A new paradigm for growth modeling: Action

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THE BEHAVIOR OF BIOLOGY AND THE LAWS OF PHYSICS

Physics and biology are closely related. To facilitate understanding it is possible to make an analogy when thinking of physics and biology as sisters, and yet, because biology is the newest seek advice with the oldest and most experienced, physics (Grandipeierre, 2011). Thus, when one wishes to study relationships and the path from an initial state to its end, the principle of the action of physics shares and clarifies events of biology in a very timely manner. It is possible to generalize that in biology, this concept could be defined as greatest action principle (Johnson, 2006; Grandpierre, 2007).

According to the corollary "If all the fundamental physical laws can be derived from the first principle of physics, then the least action principle characterizes all physical behavior" (Grandpierre, 2011). Thus, it is surprising that all the fundamental laws of physics can be derived from the principle of less action.

Action, in physics, is an attribute of the dynamics that presents the scalar dimension: energy × time. That is, the integral of the whole process, from the beginning to the end, that in biology would be the study of the growth of an organism (birth to maturation). In this way, biology resembles, but it does not equate to physics, because its flexibility allows and desires vitality and quality of life (Grandpierre, 2011).

As an example, to understand such flexibility, if a stone and a lifeless bird are released from the top of a tower, in that condition the laws of physics would reign completely to explain the trajectory of both bodies. But if the bird is alive, the principle of more action is manifested. However, for stone only the path of least action is that it will always be obeyed (Grandpierre, 2011). Despite distinct behaviors, however, the behavior of biology is explained and governed by the laws of physics (Heidelberg, 2018).

In this way, in biology the study of action affects the growth trajectory of an organism, according to the accumulation of new biomass (kinetic energy), which is finalized when reaching the maximum level in accumulated biomass (potential energy), characterizing the well-known asymptote of the curve (Heidelberg, 2018; Johnson, 1992).

Although physics defines the unit by the SI in joule-seconds, biology, by its flexibility, allows to adopt other units, to better characterize the phenomenon under study, as for example, in representing the growth of cases of Aids or Zica we would have individuals like unity (Jones et al., 2019; Sebrango-Rodrigues, 2017). However, one can have kg, μmg, meters or any other unit that best characterizes the expansion of the event studied.

Even following the principle of more action, biology follows the state of minimum work, which would be the case of the live bird released in the tower, which when feeling loose, would seek a safe place, but making the least possible effort (Johnsen, 2006; Heidelberg, 2018, Grandpierre, 2011).

It is curious to note that just as a live bird launched from the top of a tower chooses its safest landing endpoint in quantum physics, this endpoint, too, is a choice (Grandpierre, 2008). This fact is a strong argument to demonstrate how the action allows to simplify and connect these two sciences (biology and physics).

This is the beauty of physics applied to living organisms, which, through the principle of action, increase or enable more life in each cycle (Heidlberg, 2018). According to Grandpierre (2008), the principle of action presents itself as the most powerful tool in physics that accommodates itself elegantly and harmoniously with biology, and even more can be considered as the "first principle of biology ".

In the same way as in physics, the principle of action allows to base all its laws (Moore, 1996). Similarly, it is possible to establish action as the first principle of biology, and thus allow, also, that all the fundamental laws of biology can be derived from the action dimension (Grandpierre, 2008).

THE DIMENSION ENERGY × TIME

The most basic units of physics, on a mechanical basis are: mass, length and time. From this, all quantifications of mechanics are attributes or the division or multiplication of these basic properties, as illustrated below (Figure 1):

