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ORGANISM, SELF, *UMWELT*: AN NEW APPROACH TO ORGANISMIC INDIVIDUALITY

1. The return of the concept of organism

After the discovery of the DNA in the 1950's, 20th century biology focused on the concept of the gene. In the 21st century, however, the concept of organism is regaining its primary role in biological thought. At present there is a rapidly growing literature verifying that living beings are able not only to deeply reorganize themselves but also to modify their genomes [Shapiro 2011; Sultan 2015; Jablonka 2017]. The emergence of a theory of organism requires, however, first the elaboration of a logic of organismic causality that proceeds from organismic phenomenality. In the following I will attempt to outline what I label "logic of organisms". In order to achieve this aim I will first try to articulate a "logic of mechanisms" because it constitutes a sharp contrast to the "logic of organisms".

2. Mechanisms as a form of explanation

For decades, Carl Hempel's theory of explanation was the backbone of theorizing about explanation. In contemporary philosophy of biology there is broad consensus that the explanative relevance of biological modeling cannot be captured by Hempel's account. As «life scientists commonly seek to uncover the mechanism responsible for the phenomenon of interest», in the life sciences phenomena are explained by *mech-*

anisms [Bechtel *et al*. 2010, 322]. Leading advocates of what is often described as "New Mechanical Philosophy" or "New Mechanism" argue that in many fields of science what is considered a satisfactory explanation requires providing a description of a mechanism. The generation of a phenomenon by a mechanism is demonstrated by a model. In systems biology it is always a computer simulation that shows how the Explanandum results from a mathematical model consisting typically of differential equations [Brigandt 2018, 985]. At the present computer simulations of both small and large systems of equations are considered mechanistic explanations. Complex mathematical models consisting of coupled differential equations have been introduced among other things for the computation of the cell cycle [e.g. Karr *et al.* 2012], genetic and metabolic oscillations, signal pathways within and between cells, and the prediction of the development of spatial patterns during embryonic morphogenesis [Murray 2002; Meinhardt & Gierer 2000]. Mathematics has become indispensable in contemporary biological explanations.

3. Logic of (biological) mechanisms

Systems biologists employ a variety of different methods depending on the problem to be solved. Systems biologists who model organismic processes as systems of differential equations often focus on the modeling of the dynamics of genetic, metabolic and signal pathways.[1] They also study the behavior of larger network systems constituted by coupling these pathways, such as might occur in embryogenesis.[2] From their perspective, the final-state-directedness of embryogenesis, cell cycle, and other final-state-directed phenomena is thereby reduced to the dynamics of enormously complex systems of positively and negatively coupled biomolecular reactions, represented by positive and negative feedback loops in the corresponding diagrams.

In order to demonstrate how this approach works, I will introduce an exemplary case of the mathematical analysis of a biological system implemented with differential equations. Timothy Gardner, Charles

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1 Tyson *et al*. 2003; Murray 2002; Van Hoek 2008.

2 Meinhardt 2003; Panning *et al*. 2007; Murray 2002; Karr *et al*. 2012.

Cantor, and James Collins presented a model for the mutual regulation of the activity of two genes. This model is often considered a milestone of synthetic biology [Gardner *et al*. 2000]. Both genes transcribe a so-called repressor protein which blocks the activity of the other gene, so that both genes inhibit each other. The dynamics of this system consists of two interwoven causal relationships that can be described by two quantities, U and V, which are associated with the concentrations of each repressor protein respectively. The variation of the concentrations of both proteins can be represented by two coupled differential equations [Gardner *et al*. 2000, 339].

$$\frac{dU}{d\tau} = \frac{\alpha_1}{1+V^{\beta}} - U \qquad \text{(formula 1)}$$

$$\frac{dV}{d\tau} = \frac{\alpha_2}{1+U^{\gamma}} - V \qquad \text{(formula 2)}$$

The quantities U and V are *variables* because their values change with time. In modeling, the temporal behavior of variables represents the phenomenon to be explained. In other words, the values of the variables are the Explanandum. The quantities α_1, α_2, β and γ are *parameters*. Their value is determined by the experimenters. It is important to keep in mind that the dynamics of the system is not merely the result of the time-dependent variables U and V, but depends also on the value of the four parameters α_1, α_2, β and γ which can*not* be varied by the system's dynamics. Certain combinations of the four parameters lead to a specific behavior of the system, i.e. to specific dynamics of the variables U and V.

