

## Research Article

### Biological Aging: From the Boolean Networks, To the Geometric Phase

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**Abstract:** The objective of the study is to verify the possible relationship of the basal metabolic rate according to dry weight (BMR/dry kg.), with the capacity to generate body mass (estimated as delta dry weight or DDW) and with generated body mass (estimated as dry weight or DW). The findings are analyzed within a theoretical framework of random Boolean networks and the concept of the geometric phase applied to living beings considered as systems. No significant relationship was found between the BMR/dry kg. and the DDW, so aging cannot be attributed to the continued declining of the BMR/dry kg. In contrast, a high correlation between the BMR/dry kg. and the DW was found. Such a correlation could contribute to the explanation regarding the gradual loss of homeostasis that occurs in aging. Random Boolean networks of the NK2 type may help explain the origin of homeostasis and self-organization, but they cannot explain the gradual loss during the process of aging. Applying the concept of the geometric phase could contribute to the explanation since cycle after cycle the variables do not regain the original values and the system declines.

**Keywords:** Body mass, basal metabolism rate, homeostasis, self-organization

## INTRODUCTION

Living beings are complex physical systems (Von Bertalanffy, 1956, 1972) (Gell-Mann, 1997; Ekstig, 2010), constituted by the association of a system that dissipates energy and a self-organization that uses this energy to generate its own structure (Margalef, 2002; Sánchez and Barragán, 2010). Considered as systems, living beings are characterized by their capacity for homeostasis and self-organization (Kauffman *et al.*, 2008; Margalef, 1995).

Random Boolean Networks (RBN), such as the NK2 type, is a good model of the origin of such properties. In the RBN order emerges spontaneously and the network is able to circumvent any disturbances (Kauffman *et al.*, 2008; Gershenson, 2004).

This is because cycle after cycle of permutation, some variables resume their original values. (Graudenzi *et al.*, 2011, Ribeiro *et al.*, 2008) (Shmulevich *et al.*, 2005) Living beings also present cycles or oscillations: from cell cycles to hormonal circadian cycles (Brown, 1959; Chen *et al.*, 2007; Ikegami and Suzuki, 2008 and Lemmer, 2014).

However, both self-organization and homeostasis, suffer a gradual decline during aging (Campisi and Sedivy, 2009, Koga *et al.*, 2011 andreu, 2003).

The geometric phase has a decisive effect that can help explain aging: if the value of the variables in the

state of an oscillating system are defined, some variables, cycle after cycle will not recover their original value in the environment which undergoes slow changes, (Berry, 1988, Berry, 1989) (Segev *et al.*, 1992) Thus, properties such as self-organization and the capacity for adaptation, will show a gradual decline (Strehler, 2012).

Although developed to describe the behavior of certain quantum systems, this may also be applied satisfactorily in optics and some classical physical systems (Carollo *et al.*, 2003; Marcer *et al.*, 2004). This concept can also be used in biology (Marcer and Mitchell, 2001, Marcer and Schempp, 1998, Hameroff, 2001).

When it is said that living beings use energy that they dissipate in generating their own structure, this means that their own body mass is generated.

Considering Dry Weight (DW) as structure is a reasonable estimation, being that it is body mass free from water. It is the active metabolic body mass engaged in the dissipation of energy. However, to consider metabolic live weight as structure would introduce undesired distortions, as pointed out by the authors in previous studies (Sánchez and Barragán, 2011).

It is necessary to be more precise: the capacity to generate body mass is not the same as generated body mass. This concept is important in the current study as

the decline in the capacity to generate structure with dissipated energy will be analyzed.

The generated body mass corresponds to the value of DW in a given moment, while the capacity to generate body mass corresponds to the difference of DW between two consecutive moments. The difference of DW between two consecutive moments of life, is called "Delta Dry Weight" or DDW.

We must also be precise with the dissipation of energy. In order to avoid inconsistency in the decline of the metabolic capacity per unit of body mass that occurs in living beings with the passing of life and is seen in the gradual reduction of the percentage of water, one must estimate the dissipated energy in terms of the basal metabolic rate per kilogram of dry weight or BMR/dry kg (Barragán and Sánchez, 2014).

