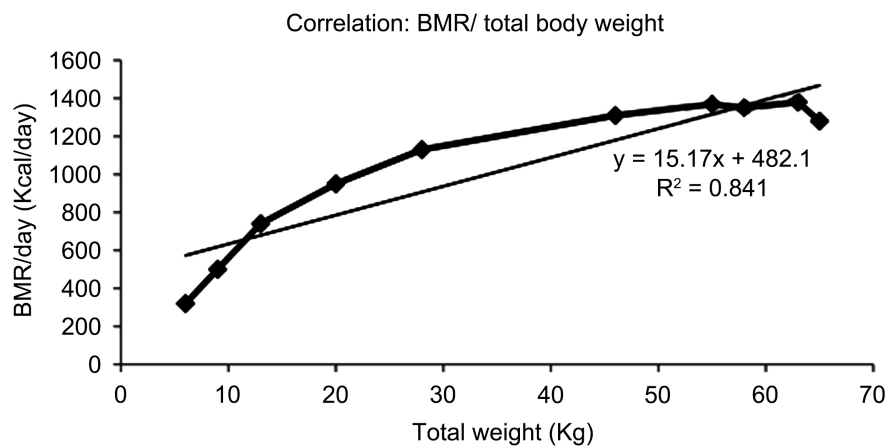


Figure 2. Relationship between dissipated energy and volume (total mass) ($R^2 = 0.84$ (NS)).

Furthermore, since dissipated energy is recovered as information, it turns out that the information also has a more precise relationship to its surface area (**Figure 1**) than to its volume (**Figure 2**). [20]

This is of great importance because when the information in a limited spatial region is proportional to its surface rather than its volume, the holographic principle is fulfilled. Living beings are holograms, and therefore, in any of their structural units, there is information about the entire system (as in any hologram).

It is a mistake to associate the concept of a hologram with an artificial creation of human technology when, in reality, it is a concept of physics that exceeds our technological capabilities. [21]

When studying the Holographic Principle, the concept of information density limit or Bekenstein's boundary is crucial since if we are dealing with a limited spatial region, its volume is limited, and its surface is limited. There is then a minimum unit capable of containing the information about the entire system, which in the case of living beings is the cell. This concept is also fundamental to understanding the basis of complexity in biology. [22] [23]

To be clear, we don't compare living beings to holograms, but rather define them as such. The reason is compelling: the energy dissipated and the information recovered have a greater relationship with their relative surface area than with their volume (or total mass). Living beings comply with the holographic principle.

It is important to understand the physical laws that support Margalef's Principle and to do so, we must advance on the dynamics of energy (laws of thermodynamics) and the dynamics of information.

2. Dynamics of Energy and Information

Regarding the dynamics of energy, we can say no more than what is stated in the laws of thermodynamics, which living beings comply with like any other physical system. Energy degrades when it flows, although the total amount of energy remains constant because it is neither created nor destroyed, but rather transformed. The same does not occur with the organization of matter, since it can be recycled and present a set of relationships that configure the structure of a physical system.

Living beings are physical systems that comply with the laws of thermodynamics, like any other physical system. What distinguishes them from other physical systems is what they do with the energy they dissipate. What they do is recover the dissipated energy as information about the system. [24]-[26]

Therefore, the information recovered is directly related to the energy dissipated. So if energy is neither created nor destroyed, then information cannot be created or destroyed either, but it is transformed. Although it may seem strange that information is transformed, that is what happens: the information that is in the structure of a carrot does not disappear when a rabbit eats it, but it is transformed into information that is now in the structure of the rabbit. Eating a carrot not only implies an energetic transformation but also a transformation of structures and information.

But if we want to move forward in this analysis, we must define the concept of information, as a set of data in a context that allows decisions to be made. It is important for more than one reason. The person who makes the decisions is always a living (human) being, so the concept of information is linked to them.

On the other hand, the fact that it allows decision-making implies that decisions are not automatic. Information allows decisions to be made, but it does not imply that the decision is made by the living being. [27] [28]

So we must ask ourselves, what does decision-making depend on? Well, it depends on the information being available to the living being. Thus, this leads us to a simple but important question: how does information flow? Information flows from the state that is not available to the state that is available to the living being.