Parameters are either constants or entail many constants the value of which cannot be varied by the system's dynamics. In most cases all parameters are preset by the model makers and are held constant in experiments with real organisms and corresponding computer simulations. In other words, *parameters are externally fixed factors that cannot be varied by the system's own dynamics*. The reason for this is that those quantities canalize the development of the time-dependent variables so that they are logical presuppositions of the systems possible dynamics. The parameters are an important part of the Explanans.

A few years ago, van Hoek suggested a metabolic pathway model for the behavior of the bacterium *Escherichia coli*. Following the same methodology as that of the authors introduced above, he employed ten coupled differential equations for the solution of which he used 58 parameters [Van Hoek 2008, 18-20, 45-47]. In the last decade, several research groups performed computer simulations of whole cells. A model of the cell cycle of yeast operating with differential equations was published a few years ago [Panning *et al*. 2007]. In this model the yeast cell is reduced to 36 state variables. For their computation the model makers use 143 parameters. So, on average for the computation of one variable they use four parameters.

Systems biological models share an essential feature: They operate on the same *implicit* assumption about the roles of different *causal factors* – variables, parameters, and equations – in dynamics of biological systems. For the purpose of this essay, this is the most important feature of those methods.

I use the term "causal factors" to refer to all factors that contribute to the determination of a dynamic system's development. In what follows I will use the generic term "factors" to refer to causal factors. In formal models used in both physics and systems biology there are two clearly distinct kinds of factors at work: intrinsic and extrinsic ones.

Intrinsic factors of formal models include those factors which are generated by the system's dynamics itself. They are the time-dependent values of the variables. In formulas 1 and 2 the changing values of U and V are the only intrinsic factors.

Extrinsic factors of formal models include all the factors that contribute to the generation of intrinsic factors but are *not* influenced by any intrinsic dynamics, i.e., the respective state of the system. Parameters, such as the quantities α_1, α_2, β, and γ are extrinsic factors.

In this essay, "intrinsic" means "dependent upon dynamics" and "extrinsic" means "independent of dynamics".

In the formalisms of systems biology the most complex factors are described by the *differential equations* or *the systems of coupled differential equations* (e.g. formulas 1 and 2) which determine the variation of the variables. Those systems of equations are relations between the less complex intrinsic and extrinsic factors, i.e. the variables and the parameters. In contemporary formalisms, the formal structures are not influenced by the system's change of states. They are static, which clearly qualifies them as extrinsic factors. As relations between simpler factors, they can be characterized as *second-order extrinsic factors*. Analogously, variables can be understood as *first-order intrinsic factors* and parameters as *first-order extrinsic factors*. A system of coupled differential equations such as the system consisting of formulas 1 and 2, is a single indivisible second-order extrinsic factor.

There is an essential difference between first order intrinsic factors on the one hand and first- and second-order extrinsic factors on the other: Whereas new values of the variables are continuously generated, all extrinsic factors are usually held constant during an experiment or a computer simulation of a process. In other words, all extrinsic factors are static.

In the models of systems biology the number of first-order extrinsic factors are several times the number of the first order intrinsic ones.

4. Logic of organisms

The distinction between intrinsic and extrinsic factors can be applied to organisms as well if the terms "intrinsic" and "extrinsic" are interpreted as "dependent upon dynamics" and "independent from dynamics" respectively, as introduced above. First-order intrinsic organismic factors are all material and energetic quantities generated by an organism that have an effect on its dynamics, such as the concentration of regulatory proteins, scleroproteins, hormones, ATP molecules etc. This category includes also environmental factors that the organism influences in order to improve the conditions of its life. In this sense, regulated atmospheric humidity and room temperature are first-order intrinsic organismic factors as well. First-order extrinsic organismic factors are all factors that influence but are not affected by an organism's dynamics. Those factors include initial conditions, such as the parental genetic constitution and the environment of a zygote at the time of its fertilization, fundamental laws of nature that determine physicochemical processes, and environmental conditions that cannot be changed by organismic activity, such as gravitation, radioactivity, geological processes, solar activity, and the forms and quantities of available energy and matter. However, one of the most essential characteristics of life is that the borderline between first-order intrinsic and extrinsic factors is fluent. Especially during evolution of intelligence some of the extrinsic environmental factors just mentioned have been transformed to intrinsic ones. The idea of second-order factors applies also to organisms, as we will see shortly. However, real organisms do not obey the logic of mechanisms for two reasons: *First*, in sharp contrast to those mechanisms, organisms are able to change the value of most quantities that in systems biology models are represented by parameters. In contrast to these contemporary biological formalisms, in real organisms the number of extrinsic factors is only a tiny fraction of the number of all dynamic quantities. In other words, in real organisms the number of first-order intrinsic factors (variables) exceeds by many times the number of first-order extrinsic ones (parameters). *Second*, during growth, regeneration, and re-adaptation of unicellular and multi-cellular organisms and in the embryogenesis of the latter a vast array of new sorts of proteins is synthesized. This requires that the material constitution of each real organism is permanently subject to change. As a result, the structure of an organism is a sequence of permanently generated new relations between its own first-order intrinsic and extrinsic factors, which in current systems biological formalisms are represented by systems of fixed differential equations (e.g. formulas 1 and 2). As noted above, in current biological formalisms those systems of equations are second-order extrinsic factors. In contrast, even in primitive unicellular organisms, relations between both kinds of first-order factors are themselves intrinsic factors. This is the case, since, on the one side, they are permanently varied by the organism's dynamics, even though in some cases only slightly, and, on the other side, they canalize this dynamics. Embryonic processes display an even more radical dynamics. A system of differential equations representing the development of an embryo would have to undergo a transformation that is so radical that not only most of its parameters would have to be replaced by variables but also that formal system's structure – i.e., form and number of the equations themselves – would have to be subjects to permanent radical variation until maturity is reached. To put it in a nutshell: In real organisms second-order factors are necessarily intrinsic factors or, in other words, there are no second-order extrinsic factors in real organisms [Koutroufinis 2017].