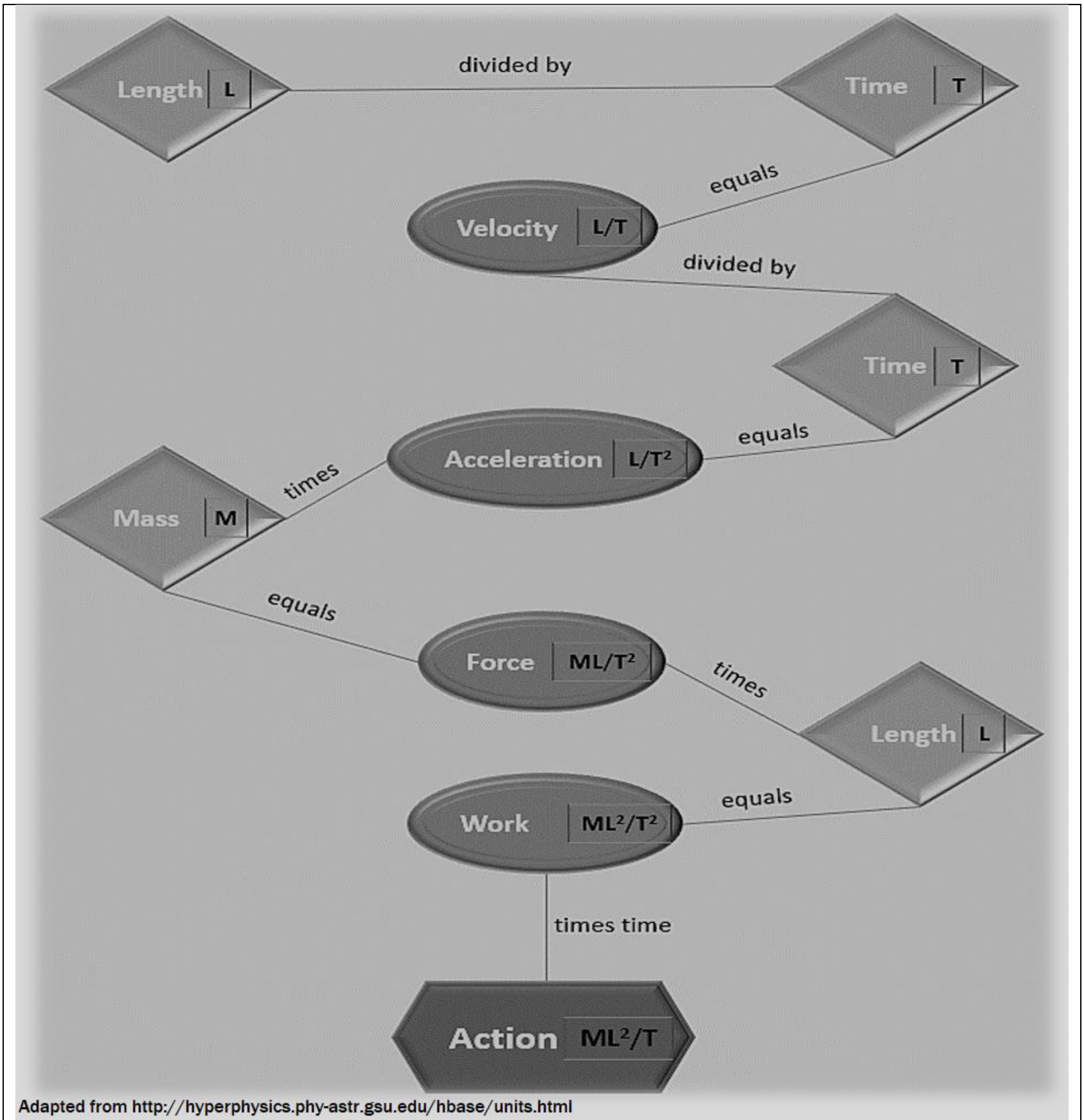

Figure 1. The standard units are the *Systeme Internationale* or SI units: Length, mass and time. Adapted from: http://hyperphysics.phy-astr.gsu.edu/hbase/units.html

Power tells you how fast a job is done (J / s). The action, on the other hand, clarifies how great the performance of work is in a given period of time (J × s) (Girtler, 2011).

The action presents as quantitative base the dimension energy × time, integrating the evaluation of the entire interval of the event under consideration, from the beginning until its end endpoint (Grandpierre, 2011). Endpoint - at which point the process or stage is complete, as an example, the turn of color in a chemical titration.

In this way, energy is continuously transformed from kinetic (new biomass) to potential (biomass), until it reaches its state of maturity (growth saturation) (Hutzinger, 1989; Jorgensen, 2000).

Action allows a new selection criterion to promote a better evaluation by incorporating not only mass (m), but mainly the effect of velocity (v) and its quadratic attribute (Kinetic energy = KE = $m \times v^2 / 2$).