It is a deep analysis of what happens with information in biology, because information is there, it is not gained or lost (it is neither created nor destroyed, it is only transformed). The gain of information in a system is only apparent, because the information has become available. In the same way, the loss of information

(let us suppose the fall of a material structure into a black hole) is also apparent, because the information is no longer available: this reverse flow (towards the unavailable state) can only occur in inert systems.

In living beings, the flow of information is always toward the available state, and only then does the biological system make a decision. Whatever the decision, it consists of an irreversible process, because we go from the indeterminacy of a possible decision to the determination of a decision taken.

The reason for irreversibility is the ubiquity of information. Information is ubiquitous in space and time. Once the decision is made, which is expressed in the generation of structure or irreversible changes to it, living beings are bound to the creation of their own history (history: producing irreversible facts). The same “Schrödinger’s cat” makes the decision once the information is available. Then, it lives or dies at that precise moment and place, depending on the information it has available. [29]-[31]

It is better to mention the general principles of information dynamics (based on the principles of thermodynamics):

1) Principle of equilibrium. A biological system is in equilibrium with respect to another when both have the same information density.

2) Principle of conservation. The information of a biological system is directly related to the energy it dissipates, since the dissipated energy is recovered as information of the system. So if energy is neither created nor destroyed, information cannot be created or destroyed either, but only transformed (as in the example of the rabbit and the carrot).

3) Principle of availability. The availability of information in a biological system changes as the system matures. An immature system is predominantly dissipative, and the information recovered (available) is little and is subject to a high rate of replacement. A mature system has less dissipative capacity, but has more information available in the form of a larger structure that is subject to a low rate of replacement. In a biological system, the flow of information is unidirectional and irreversible (from unavailable to available) if the choice (decision) is not forced by disturbances.

4) Zero rate principle. The information of a biological system starts from the minimum density that allows the identity of the system to be sustained. A small cell with a large relative surface area whose structure is subject to a high rate of replacement. As it develops and matures, its size increases, and its relative surface area decreases; its structure presents a progressively lower replacement rate. Thus, it reaches the highest possible information density. And again, if the choice is not forced, as it matures, it tends to the lowest possible replacement rate (zero rate).

3. Beyond Bekenstein’s Border

The relationship between information and the geometry of a physical system was deeply studied by Jacob Bekenstein. The concept of information density limit (Bekenstein Border) is directly related to the Holographic Principle.

As we have already stated, there is a limit to the density of information that determines the size and dimension of the region of space that can contain the minimum retainable information. Beyond this limit, the spatial region in question gains a degree of freedom (for every four Planck units, there is one degree of freedom). [32] [33]

This means that if we imagine a flat surface and define a figure on it, for example, a flat equilateral triangle, the information contained in it is proportional to its perimeter rather than to its area (Holographic Principle). When it reaches its information density limit, it will gain a degree of freedom, and we will then have a spherical triangle, which will have the same size, but greater dimension than the flat triangle. In the flat triangle, the dimension is 2, while in the spherical triangle, the dimension is 3.

We define the size of a flat figure as the measurement of its surface area. In the case of a three-dimensional geometric body (instead of a flat figure), its size is the measurement of its volume. We define dimension as the number of linearly independent vectors in a given space, which in the case discussed is 2 for the flat triangle and 3 for the spherical triangle.

This conceptual difference between size and dimension must be taken into account. Otherwise, some issues cannot be understood, such as the fact that two circles of different sizes are formed by the same number of points. This is because they are figures of different sizes, but of equal dimension.

When the information density reaches its limit, the space in which the system is defined acquires a larger dimension. It is $n + 1$, whatever its original dimension. This causes some detectable phenomena in the behavior of its variables. Cycle after cycle, some of the variables (sensitive to changes in the geometry of the system) do not recover their original values. This represents a notable contribution to understanding the reason for the progressive decline of the system after reaching its information density limit. But it does not explain the tendency toward order that the system shows before reaching this limit.

The tendency towards order in a system is always related to its geometry. So, its geometry is determined by its information density. When a biological system begins its development, it has a low information density. Gradually, the system incorporates more and more information (recovered from dissipated energy), but as it does so in an ever-increasing space (because it is growing), its information density remains constant.

The situation could be summarized as follows: the growth of the system increases its size, but not its dimension. Thus, it forces the maintenance of the planarity (not curved) of its geometry, whatever its dimension.