5. Individual self

The term "second-order intrinsic factor" refers to the dynamical and plastic self-perpetuating structure of the organism. In other words, it designates a living being's most fundamental organizing principle. All aspects of its material and energetic constitution are organized around the maintenance and perpetuation of this form of organization. In a paper published with Terrence W. Deacon I suggest that «a dynamical process organized in such a way that it minimizes the probability that its organization will be lost» may be labeled a *self* [Deacon *et al*. 2014, 417]. Based on this processual understanding of selfhood, a second-order intrinsic factor can be characterized as a "self". A self is a process that reinforces the synergistic relationship between its elements.[3] The organismic self is «a form of individuality» [Deacon 2012, 309] because in any second-order intrinsic factor the related first-order intrinsic and extrinsic factors become inextricably interwoven so that the whole self-determining process cannot be physically divided into more elementary processes.[4] The individuality of the second-order intrinsic process is due to the inextricable causal interweavement of its permanently occurring first-order processes.

A very widespread position in the writings of contemporary bioscientists and philosophers of biology who subscribe to a form of materialism that could be described as "scientific materialism" is that organismic dynamics is canalized by *constraints*. Deacon thinks that «self is defined by constraints» [Deacon 2012, 473] and ascribes what he labels the «reflective individuation» of the organism to a «special form of closure» [Deacon 2012, 468]. In his highly sophisticated book *Incomplete Nature*, he claims that organismic order and individuality

[3] According to Deacon a self is a synergy of parts that reinforces their synergistic relationship [Deacon 2012, 469].

[4] See also Deacon 2012, 469.

emerge from the canalizing causal action that interwoven dynamical constraints mutually exert on each other. Maël Montévil, Matteo Mossio, and Alvaro Moreno define constraints as «contingent causes, exerted by specific structures or dynamics, which reduce the degrees of freedom of the system on which they act» [Montévil & Mossio 2015, 181], so that «they simplify its description, and contribute to provide an adequate explanation of its behaviour, which would otherwise remain underdetermined» [Mossio & Moreno 2010, 271]. Mossio and Moreno argue that organisms «maintain themselves […] through a self-maintaining organization of constraints» [Mossio & Moreno 2010, 276] each of which exerts a causal influence on the generation of other constraints while its own generation is reciprocally influenced by some of them so that the whole system of constraints achieves «organizational closure» [Mossio & Moreno 2010, 277, 275-280; Montévil & Mossio 2015, 186f.]. While these authors do not reduce organisms to organizational closure, they claim that the latter «can be taken as an essential *mark* of living organisms» [Mossio & Moreno 2010, 285].