Action is thus the fundamental tool when one wants to study the conditions from the beginning to the end of a growth, development or expansion trajectory (Hanc, 2006; Grandpierre, 2011).

THE TRAJECTORY OF THE GROWTH

One can define action in biology as being the accumulation of work done, that is, all the effort made that allowed the expansion or growth of an organism until reaching its endpoint, that is, the end of the trajectory of the growth that characterizes the plateau of the growth curve (asymptote) (Grandpierre et al, 2014; Arons, 1999; Jorgensen, 2018). Therefore, more action: an organism's ability to acquire and convert energy into new biomass (Owen-Smith, 2005).

It should be noted that action must be understood as a property that characterizes the whole trajectory of growth, rather than as a single point along that path (Gribbin, 1998; Johnson 2006). From the above, it is essential to determine precisely the growth trajectory, and nothing more opportune than the flexibility of the sigmoid curves (Yin et al., 2003, Kebreab et al., 2010), when describing the three distinct phases: acceleration phase, linear phase and, finally, the saturation phase.

Among the several curves available, the Richards function is one of the most flexible, although it requires one more parameter when compared to logistic or Gompertz, both of which are intrinsically inflexible, or because of their symmetrical nature or because they overestimate the asymptote, respectively (Yin, 2003).

Many studies value biological interpretations for the parameters of the equations, being this one of the virtues pointed to indicate the logistic and Gompertz curve, and the reason of Richards to be criticized. However, the present proposal presents the adjustment of the equation as a first step, and not as the end of the analysis using the PPFM program (Practical program for forces modeling) (Figure 2). Reason not to require biological interpretations for all parameters, but flexibility (Kebreab et al., 2010). It is worth remembering that "if physics has its laws, biology has its variety" (Dover, 1988). Thus, biology shows its greatest virtue, autonomy (Grandpierre, 2011).