Biological, physical systems are defined in a certain limited region of space and tend towards order when their curvature is zero, neutral, or positive and of equal value at all points. The reiteration of these patterns during embryonic development beyond the species barrier is a clear demonstration of the power of this general description. [34]

When complex living beings reach puberty, they continue to recover information about the dissipated energy, but now they do so in a space that no longer grows. The information density then grows until it reaches the Bekenstein boundary, generating one more degree of freedom. The system now has the same size, but greater dimension.

The space in which its variables are defined undergoes a curvature that is appreciated in the presence of geometric phase changes. Thus, cycle after cycle, the variables sensitive to changes in the geometry of the system stop recovering their original values. The system declines and gradually loses its capacity for homeostasis and self-organization. [35] [36]

Geometric phase shifts have been accurately measured in previous work by the authors. Recalling some examples may be useful. [37]

Before puberty, the heart rate presents a standard deviation (SD) = 27.64. A value that is not consistent with a normal distribution pattern ($SD < 3$). While after puberty, the values are (SD) = 5. Although neither is this compatible with a normal distribution pattern ($SD < 3$), it shows five times less dispersion than before puberty. The coefficient of variation (CV) is 30.22% (statistically significant). (Figure 3)

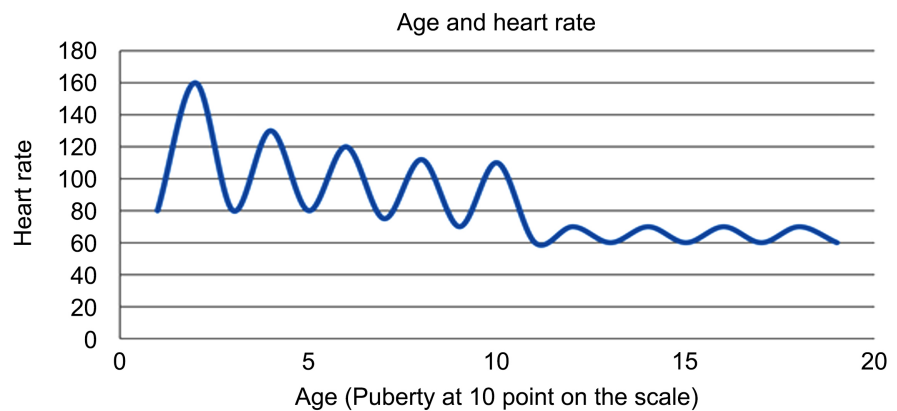


Figure 3. Heart rate variation throughout life (CV = 30.22% (significant)).

The respiratory rate before puberty presents $SD = 12.93$. After puberty, their values are $SD = 2$. These values show a reduction in dispersion and a normalization of the behavior of the variable after puberty ($SD < 3$). The CV is 49.40% (statistically significant) (Figure 4).

The phase shift of wave phenomena within different periods is of great importance in the case of biological and physical systems: the chronodisruption that we observe in aging is the result of the changes that occur in the geometry of the system.

It is clear that the biological phenomenon can then be represented as a vector that is linearly independent of the vectors of space and time. Thus, the biological systems that we know can be represented as energy-information tensors. However, this requires an essential conversion of units so that the formalization is dimensionally coherent.

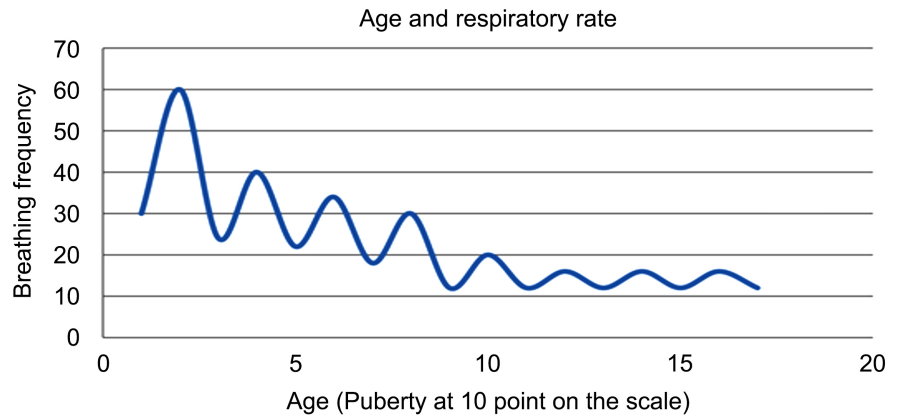


Figure 4. Variation in respiratory rate throughout life (CV = 49.40% (significant)).

