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Biological Aging: A General Theory

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ABSTRACT

The evolution of the relationship between basal metabolic rate and body weight in humans can be represented as a hologram. Previous studies by the authors verify the validity of said representation and analyze its meaning. A logical equivalence then arises between complex biological systems and non-inertial systems studied by mechanics. Self-organization leads to the development of complex systems consisting of systems subsumed into systems, and this affects their thermodynamic characteristics: the energy dissipated per unit mass declines, while the total dissipation increases. If we integrate this representation with the description of these organisms as coupled oscillator systems, a precise statistical measure of the geometric phase change that occurs in them at the end of their growth is obtained. This implies the development of a curvature in the space in which the values of the variables of these systems are defined and the possible vectorial description of the same as an energy-information tensor.

Keywords: Hologram; Complexity; Non-Inertial Systems; Equivalence; Biological Oscillations; Energy-Information Tensor

INTRODUCTION

Previous studies by the authors show how the relationship between the ability to dissipate energy and the ability to generate its own mass evolves in human beings throughout life[1]. This is a fundamental relationship in biology, shared by all living beings, since all living beings dissipate energy and use it to generate their own mass (it's the Margalef's Principle)[2]. As the material elements that constitute the mass of the living being develops particular relationships among themselves, they are ordered and form the structure (the set of relationships between the material elements of a system) of the living being. The emergent order leads us to consider the concept of information in living beings[3,4]. These are not systems that merely dissipate energy, but systems that generate their own structure and self-organize. This led us to investigate the principles of self-organization and its foundations according to different theories. But even more important is to recognize that it is a particular force of aggregation of matter, an aggregation that also orders matter[5,6]. We are then in a position to answer the following question: Where is the information of living beings? The answer is: the information of living beings is found in their structure (the set of relationships between the material elements that make up the system). Of course it is also beyond it, but in its most basic form the information of a living being is nothing more than its material structure[7]. But since in living beings the size presents a directly proportional relationship with the mass, as the small variations in density do not manage to invalidate this relationship, we could think that the greater the mass, the greater the information. That would that be an error. Because we investigated these relationships and were able to verify that energy dissipation is more related to the relative surface area of the system than to its size, volume, or mass[8]. The next two figures are from previous works by the authors. One of them shows the relationship between the dissipated energy and the relative surface of the system. The other shows the relationship between the dissipated energy and the total mass of the system.

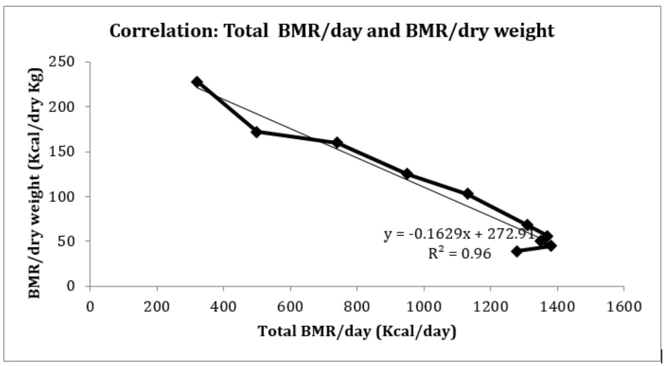

Figure 1: Relationship between total energy dissipation and energy dissipation per body mass unit[8].

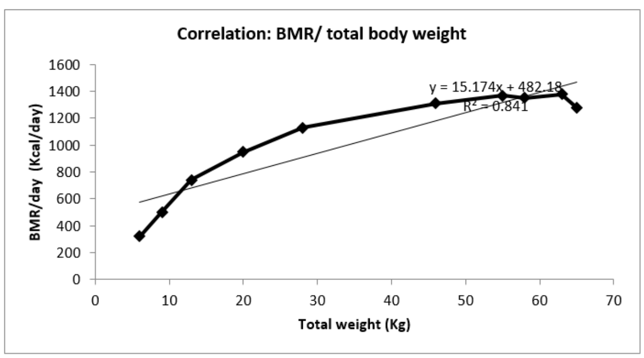

Figure 2: Relationship between total energy dissipation and the total body mass of the organism[8].