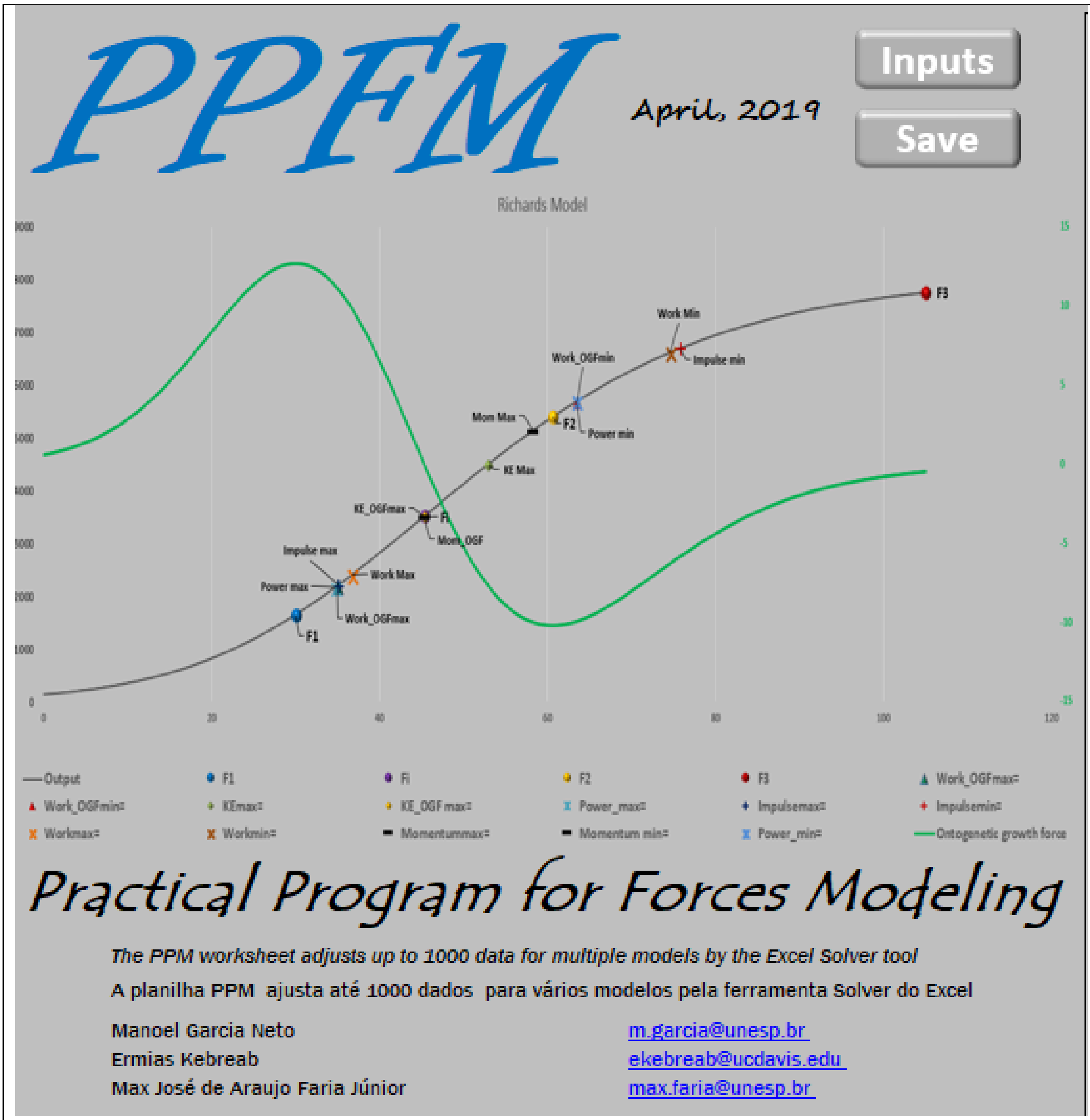

Figure 2. Practical program for forces modeling PPFM.

PPFM presents elegantly the three phases of growth (acceleration, linear and saturation), by providing a gradual transition between these phases.

It is desired that the equations accommodate time course data on the growth of an organism (Krebeab et al, 2010), and their interactions, to characterize the expansion of the organism throughout its growth path (Zeide, 1993). In this way, both the action principle and the growth curves are similar, since they represent or present the initial and final state as a basis, when integrating the whole process. Through this appreciation, both physics and biology become reciprocal (Woese, 2004).

The principle of less action manifests itself in economics for a long time (Gibson, 1900), in which it is generally desired to maximize results with the least effort (labor).

Energy, as a process, is always transformed and transmitted, and consequently, by action we have changes, whether in the expansion (e.g., volume) or growth (e.g., weight) of the organism. In this way, energy and time are inseparable, and this is for all levels of organization. Thus, the principle of less action is admittedly the key to the basic understandings of nature (Tributsch, 2016).

The growth equation could be described as an integral, by describing what was accumulated to form an organism during its developmental path (Zeide, 1993).

During the growth process each organism has the opportunity to show its ability to capture and store energy. Thus, acquiring, concentrating, and conserving energy is called more action, and is expressed in energy multiplied by time, and the most efficient will occupy the highest hierarchy level (Vanriel & Johnson, 1995; Owen-Smith, 2005).

Man is a classic example, using nonrenewable sources (e.g., coal, oil), distancing himself as a dominant species, but with the price of the drastic decline of diversity, by abusing the principle of more action (energy-time accumulation), when envisaging abundance of goods, of the biomass itself (individuals) and by increasing their longevity (Johbson, 1992).

The human being still abuses the principle of more action not only to survive, but to happiness, which requires and involves money, comfort, power, consumerism, success, etc. (Grandpierre, 2011). Now it is possible to unite psychology with physics and biology, to justify the great flexibility of man (passions), which allows him to be located in the most extreme, when compared to animals (more influenced by instincts) and at the other extreme plants. But, emphasizing that price and effects are already evident today, but that their totality will be paid in future generations (Grandpierre et al., 2014).

THE ACTION AND THE USEFUL WORK

In this way, we enter a new frontier of science, uniting more one sister, who elegantly allows the union of physics, biology and psychology, through the principle of action, as a fundamental tool that allows to describe the biological phenomena, precisely because they present or walk to an endpoint, which may be tragic for humans (Grandpierre, 2008).