In previous publications, we proposed this matrix as a general expression, but without its unit conversion or eventual equivalence. We need to consider these factors in order to give dimensional coherence to our analysis.

When we think of the relativistic four-vector, we have three spatial vectors defined in units of distance and one temporal vector defined in units of time. The conversion of time units to distance units (the process is carried out using the formula for the speed of light) is essential. So, if we propose a fifth vector, it must be dimensionally coherent with the relativistic four-vector.

4. Equivalences and Conversion Factors

To understand the topic easily, let us first remember how we construct space.

If we define two points on the flat (chart) and locate them in the reference frame of a Cartesian coordinate system, we can calculate the distance between them by applying the Pythagorean theorem. (Figure 5)

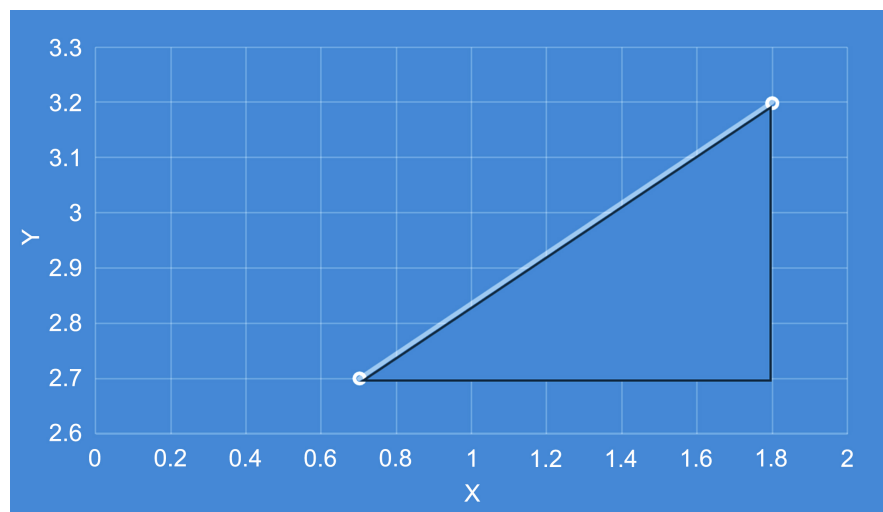


Figure 5. We define the differential of X and Y of each point as dx and dy , respectively. Then, the hypotenuse of the triangle formed between these differentials is the distance we want to calculate. We call it ds . Applying the Pythagorean theorem, we get: $dx^2 + dy^2 = ds^2$.

If we consider the case in a three-dimensional space, the formula must include a Z axis and the corresponding differentials, such as dz, according to

$$dx^2 + dy^2 + dz^2 = ds^2$$

And when considering the relativistic four-vector, we must incorporate a time axis that we call t and its differentials dt according to

$$dt^2 + dx^2 + dy^2 + dz^2 = ds^2$$

Since this is a dimensional equation, we can enclose each term in brackets, like this

$$[T]^2 + [L]^2 + [L]^2 + [L]^2 = ds^2$$

But the expression is dimensionally incoherent, because the first term is expressed in units of time and the remaining three in units of length. Possible solutions come from applying a conversion factor, as is the case for the speed of light (C), which is $= \frac{L}{T}$, a constant value.

If we multiply C by T , we convert time units into distance units.

$$C^2 \times [T]^2 + [L]^2 + [L]^2 + [L]^2 = ds^2$$

$$[L]^2 + [L]^2 + [L]^2 + [L]^2 = ds^2$$

We call this theoretical configuration “proper space”. [38]

This is the space formed by the null vector and by all the eigenvectors (non-zero vectors that, when operated by a scalar λ , give rise to a scalar multiple of themselves, so they do not change their direction -their direction is also not affected by linear transformations of space).

