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The "Triplex" of Information – The Dynamics of Transduction, Modulation, and Organization in Living Beings

Introduction

Gilbert Simondon (1924–1989), a French philosopher of technics and science, has only quite recently (in 2000s) become known outside of his country. Simondon is mostly known his now-classic text *On the Mode of Existence of Technical Objects* (MEOT; orig. 1958), which was finally translated into English in 2017. Thus, the research and use of Simondon has been mostly in the field of technics. However, in 2020 his *magnum opus* – and the main thesis from 1958[1] – *Individuation in Light of Notions of Form and Information* (ILFI) was finally published in English. Originally published in two parts – first in 1958 and second in 1989 – the work strives to offer general account of the principal of individuation, which is set against substantialism/hylomorphism, and which gathers its foundations from physics (and quantum physics), biology, psychology, anthropology, sociology, and cybernetics.

Although Simondon can be described as a process philosopher, he underlines occasionally that his philosophy is theory of *operations* ("allagmatics")[2] (e.g., ILFI, 661–671), and in many times he seems to identify process as operation (Bardin 2015b, 8). This notion comes mainly from his engagement with cybernetics, a study of communication and control started by, among others, Norbert Wiener. However, Simondon's criticizes cybernetics from several points, especially the strive of various cyberneticians to – explicitly or implicitly – identify living beings with machines. To overcome the mechanistic and reductionist viewpoint in general, Simondon derives from number of vitalist writers, especially Henri Bergson and Georges Canguilhem. Although, he does criticize vitalism (which he also tries to overcome), the central idea that he lifts from these writers can probably be summarised as a kind of conception of emergence which living beings have and, thus, cannot be mechanistically reduced to parts (see, e.g., Choukah & Theophanidis 2016, 292)[3].

At the heart of Simondon's philosophy is the principle of individuation. This is not a new concept in the history of philosophy, but he strives to give it a novel meaning and importance. The "new individuation" is contrasted with hylomorphism, which Simondon *does not abandon but underlines that it does not account for the "true" ontogenesis of individuals – it focuses on already formed form and matter, and thus individuals*. It is worth to note that the individuation is a more general concept – or general operation (e.g., Fagot-Largeault 1994, 29) – that has various "modes" or "actualizations" as well as different speeds and tensions[4]. Simondon differentiates several domains from reality: physical, vital (biological), psychic-collective, and, finally, technical. Thus, the individuations happen at various orders of magnitude (or levels). However, the individuation that Simondon suggests requires certain hypotheses, like postulating something that is prior to the individual [σύνολον; *sunolon*[5]]: pre-individual domain. In addition, the individual itself must be thought as *a kind of being*

[1] MEOT was his secondary thesis.

[2] Or "theory of changes": "Simondon calls his own theory allagmatic, which means theory of changes; it is fixed on the description of the change of a structure in an operation and of an operation in a structure: this is not a traditional theory of knowledge; it can be maybe conceived as a sort of *keeping-in-touch* with processes from an internal, endogenous viewpoint." (Carrozzini 2015, 36.)

[3] See also on the importance of vitalism, Bechtel 2007; Hui 2019, e.g., §38. (Also, see summary of Simondon's criticism of creationist theory in Fagot-Largeault 1994, 37: also, ILFI, 370.)

[4] In general terms, Simondon ILFI book can be seen as providing general metaphysics and MEOT kind of practical applications of these ideas in the domain of technics. Seibt's general process theory's one-type entity, "general process" might be close to this idea of general individuation (e.g., 2018, 115).

[5] The term "sunolon" (or "synolon"), which comes mainly from Aristotle, can be translated, for example, as "concrete thing", "concrete substance", "concrete whole", "compound", "composite", "whole-together", "concrete individual thing", "individual compound" or "substantial individual" (see, e.g., Theophanidis 2014).

of the relation between the individual and its milieu[6]. That is, the individual *is the relation*. Thus, the individual is more general concept that includes the organism and conception of subjectivity (and intersubjective dimension). Finally, at the heart of individuation process, Simondon suggests a novel notion of information, which could be summarized as understanding the information as a constructing process.