The derivative of a growth function allows to obtain the absolute growth rate, and deriving again the curve of the speed obtains the curve of the acceleration of the growth (Figure 3).

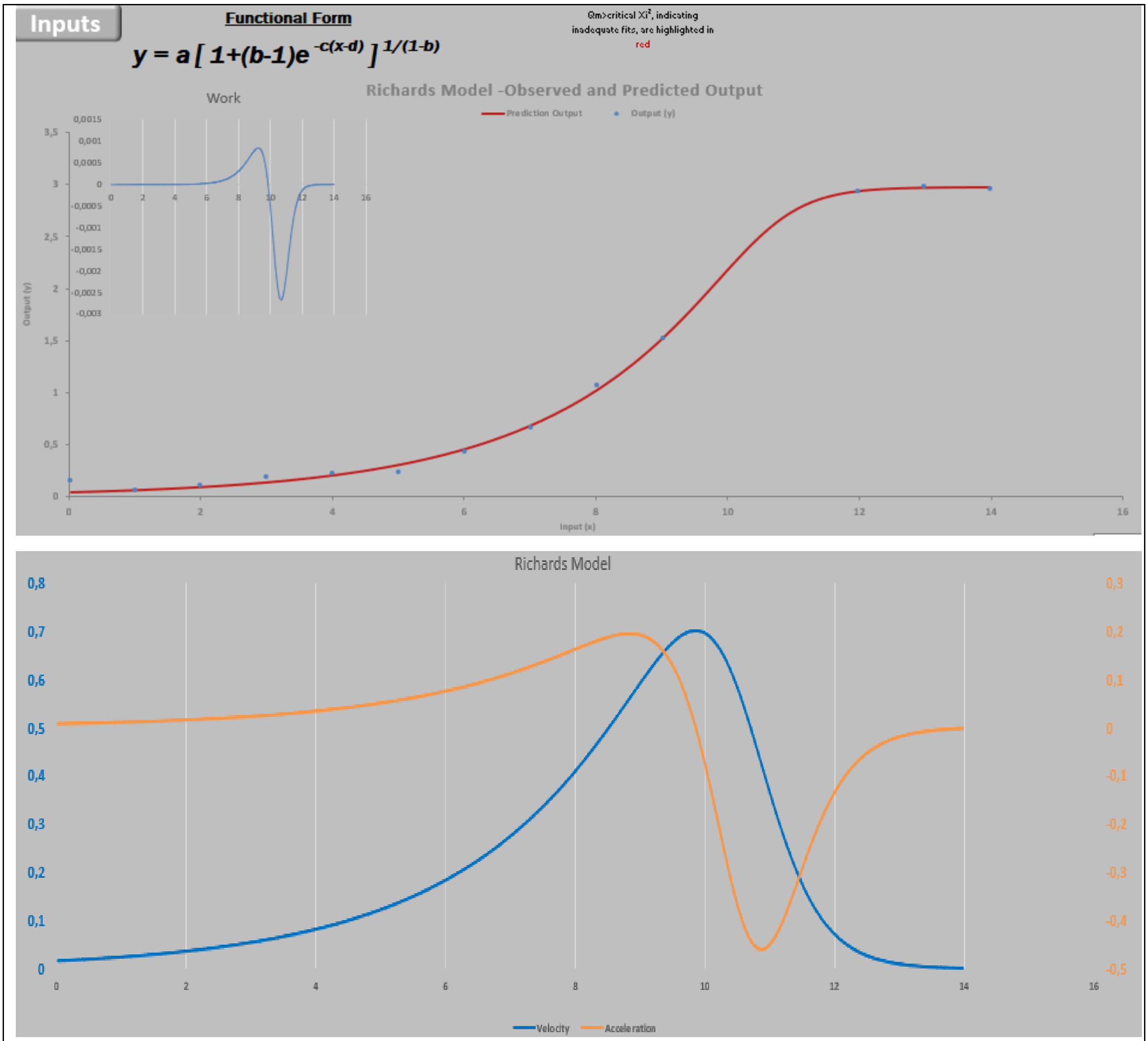

Figure 3. Growth function and two derivatives (velocity and acceleration).