If we divide the terms expressing distances (L) by C , we convert units of length into units of time. Thus,

$$ds^2 = [T]^2 + \frac{[L]^2 + [L]^2 + [L]^2}{c^2}$$

$$[T]^2 + [T]^2 + [T]^2 + [T]^2 = ds^2$$

And we call that theoretical configuration “proper time.” [39]

This is the time measured by all observers who are each at rest with respect to the other observers, for an event that also occurs at rest with respect to all of them. Observers who move at a constant speed with respect to themselves and, therefore, with respect to the event, will perceive the phenomenon of time dilation (they themselves will also have their own time).

The issue of speed requires the following clarification: If the speed of motion is much lower than the speed of light ($v/c \ll 1$), coordinate time and proper time coincide. This allows any observer to assume that something like an absolute time or universal temporal reference exists.

But if the speed of movement is close to the speed of light, the coordinate time and the proper time do not coincide. Then, the metric of time is not static and,

therefore, it is possible that two observers who start from the same point and arrive at the same point along different trajectories differ in the observation of the elapsed time (twin paradox). [40]

If we represent the biological phenomenon (recovery of energy dissipated by the system as information or structure of the system) as a vector linearly independent of the vectors of space and time, facts emerge that can lead to understanding biology in a completely different way from the classical one. It is a profound biology linked to information. This information is linked to the geometry of the space in which living beings are defined.

Let's see. Since metabolic rate is equivalent to mechanical speed, dissipated energy is equivalent to distance or length, and mass is equivalent to time. Thus, within the framework of the biological reference system, no conversion of units is necessary.

Before moving on, it is necessary to explain that the relationship between metabolic acceleration and mechanical acceleration is not a mere similarity (an analogy). It is an equivalence, because it is based on the fact that both have exactly the same rate of change. This implies an objective and precise mathematical formalization. Let's see:

We formalize the metabolic acceleration as $Ma = BMR/m^2$, where Ma is the metabolic acceleration; BMR is the energy dissipated, expressed in kcal per unit of mass kcal/m, and m is the mass expressed in kg of weight.

So, the metabolic acceleration is $Ma = (\text{kcal/m})/m = \text{kcal/m}^2$.

We formalize the mechanical acceleration as $A = \frac{d}{t^2}$, where A is the mechanical acceleration; d is the distance traveled per unit of time, expressed in meters per second; and t is the time expressed in seconds.

As the speed is $v = \frac{d}{t}$, where d is the distance expressed in meters and t is the time expressed in seconds.

Therefore, the mechanical acceleration is $A = (\text{m/s})/s = \text{m/s}^2$.

We define this logical equivalence as

$$\frac{BMR}{m^2} \Leftrightarrow \frac{d}{t^2}$$

Now, we can continue.

Let us consider the case of the spatial region in which a cat is defined. Each point in the space included in this region has five components.

$$dl^2 + dt^2 + dx^2 + dy^2 + dz^2 = ds^2$$

Since energy is dissipated at every point in this space and recovered as the material structure or mass of the system, the five vector components can be expressed as follows,

$$[\text{kcal/m}]^2 + [\text{kcal/m}]^2 + [\text{kcal/m}]^2 + [\text{kcal/m}]^2 + [\text{kcal/m}]^2 = ds^2$$

We should refer to this theoretical configuration as "self-metabolic rate" or self-life.

This is the elapsed life (any biological event) that is measured at any point (observer) of the system that is at metabolic rest (zero difference in relative metabolic rate) with respect to the other points of the system on an event that also occurs at rest with respect to all of them.

Thus, at any point in the system, the proper vectors will be appreciated and will seem completely natural to assimilate the course of life to the course of time. The biological phenomenon will appear to be a particular material condition that evolves in time. This is what happens to any living being with respect to itself or to another organism of its own species (with which it does not present relative differences in metabolic rate).

On the other hand, points, observers or systems that move at a constant metabolic rate relative to themselves (they are not at metabolic rest) and, therefore, relative to the event will perceive the phenomenon of dilation of the course of life (they themselves will also have their own life, with their own metric).

That is what happens to us when we observe other organisms that present different relative metabolic rates (non-zero difference in relative metabolic rates): an elephant appreciates the life of a mouse as very short, and a mouse appreciates the life of an elephant as very long, but in reality both develop their lives according to their own metrics (“elephant-mouse paradox”).