The paper strives to open up Simondon's conception of information in the light of biology; thus, it focuses only on biological individuation ("vital" domain) and "biological" individual. For Simondon, information moves through different orders of magnitude affecting different systems on various levels. It is quite clear that physics (and especially quantum physics) and chemistry contribute to the formation – individuation – of living beings. However, it might not be completely right to say that they are in some way their foundations, or it is not exactly clear how and through which processes these domains (physical, chemical, living) are connected[7]. John Dupré has underlined that biology requires new metaphysics, and preferably something other than Aristotelian, as a background. With the help of Simondon's critique of hylomorphism and his notion of information – and its "triplex" of underlining concepts of transduction, modulation, and organization – the paper tries to understand novelty and organization of living beings.

Individuation (a summary)[8]

At first, it is important to note that this summarization gives (a short but) *a general account of Simondon's idea of individuation, thus giving it grander scope than "biological individuation" necessary requires, to work as a background framework*. The idea of individuation is a central concept in Simondon's philosophy, and it is defined hermeneutically throughout the book ILFI. As pointed earlier, Simondon contrasts individuation with hylomorphism. Andrea Bardin summarizes (2015a, 23), following Simondon's opposition to hylomorphism's capability to describe individuation, that "…matter always presents the implicit results of an earlier formation, and therefore is always partially individuated [and…] no accomplished form exists in nature, neither is it a perfect idea in the artisan's mind: it is instead an operative sequence, a complex process with a determinate history". Thus, to Simondon, "any substantial being that exists in reality has already undergone (or is already undergoing) a process of individuation" (Bluemink 2020). The concept like unity, identity and even form exists only because of individuation (ibid).

We can start by saying that Simondon provides an ontological account of the formation of the individual being from the heterogenous matter of reality. This ontogenetical process is called *individuation*, which strives to understand the individual *through individuation* – individuation is not, for example, a property of an individual (e.g., Combes 2013, 2; Miquel & Hwang 2016a). To Simondon, reality is in a state of constant becoming and is divided between the individuated being and *pre-individual* being, which are like the two sides of the same coin. The individual, which is *a system* to be preserved through becoming, is never by itself: it is in constant interaction and structural communication or resonance with its *milieu*. Thus, Simondon proposes that individuation always presupposes two systems that are in relation with each other, and this process of reciprocal relating and structuring Simondon calls *transduction*[9]. In transduction, which can describe physical, biological, mental, or social processes, "activity propagates incrementally within a domain by basing

[6] It is worth to note that the concept of "milieu" is not *just* "environment", but it can mean, for example, "mediating liquid" or medium in general.

[7] See, e.g., Cao & al. 2020, for problems in quantum biology. (Also, Ellis & Kopel 2019; McFadden & Al-Khalili 2018; Marais & al. 2018.)

[8] Some of these points have been derived from Rantala 2019; 2020 and earlier presentation given in PhD seminar (2021). Also, Hansen 2009; 2012; Bardin 2015a; Combes 2013; Mills 2016.

[9] Transduction comes from signal processing and is used also in, e.g., biology, where it "refers to the transfer of bacterial DNA from a sender to a receptor cell via a viral message" (Faucher 2013, 39). (Also, Lauk & al. 2020.)

this propagation on a structuration of the domain operated from one region to another" (ILFI, 13; Combes 2013, 6). Transduction leads to a resolution and stabilisation of these systems: it resolves the tensions presented to it by the environment or other systems by modifying its internal relations and structures (ILFI, 11–12; Mills 2016, 59). However, this "resolution" is not complete nullification of tensions but *the creation and finding of new structures that are compatible with the tensions*.