**OBJECTIVES**

Verify the relationship between the evolution of DDW and the evolution of BMR/dry kg. during one's life span.

Describe the relationship of the evolution of DW with the BMR/dry kg. and observe its relationship with the evolution of DDW during one's life span.

**MATERIALS AND METHODS**

We analyzed the average data from Weight Charts and Basal Metabolic Rates Chart from different age groups in healthy human being from both sexes. To verify the relationship between the variables, the Pearson Test was applied.

Table 1 shows the data of evolution of DW, DDW and BMR dry/kg. from healthy men of different ages Table 1.

Table 2 shows the data regarding the evolution of dry weight, delta dry weight and the BMR/dry kg. for healthy women of different ages Table 2.

**RESULTS**

The relationship between the capacities to generate structure, estimated as DDW and the BMR/dry kg. (dissipated energy) in both sexes, evaluated with the Pearson Test, does not show significant results, with value R = -0.12 for males and R = -0.42 for females.

This low correlation between both variables is seen in Fig. 1 and 2. The logarithmic transformation of the data allows for a better observation in the graphic representation Fig. 1 and 2.

The relationship between the evolution of DW and BMR/dry kg. is highly significant for both sexes. R= -0.91 for males and R= -0.93 for females. Figure 3 and 4, in which the logarithmic transformation of data was also used, illustrate the strong relationship between the variables (Figure 3a and 3b and 4a and 4b).

The comparison of the Figure 3a and 4a with those that show DDW in both sexes (Figure 1 and 2), can be

Table 1: Taken and modified from previous papers by the authors (Sánchez and Barragán 2011)

MALES (category)	Age (years)	Dry Weight (kg)	Delta Dry Wright (kg)	BMR/ DW (kcal/kg)
1 Babies	0.0-0.5	1.40	-	228
2	0.0- 1.0	2.90	1.5	172
3 Children	1-3	4.60	1.7	160
4	4-6	7.60	3.0	125
5	7-10	10.9	3.3	103
6 Males	11-14	18.0	8.9	80
7	15-18	27.7	9.7	63
8	19-24	30.9	3.2	57
9	25-50	34.7	3.8	51
10	51+	34.6	-0.1	44

Table 2: Taken and modified from previous papers by the authors (Sánchez and Barragán, 2011)

Females (category)	Age (years)	Dry Weight (kg)	Delta dry weight (kg)	BMR/DW (kcal/kg)
1 Babies	0.0-0.5	1.40	-	228
2	0.5-1.0	2.90	1.5	172
3 Girls	1-3	4.60	1.7	160
4	4-6	7.60	3.0	125
5	7-10	10.9	3.3	103
6 Females	11-14	19.3	8.4	68
7	15-18	24.2	4.9	56
8	19-24	26.6	2.4	50
9	25-50	30.2	3.6	45
10	51+	32.5	2.3	39