This characteristic allows us to understand that living beings as physical systems (they are nothing else) comply with the Holographic Principle, since if the dissipation of energy is proportional to the surface and the information is proportional to the dissipated energy, then the information is also more related to the surface of the system than to its volume. Thus, if we take into account that the mass is limited to a certain region of space, its surface is also limited[8]. There is then a limit of information density, which is more related to the surface of the system than to the volume of the living being[9]. The concept is of great importance, because it is related to the size and level of organization of biological systems. The size and level of organization have a decisive influence on the thermodynamics and aging of living beings.

A LOGICAL EQUIVALENCE

When we study the evolution of energy dissipation in living beings, important considerations soon arise depending on whether they are unicellular organisms or complex multicellular organisms[10]. When a cell reaches its information density limit, it may divide and continue with its unicellular lineage, or it may divide and associate with other cells, generating a new level of biological organization. Whether it does one thing or the other depends on the information it encodes in its genes. It may happen that the cell simply dies. We know from the second law of thermodynamics that in any event the ability to dissipate energy will decline throughout life. But there is a fundamental difference between the thermodynamic evolution of a unicellular system and the evolution of a complex multicellular system. In the case of the unicellular organism, the decline in the ability to dissipate energy is constant generation after generation of cells. In contrast, in the case of a complex multicellular organism, the decline in the ability to dissipate energy accelerates generation after generation of its cells. This is because in the first case the cell itself constitutes the entire system, but in the second case the cell is subsumed in more complex levels of organization[10]. When the self-organization force exceeds the cellular level, it causes certain distortions in the thermodynamic patterns: if we consider that by the action of self-organization the total mass of the system increases, it is not surprising to find that energy dissipation increases with the passage of time. But this could lead us to the mistaken idea that complex living beings do not comply with the second law of thermodynamics. This idea would be a big mistake. Because if we study the dissipation of energy per unit of mass, we will see that it declines rapidly in complex multicellular organisms[10]. The relationship between the evolution of the energy dissipated per unit of mass and the evolution of the total mass in a complex multicellular organism such as the human being, can be formalized as follows:

$$SOa = \frac{\frac{kcal}{m}}{m} = \frac{kcal}{m^2} \rightarrow SOa = \frac{kcal}{m^2}$$

$SOa,$ is the acceleration of self-organization,

$\frac{kcal}{m},$ is the energy dissipated per unit mass, and

m, is the total mass.

We then propose the equivalence between a living being as a complex self-organized system and what we know in mechanics as a non-inertial system. We know that there could be other types of equally valid equivalences from the logical point of view (that have the same truth value), but we are interested in this particular equivalence because it has important consequences on the structure of the space in which a biological system is defined. It is not an analogy, it is an equivalence[11]. A non-inertial mechanical system is basically an accelerated system. A gravitational field is a good example. And the formalization of the acceleration due to gravity is:

$$g = \frac{\mathrm{m}}{s^2}$$

Of course it is not a mathematical equivalence, since it is about different variables and units of measurement[11]. But each one, in its theoretical framework, has the same truth value and the same formalization[12]. In the same way that the action of gravity causes the curvature of space in the region of space where its influence is notable (gravitational field) and that an observer appreciates as time; the region of space in which the acceleration of self-organization is appreciated of a complex biological system causes the curvature of said space and is observed as system aging. This can be seen in the phase change suffered by the oscillating variables of the system, causing a chrono disruption phenomenon. In previous studies we quantified these changes. Since these phase changes occur due to the change that occurs in the geometry of the system when it reaches its information density limit, it is valid to consider that it is a geometric phase change[13].