From these two derivatives (velocity and acceleration) it is possible to apply the mechanics point of view to the bases of growth analysis, and it is possible to define the growth force (F = m × a) (Figure 4), where m = mass of the organism and a = acceleration (second derivative) of its growth (Shimojo et al., 2006).

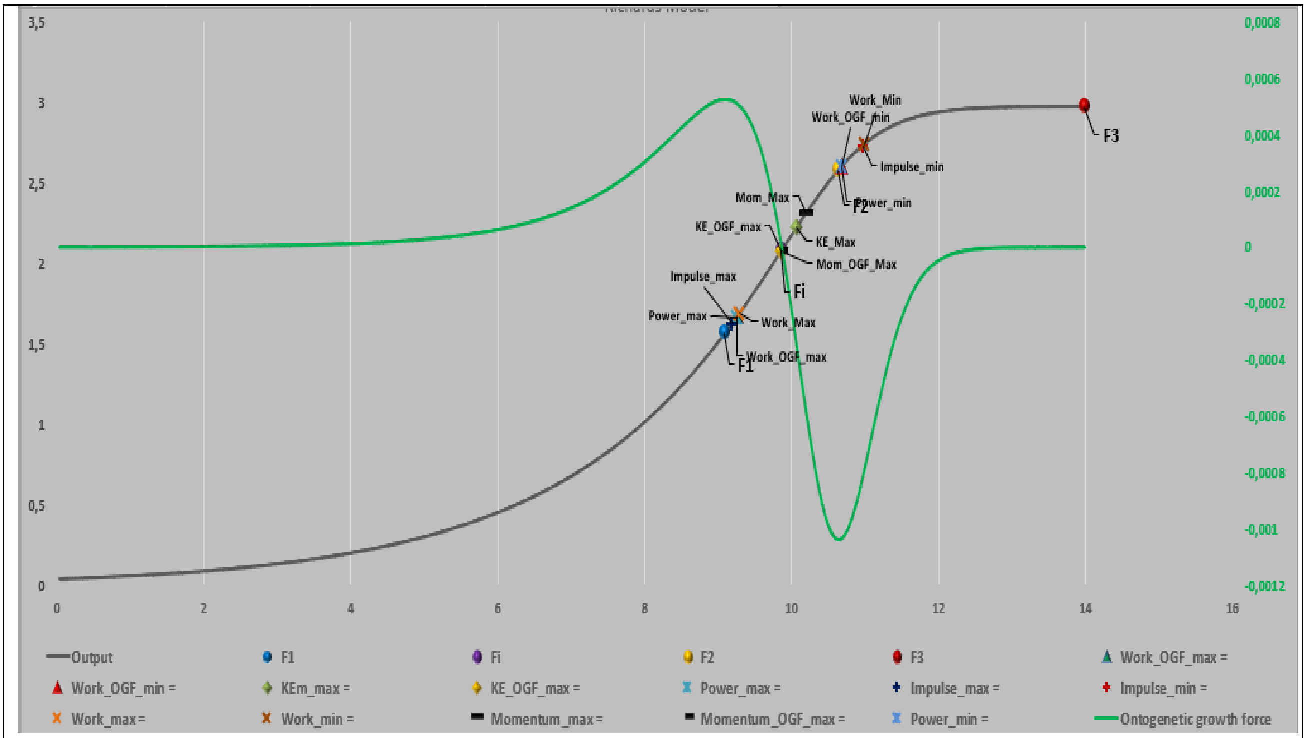

Figure 4. Growth force, according to Newton's laws (F = m × a).

Thus, using the mathematical properties of mechanics to evaluate the growth of an organism, according to Newton's laws, it is still possible to calculate the kinetic energy (KE = m × v^2 / 2), where v = growth rate (first derivative).

Finally, the integral of the KE as a function of time yields the Action, which in a simple way would be the sum of all the useful work of the growth path (Figure 5).