There are three types of individuation: physical, vital (living being) and psychic *and* collective (e.g., Mills 2016, 73). There are differences between the individuation of a physical being and a living being: the former resolves the metastable state (a diamond can harden), and the latter is constantly trying to *preserve* its metastability.[10] Although both physical and living beings are connected to the pre-individual, only living beings constantly re-individuate through this domain.[11] The pre-individual is a domain that is, to put it metaphorically, "with the individual". It can be said to be full of potentials (of "nature"), but formally it means just that the *true* individual[12] is always more than its *phase* (of its own becoming)[13]. Thus, the beforementioned resolution of tensions is connected to this domain: the resolution executed by the living beings is precisely finding of compatible structures because otherwise it would exhaust the tensions (potentialities) and would resolute stabilization (death). The living beings, individuals, resolve tension by individuating further[14]. (ILFI, Introduction; Combes 2013, 3–5; Bardin 2015a, 36.) That is, the individual never exhausts, in a single stroke, all the potentials of pre-individual reality (ILFI, 3).[15]

> "The pre-individual, as a potentialised ground [*fond]* exceeding actualised individual forms, is advanced by Simondon to explain why the existence of an individual cannot be adequately theorised in terms of its unity. The individual exists insofar as it can relate to a 'charge of pre-individual reality' that ensures continued individuations." (Keating 2019, 217.)

In any rate, as a metastable system, the individual has a certain degree of "indetermination" or openness ("non-determinacy") to the effects and information of the outside. Individuation as a transductive process of the exchange of information de- and re-structures the individual, as well as the milieu *and their relations* (ILFI, 10–14; Bardin 2015a, 38). As the living being strives to resolve

[10] "[B]iological systems can be understood in terms of 'extended critical transitions', which mean that they form coherent structures, whose proper symmetries are inherently unstable" (Montévil & Mossio 2015, 181). This is close to "false equilibrium" (Combes 2013, 3), "far from thermodynamical equilibrium" (Nicholson 2018, 144), and dissipative or far-from-equilibrium systems (Venn 2010, 132; also, Atamer 2011; Prigogine & Stengers 1984).

[11] Simondon underlines, e.g., that, "…we will suppose that vital individuation does not come after physicochemical individuation but during this individuation and before its fulfillment, by suspending it at the moment when it has not reached its stable equilibrium and by making it capable of expanding and propagating before the iteration of the perfect structure merely able to repeat itself, which would conserve in the living individual a bit of pre-individual tension, of active communication, in the form of internal resonance between extreme orders of magnitude." (ILFI, 163–164.)

[12] The individual is always more than just "the thing" under consideration/perception/analysis etc.

[13] To state it otherwise, the reality can be thought as a "supersaturated solution" in metastable state in which the "excess" is the pre-individual dimension (cf. Bontems & Ronde 2019, 613). Although the physical and living being differentiate from each other, the pre-individual "surrounds" both of them and they both, in their own ways, "carry" pre-individual potentials. A solution can crystallize due to outside germ seed, and a living being constantly grows (or gets older).

[14] There seems to be almost "logical necessity" for the pre-individual: if the already individuated individual is not able to account its ontogenesis, then there must be something "pre-individual"; to preserve metastability, there must be something where its possibility of change comes from. In addition, as Bluemink summarises (2020), to understand pre-individual, we must "take into account what were, at the time, recent developments in quantum mechanics".

[15] "This pre-individual nature, which remains associated with the individual, is a source of future metastable states from whence new individuations will be able to emerge. According to this hypothesis, it would be possible to consider every veritable relation as having the status of being and as developing from within a new individuation; relation does not spring forth between two terms that would already be individuals; relation is an aspect of the internal resonance of a system of individuation; it belongs to a system state. This living being, which is both more and less than unity, conveys an interior problematic and can enter as an element into a problematic that is vaster than its own being." (ILFI, 8; emphasis omitted.)

the problematics positioned by the milieu (or physical domain in general), it confronts the problems that require more than its individual inner and outer structures can handle. This leads the individual to continue vital (biological) individuation with psychic *and* collective individuation – that is, through what Simondon calls the transindividual relation.

For Simondon, as indicated earlier, the individual can be considered as a system that covers both the individual and its milieu. However, the processual nature of individuation is the key here. He writes: "[t]he individual is not a being but an act, and the being is an individual as an agent of this act of individuation through which it appears and exists (ILFI, 208–209).[16] Thus, strictly speaking only as an open system – that is, open to milieu and to other individuals – one can think the individual "as an individual". As the individual is in constant individuation, "it has with respect to itself a *relative* coherence, a *relative* unity, and a *relative* identity" (ILFI, 160; emphasis added). However, the formation of the individual requires understanding information in Simondonian way. First, we must situate Simondon's ontology with what Dupré calls "metaphysics of biology" (2021).