Although I do not doubt the importance of constraints, I think that there are good reasons for not attributing an essential role to constraints within our understanding of organisms. My skepticism is due to the fact that any scientific explanation of organisms articulated by a formal model that allows a quantitative description of the organismic dynamics (e.g. prediction of variables) *cannot forgo mechanisms*. This is true regardless of whether the model is based on organizational closure or any other possible form of constraint-based organization. This means, however, that as soon as constraint-based organization is translated into a formal language, it must be described in mechanistic terms and is thus necessarily subject to the logic of mechanisms. Even if a future model of organizational closure that goes far beyond what is imaginable today succeeds in computing all constraints, the computation will necessarily employ parameters and thus first order *extrinsic* factors that it cannot generate autonomously. Obviously, insofar as these extrinsic factors act as constraints on the computation of variables, this model of organismic dynamics is not organizationally closed. In other words, organizationally-closed systems of constraints are nothing but attractive narrations that might be possible within natural languages but immediately collapse as soon as they are articulated in formal languages that operate with mechanisms. For this reason, I think that an alternative understanding of organismic selfhood must be developed which is based on metaphysical assumptions that are alien to contemporarily established scientific materialism.

Before undertaking such an attempt it is important to consider that there is a «critical but contingent relationship between selves and physical boundaries» that complicates the identification of biological selves [Deacon 2012, 471]. Since any living being maintains itself through a selective exchange with its environment, we must bear in mind that «[t]he organism is not a solitary, self-creating artist» [Wolfe 2010, 206]. Hence, any adequate theory of organismic selfhood and individuality must necessarily be an organism-environment theory.

6. Umwelt

An organism incorporates within its organization information about those aspects of its environment that are relevant to its self-perpetuation and reproduction. This information is embodied in the specific organization of the set of processes that maintain organismic integrity with respect to potentially beneficial or harmful aspects of its environment. In 1909, Jakob von Uexküll introduced the term *Umwelt* referring to those features of a living being's environment to which it is sensitive [Uexküll 1909]. In other words, *Umwelt* refers to those features of a living being's surroundings that are meaningful to it. Therefore *Umwelt* may be translated as "meaningful environment". The creation of a self-other boundary by the organism incorporates a representation of its *Umwelt* [Deacon *et al*. 2014, 417]. *Umwelt* and self are two sides of the same coin. This is characterized by biosemiotician Kalevi Kull's translation of *Umwelt* as «self-centered world» [Kull 2010, 348-349].

Uexküll's work deserves particular attention because he not only created an organism-environment theory but anchored it in the philosophy of Immanuel Kant which clearly does not subscribe to a metaphysics of scientific materialism. Of course, this applies also to the theories of other seminal thinkers of the last century, such as Bergson, Whitehead, and Jonas. However, Uexküll succeeded more than anybody else in the elaboration of an organism-environment theory that is grounded both philosophically and biologically.

Uexküll considers animals *subjects*, which in virtue of their structure select stimuli within their surroundings and respond to each in a specific way. The stimuli build «certain indications [*Merkmale*], which enable the animal to guide its movements, much as the signs at sea enable the sailor to steer his ship» [Uexküll 1926, 126]. Many indications are merged together into coherent units that occupy a moment and a place or a direction in space [Uexküll 1926, 78, 97-99]. Uexküll calls them "things" (*Dinge*). Those units are instantaneous data of experience. "Things" are events rather than persistent entities. Animal and human subjects synthesize them unconsciously [Uexküll 1926, 93]. The unconscious creative process also creates more complex cognitive entities – "objects" (*Objekte*). An object is an enduring thing, a thing extended in time. It is an enduring sequence of data of experience that occupies a particular spatiotemporal region in the subject's perceptual field. Objects constitute higher units of experience than things [Uexküll 1926, 98] and can be involved in lawful causal relations. Uexküll calls objects that possess a framework merging their parts into an organized whole "implements" (*Gegenstände*). Implements occupy the highest level of complexity. They are objects in which «the parts stand in the same relation to the whole as the individual sounds to the melody» [Uexküll 1926, 103]. Implements are organized wholes of data of experience. The perceptual environment of both humans and most animals is constituted by these three kinds of cognitive entities: things, objects, and implements.

According to Uexküll, all three are differently complex products of one and the same unifying process, the so-called *apperception process* [Uexküll 1926, 78]. The apperception process lies at the root of all perception [Uexküll 1926, 15]:

> Whatever the perception, the activity is of the same kind; different qualities are constantly being associated into unities. The power of the subject [*Gemüt*] that exercises this apperceptive activity is for ever creating new structures; in its very nature, it is a formative force [*Bildungskraft*] [Uexküll 1926, 16].