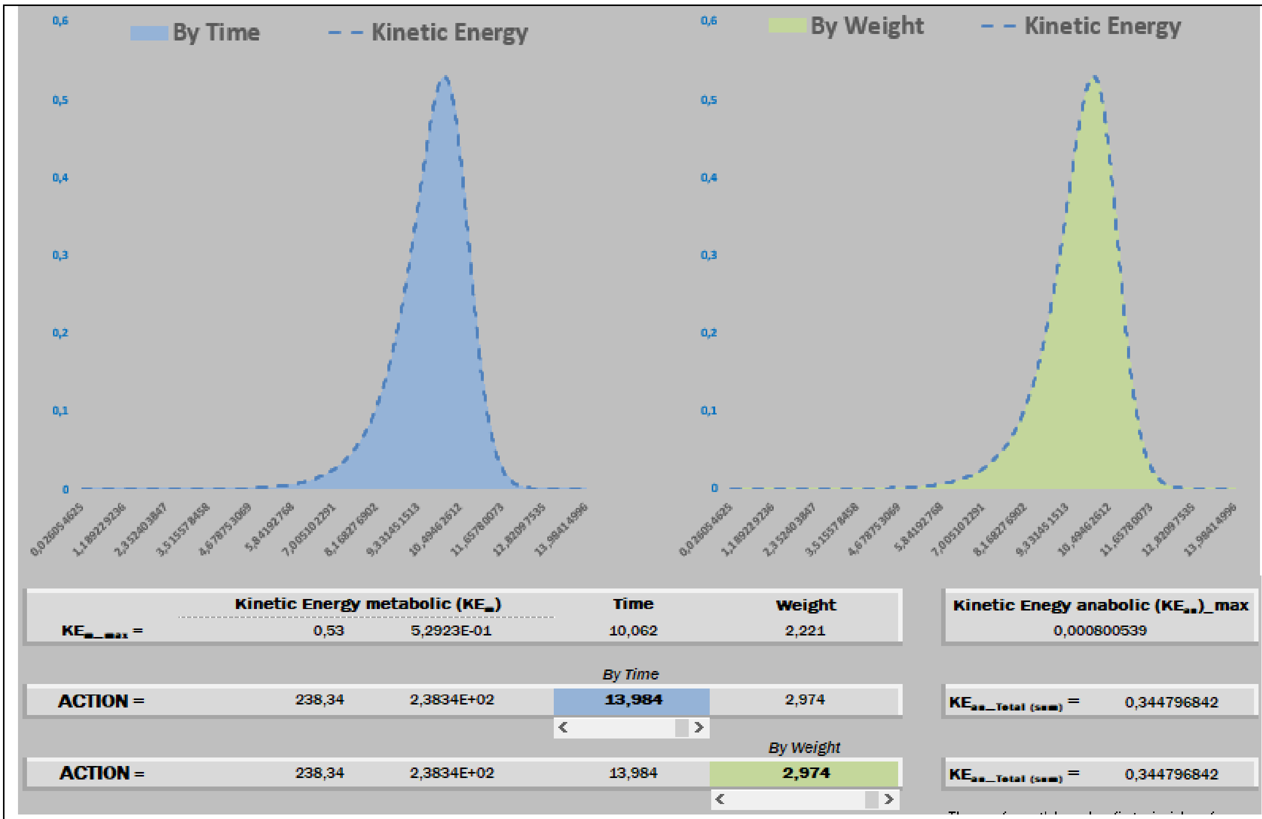

Figure 5. Action representing growth from the beginning until its completion, defined by the integral (summation) of the energy of each instant of growth.

It is surprising to note that velocity, because it is quadratic in the formula of KE, induces that its influence is much greater in relation to mass.

This fact allows to affirm that, for example, genetic houses should also direct the evaluations of the genetic progress of their genetic improvements lines not only for the biomass produced, but it is opportune to evaluate from the perspective of useful work of the growth, that includes the speed of deposition of the during the growth path, mainly due to quadratic influence ($KE = m \times v^2 / 2$). That is, there is much more merit of speed than of mass at work to grow.

The same argument is also valid to evaluate the growth of aids, in which the contamination of new individuals is more impacted by the speed of the contamination, or even the growth of a cancerous tumor, in which the rate of deposition of new cancerous biomass is much more aggressive than to evaluate only the existing biomass, and all this by the impact of v^2 of the formula $KE = m \times v^2 / 2$.