On The "Metaphysics" of Biology

In recent years John Dupré has bring forth (e.g., 2018; 2021) – basing on the process philosophy – a processual viewpoint to biology (also, e.g., Seibt 2018; Nicholson 2018). The view requires critique of traditional conceptions of organism as an easily managed whole and underlines that those organisms "display [high] levels of internal complexity, as they are functionally differentiated and hierarchically organized" (2018, 149, 151; see also, Meincke & Dupré 2021, 4). Thus, for example humans are intertwined with microbes (among other things) which leads to see them as processual assemblages of individuals (e.g., Dupré 2018, 25–26). Consequently, Dupré underlines that process ontology can answer some of the problems of substantialism (2018, 23). His ideas are very close to what Simondon strived to do especially in ILFI.

Aristotelian hylomorphism is one of the key problematics behind biology and the formal models of organism (e.g., Meincke & Dupré 2021, 2; also, Walsh & Wiebe 2021). As elaborated earlier, Simondon also saw hylomorphism as a key problem – but not something that had to be discarded. For him, the idea of Aristotelian hylomorphism – and its legacy – can be seen through two main cases, another being (I) the substantialism (or atomistic substantialism) and second being (II) "hylomorphic dualist doctrine"[17]. Shortly summarising, Aristotle's "hylomorphism is…the idea that objects are compounds consisting of matter and form […and] can address central metaphysical questions about synchronic and diachronic identity, persistence through change, individuation, the modal profile of objects, and generally the explanation of objects' nature and characteristic features" (Peramatzis 2018, 12). In this view, there are two powers: "an active power which imposes a form on the material; and on the other, a passive power which authorizes matter to receive, more or less perfectly, the form" (Bontems & Ronde 2019, 613). Thus, the matter "characterises the material from

[16] "…the individual is always in a double and amphibological relation with what precedes it and what follows it. Growth is the simplest and most fundamental of these operations of transfer that establish individuality. The individual condenses information, transports it, and then modulates a new milieu." (ILFI, 209.)

[17] I) Atomism (substantialism) understands the individual as a composite that has unity "that stems from a random encounter and will dissolve back into its elements when a force greater than the force of cohesion will attack it in its composite unity" (ibid, 2). However, "only the structure of the elementary particles exists eternally and are the veritable individuals" (ibid). According to Simondon, in the case I, the search for individuation is finished "before individuation". II) "[A]ccording to the hylomorphic schema…the individuated being is not already given: we do not observe ontogenesis because we are always situated ahead of this form-taking that ontogenesis is; the principle of individuation therefore is not grasped in the individuation itself as an operation but in what this operation requires in order to exist, namely a matter and a form: the principle is supposed to be contained either in the matter or in the form, since the operation of individuation is not supposed to be capable of supplying the principle itself but only of putting it to work." (ILFI, 2–3.) In the case II, the search is finished after individuation. Also, see Walsh & Wiebe 2021 on problematic "foundationalist materialism".

which an object is generated while the form determines what the object is" (O'Hara 2019, 226). The substantialist view, according to Simondon, "considers the being as consisting in its unity, given to itself, founded on itself, not engendered and as resistant to what is not itself" (ILFI, 1). Yet both approaches "suppose that there is a principle of individuation prior to individuation itself that can explain, producing, and guiding it" – they "avoid the direct description of ontogenesis itself" (ILFI, 1–2). In the end, Simondon is more concerned about II, which he sees as a useful philosophical approach, but it cannot describe the principle of individuation. At the centre of II is the idea that form "informs" matter, but the manner of this operation is "not sufficiently specified by the hylomorphic schema" (ILFI, 35). To summarise, Simondon strives to understand something *prior* the form and the matter (and, thus, he presents us the beforementioned concept of pre-individual).