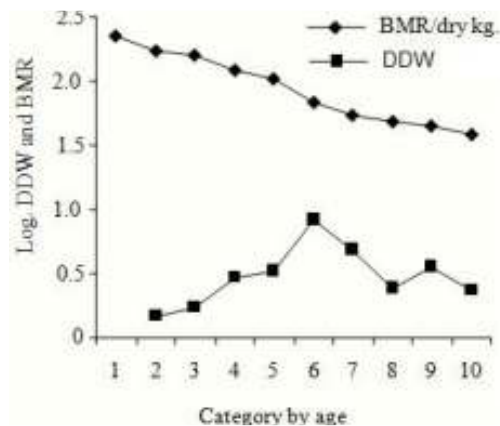


Fig. 1: Low correlation between BMR/dry kg, and the DDW is observed in females

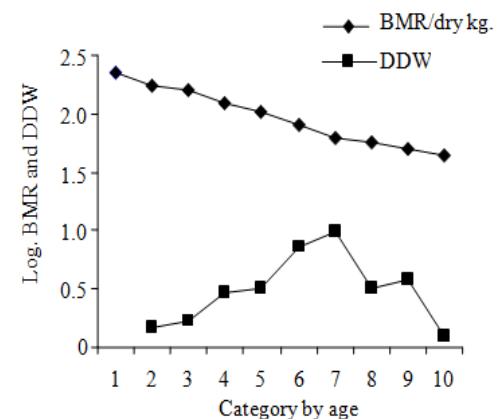


Fig. 2: Low correlation between BMR/dry kg, and the DDW is observed in males

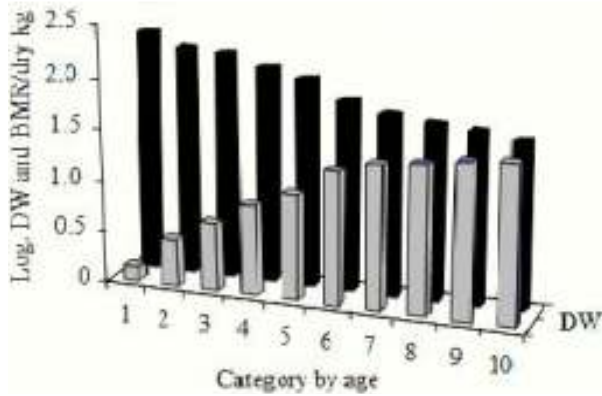


Fig. 3a: (Columns): Shows the strong negative correlation between generated dry weight (DW) and energy dissipation (BMR/dry kg.) in females

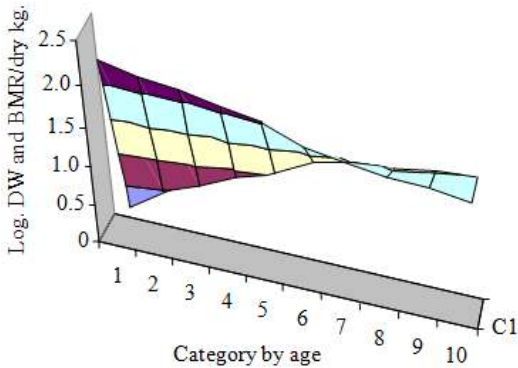


Fig. 3b: (Surface): As figure 3a shows the relationship between DW and; BMR/dry kg.in females, the authors consider necessary graphic expression in surface mode, for reasons explained in the "Discussion"

seen unified in Fig. 5 and 6. The logarithmic transformation of the data was used to optimize the graphic expression of the same (Fig. 5 and 6).

If one observes Fig. 5 and 6 carefully, the DDW reaches its peak at the same point in which the torque surface illustrates the relationship between DW and BMR/dry kg. coincides. This occurs around age 14 for females and 18 years for males.

**DISCUSSION**

There exists a low correlation between the BMR/dry kg. and the DDW (Fig. 1 and 2). The simple observation of the curves shown that with one BMR/dry kg. in continual decline, the DDW increases until it reaches its highest peak in puberty. If it later declines, it cannot be attributed to the decline in the BMR/dry kg.

If one understands aging as a gradual reduction of the capacity to generate structure with dissipated energy, the reduction of DDW after puberty is not related with the decline of the dissipation of energy per unit of dry weight that occurs at all times with advancing age.

**Relationship between DW and BMR/dry kg. by age (males)**

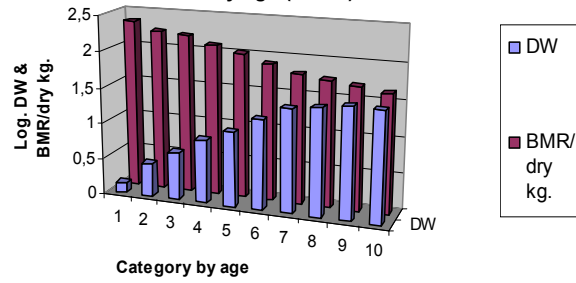


Fig. 4a: (Columns): Shows the strong negative correlation between generated dry weight (DW) and energy dissipation (BMR/dry kg.) in males