MASS AND STRUCTURE: THEIR MEANING

Whether considering the pioneer studies of Stuart Kauffman or the great diversity of alternative proposals that we currently have, in any case, self-organization is a particular form of aggregation of matter: the ordered aggregation of itself[14]. But when the matter of a living being, which we appreciate as its mass organizes itself to form complex multicellular organisms like human beings, we must pay attention to the concept of structure[15,16]. The structure of a system is the set of relationships between its material components. Therefore, if we think of the mass of a living being as an equivalent of its structure, it is only correct if we take into account that it is a self-organized, ordered mass. But mass and structure are not intrinsically the same thing. The mass of a living being, which we appreciate as its weight and therefore as its size, is simply the sum of the material elements that constitute it. But it is clear that these elements can be organized according to different types of relationships between them and with variable efficiency throughout life. The information of a living being is appreciated in its structure. In its most basic form of expression this implies the material structure of your body. Although are also involved: information that the system manages beyond what Margalef called exosomatic structures its own body structure[7]. The capacity for self-organization and its acceleration in complex multicellular organisms vary throughout the life of the system. But the mass or size of a biological system has limits. We must not forget that there is a limit of information density and that this is more related to the surface of the limited spatial region in which the system variables are defined, than to the total size or mass of the system[9]. This characteristic allowed us in previous studies to propose the holographic description of biological systems[17]. Having a size limit allows us to understand why we don't find bacteria the size of an elephant or elephants that fit on the head of a pin. No physical system, such as a living being, can exceed its own information density limit without determining changes in its geometry[13]. And since the information is recovered on the dissipated energy[7], we can formalize the calculation of the energy dissipated by the system from the same approach developed for the acceleration of self-organization.

$$Kcal = SOa\ .\ m^2$$

*K*cal is energy

*SO*a is the acceleration of self-organization

m^2 *is* the square of the mass

OSCILLATORY SYSTEMS

The action of self-organization causes an increase in mass and therefore in size in the case of a complex multicellular system such as the human being. But since size has its limits, when growth stops shortly after puberty, decisive changes occur in its geometry. The system continues to generate its own structure with the energy it dissipates, but now it does so in a space that no longer grows. If the spatial region in which the system variables are defined no longer grows, neither does its surface. The information density limit is soon reached, causing the curvature of the space in which the system variables are defined[2]. It may seem strange, but that is what happens. The biological phenomenon must be treated as a dimension of space, which due to the effect of holographic self-organization in multicellular complexes is seen as the aging of the system when it reaches its information density limit. As aging depends on general determinants such as the size and geometry of the system, it is not surprising that it is not appreciated in low complexity unicellular systems, nor in complex systems during their growth[17]. At this point it must be taken into account that a complex living being consists of a set of coupled oscillatory variables. If the geometry of the space in which they are defined is affected, the variables should undergo a phase change. That is exactly what happens, as we were able to appreciate in previous studies. We found phase shifts with statistically significant SD (standard deviation) and CV (coefficient of variation) for oscillatory variables[13]. The consideration of living beings as systems of coupled oscillators is of vital importance[18], because it allows us to treat living beings as a packet of waves[19,20]. Waves can vary their frequency, their period or their amplitude, to mention some of their properties[21]. But they always have a constant velocity in a given medium. The same is not true of material objects. That's why we can add speeds when we transport material objects, but we can't when it comes to waves. Thus when we throw a stone forward at X speed from a moving train at R speed, we calculate the speed of the stone as X + R. But if from the same train and at the same R speed we shoot forward a beam of light, we do not say that the speed of the light beam is C (speed of light) + R (speed of the train). The speed of light is always C in a given medium. In the same way, the packet of waves that constitutes a living being has a constant speed in a given medium. The middle is the region of space in which the system variables are defined. And since the medium in which a mouse is defined does not have the same structure (the same set of relationships between its material elements) as the medium in which a cat or an elephant is defined, their speeds will be different in each of these living beings. So if you put a newborn mouse, cat, and elephant next to each other, walk away, and come back after two years to observe them, the following will happen: The elapsed time is the same for you as it is for the mouse, the cat and the elephant. There were no relativistic shifts (you walked away), so don't expect changes in the metrics over time that can be seen as time dilation of any kind. Thus, in the same period of time, the mouse is already old, the cat is a young adult and the elephant is barely in its infancy. It is the metrics of the course of life that is modified. And that is why three newborns (a mouse, a cat and an elephant) differ so much from each other after the same period of time has elapsed for all three. This phenomenon is relative to the biological location of the observer (mouse, cat or elephant), so that one can appreciate the life of another as slow or fleeting compared to his own. The observation of any of them is equally valid as that of the other observers. None of them will appreciate any change in the rate of development of their own lives. There is then no such thing as a privileged observer, whose point of view is more valid than that of others. In biology, the simultaneity is relative to the observer.