The topic of metabolic rate also requires clarification, because it is about the kcal dissipated per unit of mass (kcal/m), and its value changes depending on the total mass (M) of the biological system. If the total mass (M) is much greater than the unit of mass (m) ($M/m \gg 1$), the coordinated metabolic rate and the proper metabolic rate do not coincide.

So the metric of the biological phenomenon is not static, and therefore, it may be the case that two observers who start from the same chronological point and arrive at the same point in time along different metabolic trajectories differ in the observation of the life elapsed (as in the case of an elephant and a mouse that are born on the same day, but after two years one of them is old while the other is just beginning its “long” life).

If, on the other hand, M is not much greater than m , the situation is different, because the coordinated metabolic rate and the proper metabolic rate coincide. Thus, any observer can assume that there is something like an absolute metabolic rate or universal biological reference. This is the case of unicellular organisms and organisms of very low complexity, which do not observe any expansion of the metric of the biological phenomenon.

As we stated, within the reference frame of the biological reference system, nothing more than the equivalence between mechanical and metabolic speed is required to describe the evolution of the system.

5. Temporal Perimeter

The concepts of hologram, size and dimension facilitate understanding of the role of information in living beings, allowing a general understanding of their development

and aging.

Let us remember that we describe biological and physical systems as holograms, and taking into account that the dissipated energy is recovered as information, then the information has a greater relationship with the surface than with the volume of the system.

If we take the simple case of a cell, comparable to a sphere, the mathematical description that summarizes the relationship between its surface and its volume is easy to understand: the derivative of its volume is equal to the area of its surface, and the integral of its surface area is equal to its volume. Thus, the information of a cell is proportional to the derivative of its volume.

Simplifying the analysis, we can think of the case of a circle and the relationships between its surface area and the length of its circumference. The derivative of the surface area of a circle is equal to the length of its circumference, and the integral length of its circumference is equal to the area of its surface.

Taking into account the holographic principle, the information of a circle is proportional to the length of its circumference rather than to its surface area. This point is crucial, because it allows us to express the information limit in a generic way, which in the case of the circle is $\pi \cdot d$ ($3.14 \times$ diameter). This concept can be generalized to n dimensions and allows us to determine the evolution of the relationship between volume and surface area according to the value of n .

Thus, a four-dimensional (4D) n -sphere has information proportional to its three-dimensional (3D) volume rather than to its 4D hypervolume. And if we refer to a five-dimensional (5D) n -sphere, its information is proportional to its 4D hypervolume. So, considering that living beings are defined in 5D, but are not necessarily spherical, their information is directly related to their “temporal perimeter” (4D) regardless of their shape. That is really a lot (a lot) of information. Much more than we can imagine.

The concept of DNA genes in relation to the coding of information in living beings seems, therefore extremely superficial. It is only the sequential or parallel expression of molecular structures associated with the expression of information in space and time. The information about this type of system is far beyond its genes, molecular biology, cells, and tissues. We see very little than really happens.

Why do we talk about “deep biology”? Because it goes beyond molecular structures, because it is intertwined with the physical nature of the regions of space in which the variables of living beings are defined, because it contemplates their geometry.

6. Conclusions

Living beings are regions of space that recover the energy they dissipate as information; they self-organize. During the first stages of their life, they grow in size, acquiring greater volume and weight. But this growth is not unlimited. It will occur until the system reaches the information density limit (Bekenstein Border).

From there, the system will be able to continue recovering information about

the dissipated energy, but it will do so in a space that no longer grows. The information density will increase until it reaches its limit, because there is more and more information in a space of the same size.

Upon reaching this boundary, the space gains a degree of freedom, it becomes curved. The space in which the system variables are defined has the same size, but greater dimension ($n + 1$). Then, the variables sensitive to the geometry of the system stop recovering their original values cycle after cycle, and the system begins to decline. A gradual loss of homeostasis and self-organization begins to occur in the system and is expressed as geometric phase changes.

Aging is not a rare disease to be avoided, but a unique opportunity to understand the deep and true nature of living beings. A nature that exceeds the boundaries of classical biology as we know it. Biology is one in which information, physics, and geometry are the guiding principles. Principles that guide the behavior of its simplest material manifestations, such as the molecular biology of genomes, proteomes, hormones, cells, tissues, and other morphological structures that we know.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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