**Relationship between DW and BMR/dry kg. by age (males)**

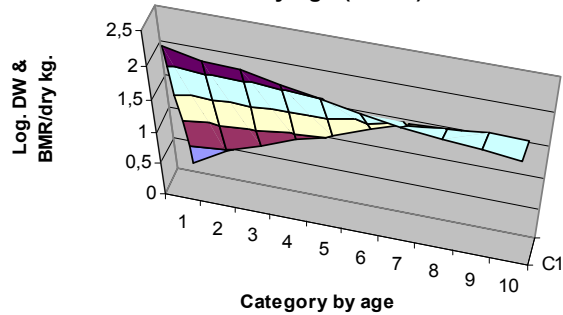


Fig. 4b: (Surface): As figure 4a shows the relationship between DW and; BMR/dry kg.in males, the authors consider necessary graphic expression in surface mode, for reasons explained in the "Discussion"

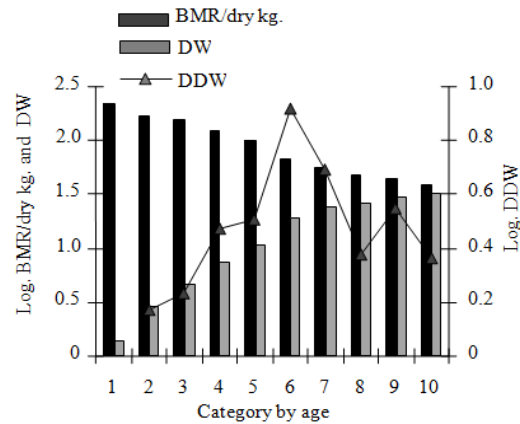


Fig. 5: DDW peak (line) coincides with the torque surface illustrating the relationship between the BMR/dry kg and DW (Figure 3b) in females

However, a high correlation between the dissipation of energy per unit of mass (BMR/kg dry) and the body mass generated (DW) is found.

It is no coincidence that an additional graphic expression in surface mode (Fig. 3a and 4b) have been added to illustrate the relationship between the generation of structure (mass generated, estimated as

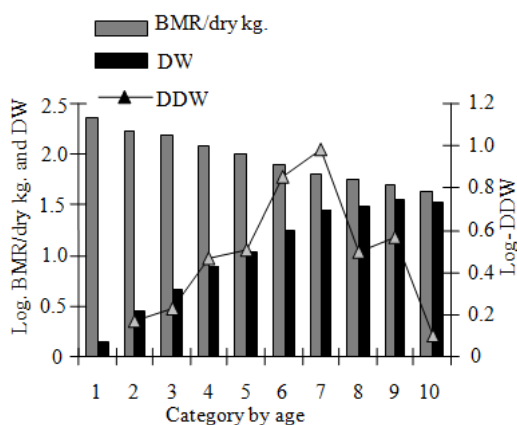


Fig. 6: DDW peak (line) coincides with the torque surface illustrating the relationship between the BMR/dry kg and DW (Figure 4b) in males

DW) and the dissipated energy per unit of mass (estimated as BMR/dry kg). The choice of a surface graphic expression is because the parameter space of a self-organized system, like the RBN, is flat: only in this mode, entries always come from the same system and cycle after cycle some variables resume their original values.

However, after puberty some variable do not resume their original values. So, within the framework of the geometric phase, this implies that the environment in which the values of the variables are defined have suffered a gradual change. Keep in mind that in the geometric phase, the changes that the environment suffers is accompanied by opposite changes in the parameter space.

It is likely that living beings do not define their variables by "chance" in an environment that suffers gradual changes, but by the different evolution of the constituted systems (dissipated system and self-organized system); the same systems provoke the changes in the environment in which the variables are defined.

DDW presents its highest peak (line in Fig. 5 and 6) when the surface that represents the relationship between DW and BMR/dry kg. reaches its torque moment (Fig. 3b and 4b). The idea is to consider the relationship between the mass generated and the dissipated energy as a surface and not merely an illustration.

When self-organization and homeostasis emerge, the space of the parameters is flat.

Obviously, such space is no more than a virtual space (unreal) of variables. The variables are defined in a certain environment and this is not only the same environment variables, but the real physical space (not virtual) in which values are defined.

When we say that the parameter space is flat, the real physical space can also be considered flat since

independently of its real geometry, its size is consistent with the planarity of the parameter space. The geometric phase phenomenon implies that the geometry of the parameter space and that of the environment are mutually consistent: if one suffers changes, the other also suffers them (Berry, 1989).

