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# The Mathematical Modelling of the Systems Theory

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## ABSTRACT

Life is an embodiment of matter that is a common feature of living organisms and can be used as a fundamental criterion for characterizing them. Everything that is common to living organisms falls under the umbrella of biological motion. Everything that is common to living organisms falls under the umbrella of biological motion. The new approach – qualitatively different and more than that of classical or borderland sciences – is the interdisciplinary perspective. The first important milestone in the scientific establishment of general systems theory was the year 1942, when the second edition of *Theoretische Biologie* by Ludwig von Bertalanffy. One of the main aims of general systems theory is to develop a general orientation and a general theoretical framework that enables a practitioner of a discipline to take up structurally and organizationally relevant contributions from others. Examples are totality, additivity, leap and slow evolution, similarity, gradual selection, growth-evolution, mechanization and centralization, individuality, adapta¬tion, aggression, hierarchical order, parts with a control function, the avalanche ef¬fect, purposiveness and unity of purpose, rhythmicity, physical and biological time.

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## Preface

The scientific and technological revolution is producing more and more surprising new scientific results. Science has become the most powerful organizing force; increasing its potential is a prerequisite for development. Life is an embodiment of matter that is a common feature of living organisms and can be used as a fundamental criterion for characterizing them [1]. A profound and effective investigation of the laws of biological existence can only be achieved through the objective language of scientific expression. The future use of transport processes and cross-effects in medicine is foreshadowed by the computerization of clinical diagnosis, which requires knowledge of the functional and structural depths of the human organism that cannot be interpreted without the application of these two fundamental biophysical proces¬ses [2,3].

The first important milestone in the scientific establishment of general systems theory was the year 1942, when the second edition of *Theoretische Biologie* by *Ludwig von Bertalanffy*, then a professor at the University of Vienna, was published [4]. The history of thinking shows that theories that break new ground do not usually meet with unanimous success among experts, and – almost as usual – provoke heated debates with those who insist on the traditional results achieved earlier in the history of scientific thinking [5]. So it was with systems theory. Some still reject it to this day, others confuse it with classical scientific findings: the systematics of plants and animals, the crystal system, the periodic table of the elements, etc., still others try to explain all phenomena by the means of this system. In our opinion, a system is a basic concept that does not need to be defined, like the concept of a set in mathe¬matics [6].

## Systems theory

According to Bertalanffy, systems theory can be used to define, by logical and mathematical means, more than one imprecisely defined and much debated concept. Examples are totality, additivity, leap and slow evolution, similarity, gradual selection, growth-evolution, mechanization and centralization, individuality, adaptation, aggression, hierarchical order, parts with a control function, the avalanche effect, purposiveness and unity of purpose, rhythmicity, physical and biological time, tension, etc. In this way, a number of "pseudo-problems" which have hitherto given rise to endless debates and which are outside the bounds of science are refuted in logical-mathematical analysis, but unfortunately without being clearly revealed [7]. The way of analysis provided by systems theory is a qualitative leap compared to the way concepts have been discussed so far, but it does not perfectly clarify the issues raised. But the excuse is that you cannot, because the process of cognition is infinite!

Consider, for example, a system of objects consisting of, say, $p_1$, $p_2$, ..., $p_i$, ..., $i \varepsilon I$ parts, where the parts are defined according to some $Q_{ji}$ ($j \varepsilon J$) quantitative characteristic. (Both the *I* and the *J* can of course be arbitrary.) Such a quantitative characteristic could be the temperature of the parts, their age, the concentration of a specific substance present in them, etc [8,9]. The values of $Q_{ji}$ in the different parts may vary over time, and in particular, what happens in one part ($Q_{jk}$) may depend on the situation in all other parts of the whole ensemble ($Q\}i$; $i \varepsilon I$, $i \neq k$), at a given moment, the extent to which $Q_{jk}$ changes in one part depends, according to a function ($f_{ji}$), on the $Q_{ji}$ value of all parts at that moment. If this is the case, then there is an interaction between the parts, which can be expressed by this simultaneous differential equation system:

$$\frac{dQ_1}{dt} = f_1(Q_1, Q_2, \dots, Q_n)$$

$$\frac{dQ_2}{dt} = f_2(Q_1, Q_2, \dots, Q_n)$$

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$$\frac{dQ_i}{dt} = f_i(Q_1, Q_2, \dots, Q_n)$$