An important fundament of Uexküll's epistemologically-founded biology of subjects is the assumption that the apperception process, although lawful, *cannot be mathematically described* [Uexküll 1926, 45]. For this and other reasons, biology cannot be reduced to physics [Uexküll 1926, 33, 46, 70, 71, 91, 103] and biological explanation cannot be reduced to mechanisms. Uexküll's conviction about the non-reducibility of biology to physics is supported by Kant's concept of *pure* or *original* or *transcendental apperception*, which is the underpinning philosophy of Uexküllian apperception process. In his *Critique of Pure Reason*, Kant introduces pure apperception as a *spontaneous a priori activity* of the subject. It synthesizes the manifold of its representations to a unity without being determined by the nature of the synthesized elements (the representations) [Kant 1998, B 129-132].

> Combination does not lie in the objects […] but is rather only an operation of the understanding, which is itself nothing further than the faculty of combining a priori and bringing the manifold of given representations under unity of apperception, which principle is the supreme one in the whole of human cognition [Kant 1998, B 134-5].

According to Kant, the unity of perceived data in all our representations «can be executed only by the subject itself» [Kant 1998, B 130] that is by a *transcendental* factor that can never be an empirical content of human perceptions. Kant's conviction that the unity of experience is executed only by the subject goes against the objectivism and anti-transcendentalism which characterizes physics and biology at present and in Uexküll's time.

Kant's transcendental philosophy was framed uniquely for human subjects. Uexküll extended Kant's theory of subjectivity to a general biological theory that he applied to both human and animal subjects. He considers human and animal subjects to be transcendental, spatio-temporally non-localizable unities of apperception. The apperception process unfolds lawfully and determines the synthetic process of perception. For that reason, the apperception process can be considered the central category of subjectivity. All three kinds of cognitive entities – things, objects, and implements – are products of *synthetic activi-*

ties that constitute different manifestations of the apperception process which is a spontaneous act of synthesis. Due to its spontaneity, the synthesis of cognitive elements to a more complex unit is a creative mental act that is neither determined by the nature of the synthesized elements nor by the relations between them.

Despite the fact that Uexküll aimed «to extend Kant's transcendental philosophy to the entire living realm» – an attempt that Kant would likely reject – «both shared the same solution: subjective spontaneity» – and considered «the subject as the center of initiatives and not as a recording black box» [Esposito 2020, 38f.].

Uexküll's theory of *Umwelt* can be extended to a theory of the organism's internal organization. In contemporary biosemiotics the cells of a multicellular organism are considered subjects that communicate through the intensive exchange of molecules serving as signs. In other words, the cells of an organism interact with each other through continual processes of mutual interpretation. From an Uexküllian perspective, a multicellular organism is the *Umwelt* of its own cells or, in the words of Claude Bernard and George Canguilhem, a «*milieu interieur*»:

> From the biological point of view, one must understand that the relationship between the organism and the environment is the same as that between the parts and the whole of an organism. The cell is a milieu for intracellular elements; it itself lives in an interior milieu, which is sometimes on the scale of the organ and sometimes of the organism; the organism itself lives in a milieu that, in a certain fashion, is to the organism what the organism is to its components [Canguilhem 2008, 111].

7. Conclusion

The second-order intrinsic causal factor is the plastic self-determining material-energetic structure of the organism. It is the organismic self that determines both the relation between the internal parts of the organism and the relation between the organism and its *Umwelt*. Its individuality is rooted in the inextricable interweavement of both relations. From the anti-mechanistic perspective that I have defended in this essay, the self is the manifestation of a creative subject that transcends the logic of mechanisms for principal reasons. The organismic subject, which is the cause of the self, may be approached from the perspectives of various philosophers, such as Whitehead, Bergson, Jonas, and Uexküll. In this essay, I have focused on Uexküll because he considered more thoroughly than any other thinker the causal and logical interweavement of subject, organism, and environment.

From an Uexküllian perspective, if the organism is understood as the *Umwelt* of its own components, *the generation and transformation of the second-order intrinsic factor – which is the organism's plastic structure – must be conceived of as the product of a creative spontaneous subject, the activity of which transcends any known form of mechanism*.

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Keywords

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Abstract

Organisms exhibit a specific form of biological individuality. In contemporary biosciences, explanations of organismic dynamics are often reduced to mechanistic descriptions. It is taken for granted that complex biological processes of different kinds are reducible to molecular and other "mechanisms". In this paper, I show (1) that organisms express a form of individuality that is realized by a particular kind of causality and (2) that organismic causality transcends the logic of mechanisms used in contemporary biosciences. Based on new insights about organismic dynamics as well as Jakob von Uexküll's concept of "*Umwelt*" (meaningful environment), I analyze organismic causality and show that the latter constitutes a form of selfhood alien to both inorganic nature and mechanisms.

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