So when it is said that the relationship between the dissipation of energy and the generated mass causes a torque in the space parameter, this implies that the real physical space (which is the environment in which the value of the variables are defined) is no longer consistent with the original flatness of the space parameter.

Thus, regardless of its actual geometry, one can ensure that the environment in which the values of the variables (the real physical space) then has a dimension "n+1".

It is probable that aging is not caused by genetic, metabolic or systems, but by a torque of space in which living beings define their variables, caused by a particular relationship between self-organized systems (DW) and the dissipative (BMR/dry kg.).

Of course it can be argued: if so, why can't this torque be seen? The answer is: it is seen. It is called aging. The metabolic processes (Rattan, 2006, Makarieva *et al.*, 2008), systemic Blagosklonny, 2010) (Schaible and Sussman, 2013) and genetics (Gaziev *et al.*, 2014; Lauri *et al.*, 2014) associated therewith, would be epiphenomena of the torque.

However, the way this process presents itself is not the same in all living beings, but it varies according to the degree of complexity of the same (Galliot, 2012, Nebel and Bosch, 2012, Yoshida *et al.*, 2006 and Schaible *et al.*, 2014).

This is because the complexity is related to the relationship between the energy dissipation by unit of mass and the generated mass. (Barragán and Sánchez, 2014).

At the same time, it is related to aging in living beings: the lower the complexity, less noticeable is the aging process (Barragán and Sánchez, 2013).

Keeping in mind Stephen Jay Gould and the wall of complexity (Gould, 1994) (Fig. 7).

The closer the organism is to the left side of the wall of complexity, the aging will be less noticeable. The farther the organism falls from the left side of the wall (the more complex it is) the aging will be more noticeable.

Another issue of interest might be: why this phenomenon does not occur in the inert physical systems. The answer is: such systems are not self-organized with dissipated energy, so they do not produce any type of torque in the space in which its stated variables are defined.

Its environment might suffer a gradual curving and also present a geometric phase, but its system cannot

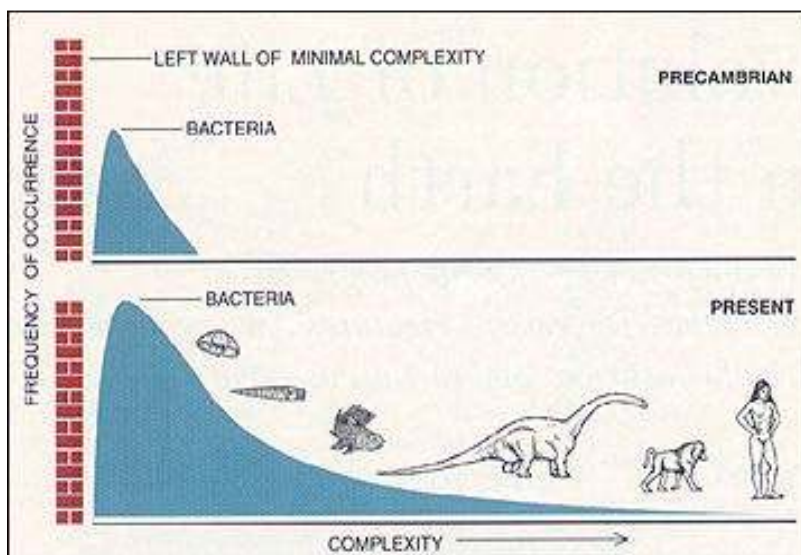


Fig. 7: The relationship between organisms and the wall of complexity (Gould 1994)

cause curving. The parallel transport of a vector, is a clear example (Berry, 1989, Furtado *et al.*, 2008, Anandan, 1992).

### CONCLUSION

The present investigation did not find a significant relationship between BMR/dry kg and DDW. Living beings do not age because of a decline in their capacity to dissipate energy.

On the other hand, there exists a high degree of correlation between the dissipation of energy by the unit of body mass free from water (BMR/ dry kg) and the generation of body mass (DW). At the same time, the capacity to generate body mass, estimated as DDW, increases until puberty. It is likely that living beings grow old because the relationship between BMR/dry kg and DW is associated with the decline of DDW that occurs after puberty.

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