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$$\frac{dQ_n}{dt} = f_n(Q_1, Q_2, \dots, Q_n)$$

Although nothing has been said about the type of functions $f_1$, $f_2$, ... $f_n$ and the connections that exist in the living organism/system, some general principles can be deduced from the system of equations.

Living organisms in their homeostasis strive to be in equilibrium, which means that dynamic equilibrium is characteristic of the whole system, but fluctuates around its individual parameters and mean value.

In the equilibrium state, the quantitative values of the parameters are denoted by $q_1^*$, $q_2^*$,... $q_n^*$, and a new variable is introduced:

$q_i' = q_i^* - q_i$

In this case, our differential equation system will be the following:

$$\frac{dQ_1'}{dt} = f_1'(Q_1', Q_2', \dots, Q_n')$$

$$\frac{dQ_2'}{dt} = f_2'(Q_1', Q_2', \dots, Q_n')$$

........................

$$\frac{dQ_n'}{dt} = f_n'(Q_1', Q_2', \dots, Q_n')$$

Suppose we can decompose the system into Taylor series:

$$\frac{dQ_1'}{dt} = a_{11}Q_1' + a_{12}Q_2' + \dots + a_{1n}Q_n' + a_{111}Q_1'^2 + a_{112}Q_1'Q_2' + a_{122}Q_2'^2 + \dots$$

$$\frac{dQ_2'}{dt} = a_{21}Q_1' + a_{22}Q_2' + \dots + a_{2n}Q_n' + a_{211}Q_1'^2 + a_{212}Q_1'Q_2' + a_{222}Q_2'^2 + \dots$$

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$$\frac{dQ_n'}{dt} = a_{n1}Q_1' + a_{n2}Q_2' + \dots + a_{nn}Q_n' + a_{n11}Q_1'^2 + a_{n12}Q_1'Q_2' + a_{n22}Q_2'^2 + \dots$$

in that case, the general solution is:

$$Q_1' = G_{11}e^{\lambda_1 t} + G_{12}e^{\lambda_2 t} + \dots + G_{1n}e^{\lambda_n t} + G_{111}e^{\lambda_1 t} + \dots$$

$$Q_2' = G_{21}e^{\lambda_1 t} + G_{22}e^{\lambda_2 t} + \dots + G_{2n}e^{\lambda_n t} + G_{211}e^{\lambda_2 t} + \dots$$

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$$Q_n' = G_{n1}e^{\lambda_1 t} + G_{n2}e^{\lambda_2 t} + \dots + G_{nn}e^{\lambda_n t} + G_{n11}e^{\lambda_1 t} + \dots$$

where $G_{ij}$'s are constant and λ are the roots of the characteristic equation. Roots can be real or complex and depending on this, the living system can be discussed whether it is in an equilibrium or in a perturbed state.

This can be explained by the fact that the living system always strives for equilibrium in the future. This corresponds to the biophysical reality, because as long as external influences do not alter the value of one or more of its parameters, a living system maintains its equilibrium state through its homeostasis [10]. This trivial finding, however, means that the living system produces the maximum effect at a given input, and this is its equilibrium state. When the living system reaches equilibrium, the differential quotients will be equal to 0, which means that the oscillations of the variables characteristic of the living system will be minimal

**Negative feedback**

Living organisms are normally characterized by *negative feedback*, i.e. if the activity of the executive is not satisfactory, the intensity of the "generalized stimulus" from the center increases – and vice versa [11].