The contrary is also true, if the objective were to evaluate the influence of a new antibiotic, the desired would be to minimize the growth of bacteria. Thus, if the purpose is to minimize the expansion, that is, to minimize the useful work of this growth of these bacteria, interfering in their multiplication of the action of the antibiotic evaluated. Therefore, nothing better than gauging the action (energy × time), precisely by evaluating or representing growth from the beginning until its completion, defined by the integral (summation) of the energy of each instant of growth. This is nothing more than the measurement of the area represented for each particular graph formed by the multiplication "KE × Time" (Girtler, 2008).

In this elegant way, it is possible at any moment of growth (time) to determine the useful work of that particular moment, and more, the sum total of this useful work, which allows the growth of the new biomass (kinetic energy), which in turn allows the completion of biomass growth (potential energy) (Joerson, 2018).

By analogy, just as the physicochemical determination of the properties of an oil, by losing its ability to avoid friction over time, culminates in the increase of wasted energy through heat, thereby reducing the useful work of the lubricant motor. It can be said that something similar occurs in the growth of a new biomass, especially at the end of its development, when the requirement for maintenance of the biomass becomes so voracious by the available energy resources, it prevents the deposition of new biomass , signaling the genetic limit of the growth, and also, by the limitation of the capture of more nutrients by the digestive tract (food conversion worse and worse). That is, the worsening of useful work to grow (Owen & Smith, 2005).

The great advantage of using kinetic energy (new biomass) as a way of calculating the growth action is in the much more precise analysis to measure different units of measurement, that is, one of the great virtues of biology (flexibility). All this is facilitated by the graphical feature that allows analysis of the area (action) that enables the evaluation of useful work at any point of the path (growth).

Despite being recognized for its importance, the principle of action in modern physics is considered as a difficult and obscure topic, and only addressed in very advanced courses and texts (Hanc & Safarik, 2006), and it is stated that even in physics, the potential of its application is still very far from its full potential of use (Grandpierre, 2008).

The unit expressed in <u>*J* × *s*</u> or <u>*N* × *m* × *s*</u> is considered difficult to interpret by physics, and thus is very little used (Grandpierre, 2007; Hanc & Safarik, 2006). However, this attribute of physics applied to biology allows a clear interpretation of the principle of action (energy × time) in biological phenomena.

Another reason for the need to use area to measure the action is that at each instant of time changes in the value of kinetic energy, necessitating the use of the integral (Rosen, 2004).

In this way, it is possible to evaluate the energy-time dimension, which in turn characterizes the action dimension (e.g., integral time of kinetic energy) (Encyclopedia Britanica, Quantum mechanics).

Moreover, the principle of action can also be defined as the integral of the product of the energy investment (kinetic energy) and the invested time, that is, the sum from the initial phase to the final state (climax, maturation) of a living organism (Grandpierre, 2011).

The action is the investment in growth, that is, the product of the invested energy and the time invested in the evaluated process, and in this way can even be considered as a cost function (Rosen, 1967 cited by Grandpierre, 2008).

Therefore, it is again evident that action is not a moment of the trajectory, but always the whole of the trajectory (Gribbin, 1998; Johnson 2006).

In this way, the principle of action is virtually universal in terms of application (Johnson, 2006). The principle of action applied to biology offers a great assistance in the understanding of useful work, which enables the expansion of an organism, until reaching its climax of development.

The PPFM makes it possible to apply, in a practical way, the laws of physics in biology, through the modeling of growth curves and their derivatives (velocity and acceleration).

The principle of action allows us to evaluate how much free energy was used to perform useful work (growth expansion), that is, living organisms have their limits of growth (endpoint), while biologically useful work (Grandpierre, 2014).

As with combustion engines, useful work can be offered as deterministic if there are no changes in the energy value over time. However, if energy is time dependent, action must be determined as integral (Dzida & Girtzer, 2016).

This allows to evaluate the performance efficiency of the work carried out that makes possible the accumulation of biomass.

CONCLUSION

The action (energy × time) allows to explore concepts of physics, to clarify biological phenomena, offering a common basis for theoretical biological physics in its most fundamental aspects.

Thus, the PPFM worksheet allows to present in a practical way, the establishment of the first law of biology, contributing to the evaluation of growth expansion, allowing a new approach, which in a refined way unifies physics to biology, allowing more understanding of the most basic attributes of nature.

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