THERMODYNAMICS AND THE ARROW OF TIME

It is good to remember that the thermodynamic evolution of physical systems such as living beings always advances in the direction of increasing entropy. One of the consequences is that as the system evolves, it suffers a decline in its ability to dissipate energy[22,23]. The transformation of energy occur in a certain precise place in space, and they do so at a certain moment, using a certain period of time. In other words, they occur in a certain place in space and at a precise moment in time. And since the course of the thermodynamics of these transformations is unidirectional and irreversible, they lead us to consider that there must be an "arrow of time", also unidirectional and irreversible[24]. It is a conceptual problem that must be solved, because if time is to be treated as a linearly independent vector of the three vectors of space (R3), forming a basis in a four-dimensional space (R4) according to the theory of relativity, it must be possible to operate with that vector and a real (a real number) in such a way that the null vector can be obtained. If the "arrow of time" really exists, such an operation is impossible; and if the operation is possible, what does not really exist is “the arrow of time”. To solve this question, we must take into account that we appreciate as time the distortion of a spatial dimension that we do not see or perceive as we do with the three dimensions of space. That is why we refer to the "course" of time[25] and not to its "size", in the same way that we do not refer to the course of space, but to its size. Thus, according to our perception, time passes and space grows. Obviously we have no problem operating with the vectors of space in three dimensions (R3) to obtain the null vector, so we have no problem understanding that a certain region of space increases or decreases in size. But we have serious problems to operate in the same way with the time vector in R4 (space-time). Although we know how to operate mathematically in R3, in R4 or in "n" dimension to obtain the null vector, the physics of our world "as we understand it" leads us to build the concept of "arrow of time". As if it were not a linearly independent vector, of a dimension of space. We associate the irreversible and unidirectional course of thermodynamics with the passage of time, and consequently time seems to pass in the same way. The "arrow of time" seems more consistent with the physical perception we have of our world, than the consideration of time as a dimension. But it is an observation bias. Time is a fourth spatial coordinate; beyond the appreciation we make of it. The "arrow of time" is nothing more than the fallacious projection of the "arrow of thermodynamics" to the temporal evolution of physical systems[24]. In a similar way we associate the course of life with the course of time and we summarize them in the concept of the aging of living beings. But it is also an observation bias. The geometric phase shift associated with the aging process shows that it is a fifth spatial coordinate[13]. And as much as we appreciate it as the "course" of life, it is really just a coordinate in a five-dimensional space (R5). The fallacious "arrow of time" does not determine the metric of life. The fifth coordinate is self-referring (like all), because it is a linearly independent vector.

ENERGY AND INFORMATION

Living beings generate their own material structure with the energy they dissipate. The dissipation of energy carried out by living beings follows the laws of thermodynamics, as in any physical system. The self-organized structure of a living being constitutes the information of the system. Energy flows from source to sink with no possibility of being recycled. In the course of the successive transformations, energy degrades and cannot be reused. The material structure, on the other hand, can be recycled and constitutes the most basic and simple way of expressing the information of the system. The information of a living being is appreciated in its structure[7]. The dissipating system provides the energy transformations and the self-organizing system recovers the dissipated energy as information (generating the structure of the system). Both systems (the dissipative and the self-organizing) constitute the biological system that we appreciate in any living being. If we return to the vectorial description of the biological phenomenon, it can be assimilated to a vector that is linearly independent of the space and time vectors. In such a space (R5), the location of any living thing can be described as an energy-information tensor.

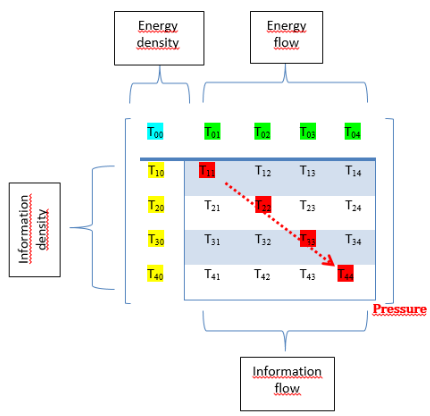

Figure 3: Energy-information tensor matrix. Taken and modified from "Kinetic-energy-momentum tensor in electrodynamics." [26]