Let's denote with o (t) the exit output and the mean value of the characteristic parameter on the system is o*(t); after the adjustment, the values of the outputs obtained shall be denoted with

$$o(t_1), o(t_2)\ o(t_3), \dots, o(t_n) = o^*(t);$$

$$\text{if} \quad t_1 < t_2 < t_3 < \dots < t_n.$$

We talk about a negative inverse value, if the following two conditions are satisfied:

$$|o^*(t) - o(t_1)| > |o^*(t) - o(t_2)| > |o^*(t) - o(t_3)| > \dots > |o^*(t) - o(t_n)|$$

$$\frac{d|o(t_i) - o^*(t)|}{dt} \leq 0.$$

Thus, in the case of negative feedback, the intensities change in inverse proportion: when the concentration of thyroid hormone in the blood decreases, the pituitary gland starts to produce and send more thyrotropic hormone into the bloodstream. And vice versa, as the concentration of this hormone increases, the pituitary gland decreases its production and release [12]. In living organisms, however, the phenomenon of positive feedback often occurs when an organ malfunctions. It is known, for example, that high levels of liver failure are associated with hormonal overload, which increases the functional failure of the liver, which in turn increases the hormonal overload.

**Maintaining the denotations above, we speak about a reverse positive connection, if it fulfils the following two conditions**

$$|o^*(t) - o(t_1)| < | o^*(t) - o(t_2) | < | o^*(t) - o(t_3)| < \ldots < | o^*(t) - o(t_n)|$$

$$\frac{d\left|o(t_i) - o^*(t)\right|}{dt} \geq 0 .$$

Positive feedback is a simul¬taneous increase or decrease in the intensity of the center and the executive, which in living organisms is not only a pathological symptom, but can be fatal if external intervention is not used to restore the normal balance of internal parameters, the homeostasis of the organism [13]. This positive feedback leads to increasing confusion and eventually destroys the system.

We define homeostasis as consisting of systemic regulatory processes that maintain stable equilibrium states of a living organism in the face of changes in the external and internal environment. Living systems achieve homeostasis primarily through the principle of negative feedback. The feedback principle applies to the functioning of all three main regulatory systems of the body: the nervous, hormonal and humoral systems. Above all, this can be shown very easily in the first two. But this principle applies to the most diverse units of the organism, from the cellular organelles, through the cell, tissues and organs, to the integration of the organism into the environment.

**Interdisciplinarity is the Future**

In the breathtaking development of the sciences, an interdisciplinary approach makes us understand that long gone are the romantic days when a lone scientist could sit alone in their study and ponder the problems that fascinated them. The struggle to understand the secrets of nature can only be successful if scientists work together, using all modern technical means. Knowing the complexity of the civilizational and social problems of our time and the intrinsic problems of the further development of each discipline, we already find the basic motivation for an interdisciplinary approach: the necessary interdependence.

As interdisciplinarity is transforming the way we think about science, its tools and methods, it is also placing new demands on education. Science is breaking through all the old frameworks, but our education system is the legacy of past centuries, reformed — it needs to undergo radical change to provide a modern scientific education that meets both societal needs and scientific progress. Today's world is characterized by an increasing amount of knowledge, which can be modeled by the following formula:

$$A = A_0 \cdot e^{0,07t}$$

Where: A – the amount of knowledge accumulated at time t; A0 – the amount of knowledge at an initial instant; e – the base of the natural logarithm.

Put in words: as long as the amount of knowledge is small, its growth is minimal, but when it reaches a certain level, its growth becomes rapid. Today, the body of knowledge doubles every decade or so [14]. Because of time constraints, a choice must therefore be made between deepening understanding and expanding the material covered. In any case, the first should be preferred in education. One has first to realize interdisciplinary communication within oneself, to lay the foundations of intrapersonal interdiscipli¬nary communication – which has to happen in school, in such a way that the minimal but optimal alphabet and semantics of each discipline are well "memorized".

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