Thus, an observer who sees the tensor approaching his position will appreciate it as information that is approaching his location. The observer is in the neighborhood of the region of space towards which the tensor advances. The region towards which the tensor advances is flat, so it tends towards order (the living being organizes itself and increases its size). There can be no other source of information in that region that causes its curvature. While if the observer sees the tensor moving away from its position, it will be appreciated as energy moving away from its location. Since the dissipated energy was used to generate the structure of the living being, once the information density limit is reached, the space in which the system is defined will suffer a curvature[9]. The observer then watches the aging of the system, its decline and the inevitable geometric phase changes in its oscillatory variables[13]. The biological system symbolized as an energy-information tensor will appreciate things differently. Since temporal coordinates (among others) intervene in its constitution, it will appreciate the course of its life linked to the evolution of these coordinates. This observation bias will lead the system to accept with total naturalness that its life is measured in terms of elapsed time, appreciating as future every event that it approaches and as past every event from which it moves away. Although each biological event (recovering the dissipated energy as information) occurs in a certain place in space and at a certain moment in time, they are linearly independent vectors. This means that they are self-referring and therefore the evolution of each of them depends on themselves and not on the evolution of the other base vectors. The course of life then has its own metric (in terms of geometric phase shifts) and is independent of the metric of time. It is clear that in any case, energy and information are only two sides of the same coin. So somehow, if we take our observations based on our senses as physical reality, time passes, life passes and everything we observe looks consistent with reality. But in some other way, the rational analysis of the situation leads us to consider that time does not pass and neither does life, but that they are coordinates of a space of greater dimension than the one we can observe. At this point it is inevitable to wonder if the reality we observe is all there is to see of it or is it only a part of it.

A CONTACT PATCH

When we look at histological sections under a microscope, we appreciate in the two dimensions of the observation plane the "contact patch" that three-dimensional structures have in that observation plane. This gives rise to particular situations, such as the case of a sphere, whose contact patch in the plane is always circular. The cross section of a cylinder also has a circular contact patch in the plane.

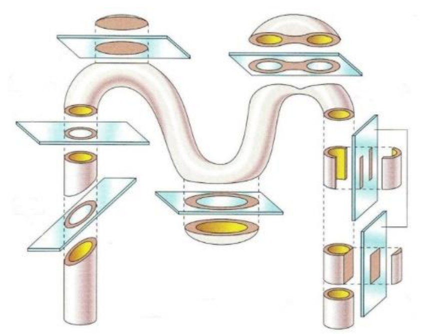

Figure 4: Taken and modified from “Técnicas histológicas”[27].

This forces the development of adequate training in the observation of histological sections, in order to accurately understand the true dimension of what is observed. Otherwise, only flat structures are observed that, even though they are equal to each other, can correspond to different three-dimensional structures without the observer understanding the situation. It is important to learn that a change in perspective can help to understand things in all their dimension. What we observe of a living being is its contact patch in space and time, of a higher dimensional structure. In the same way that a sphere is more than the circle that we observe of it in the plane, living beings are more than our contact patch in space and time. Just as a fourth dimension of space is seen as the passage of time, a fifth dimension of space is seen as the course of life (aging) in those physical systems where the fifth coordinate takes non-zero values. It takes non-null values in those systems that recover information about the dissipated energy (biological systems).

CONCLUSION

Life is intrinsically consistent with the structure of the space in which it develops. A phenomenon worthy of being observed and understood in all its dimensions, in its different aspects and forms of presentation. The diversity of living beings is a consequence of multiple factors. Also it is a happy consequence that helps to perpetuate life in its different forms of presentation. But in all living beings we observe the same common traces, because it is the same and unique phenomenon with different forms of presentation. We can achieve significant healthy survivals in different species through genetic or other interventions. But we cannot reverse the physics of the process. Physics, geometry and mathematics are above all the epiphenomena that we observe in biology. The vector description of living beings is important. If we observe a vector in the plane (a vector that is not collinear with the base vectors) and we operate with said vector to obtain the null vector, we will always affect its coordinates in the base vectors that determine the properties of the vector with which we operate. The same will happen with a vector in space, whatever its dimension. This is also important in biology.

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