More recent updates in biology, like developmental systems theory (DST) (e.g., Oyama 2000; also, Griffiths & Stotz 2018), "niche construction", and cultural evolution has explored "the nature of biological individual" (and organism) in a sense that it "cannot be abstracted from the context in which it lives" (e.g., environment) (Dupré 2018, 32). Thus, there is no organism without the environment and vice versa (just like in Simondon) (see also, Venn 2010, 140): the theories, or viewpoints, have strived to overcome simple organistic view – or even simple organism-environment couple. DST and some process philosophical positions have underlined organism's identity and dynamics as "genidentity or identity as continuity of organization" (Griffiths & Stotz 2018, 229–230). However, these theoretical positions have their problems and most of them fall under – or have elements of – static hylomorphism (or even substantialism). James DiFrisco summarises that I (substantialism) "corresponds to reductionism, physicalism, and mechanism" and II (hylomorphic dualism) "to antireductionism, emergentism, organizational or relational thinking, and even in some cases, 'vitalism'"[18] (2014, 503). Thus, in truth hylomorphism can be understood many ways, due to the fact, for example, variety of how form or matter can be conceived[19].

Other process philosophical models, like for example "General Process Theory" introduced by Johanna Seibt (2018), seems to be more formal and in line with likes of autopoiesis (Maturana & Varela 1980). DiFrisco has shown, with the help of Simondon's ideas, that theoretical models like autopoiesis as well as (M, R) systems (metabolism-repair systems), and the chemoton[20] are also hylomorphic (2014). Although in the end not diverging from hylomorphism, DiFrisco criticizes these models with help of Simondon's individuation and, finally, seems to underline the chemoton model as more dynamical and in-line with practical phenomena. These models separate "the 'form' of the living system from its 'matter'" (DiFrisco 2014, 499). In contrast, Simondon strives to show us "'genetic' or generative conception of individuation" (and, thus, form) (ibid, 503). DiFrisco divides these models two categories, top-down and bottom-up models. Autopoiesis and (M, R) systems the former category and the chematon is the latter. All these models strive to model "the minimal living system" (2014, 504). Top-down models can be described as "abstract" as they tend to leave out the matter part (ibid, 504–505). One of the main problems with this is that it assumes the "possibility of this separation in the real individual" (ibid, 505). In addition to this – and points made earlier – is that the form is taken as fixed type even though it is "only the end result of a generative process" (ibid). In short, autopoietic system can be considered as a machine, that is "a homeostatic machine whose constant variable is its own autopoietic organization as such" (ibid, 508; original, Maturana & Varela 1980, 79). The autopoiesis "is introduced by means of a strong opposition between the relations, or

[18] See, e.g., on the hylomorphism of vitalism, Ansell-Pearson & al. 2010, 352–354.
[19] E.g., "Form can be treated as the universal, the trope, or essence, and matter as the particular, the substratum or subject of predication" (DiFrisco 2014, 503).
[20] All these theories consider the models as a type of machines. This identifying of living beings as machine was one of the key criticisms of Simondon posed to cybernetics. (See some philosophical arguments, e.g., in ILFI, supplementary text "Individuation and invention".)

the network of relations, and the underlying components of the system" (DiFrisco 2014, 508). Thus, "[t]he specification of components, on the other side, is taken to be unnecessary for the living machine to find an adequate explanation" (ibid; Maturana & Varela 1980: 75) and so is "the form […] separately determinable from whatever matter would realize the autopoietic system" (DiFrisco 2014, 508). DiFrisco summarizes that "[m]any of the central problems surrounding the theory of autopoiesis are rooted in ambiguities concerning how much the theory is attempting to explain, and how much it is merely stipulating definitions" (ibid). The theory seems to "invoke a tautology" as when one looks "for the fundamental explanation, […] one finds only the definition of autopoietic systems". He continues, that "[f]or biological phenomena, an explanation which makes no use of thermodynamic, chemical or energetic considerations, and which describes no functional mechanisms, is a strange kind of explanation indeed". (Ibid.) The autopoietic model rests on form-based model in which the components are left indeterminate and, thus, the formal structure (and its possible relations) and components can achieve only "extrinsic relation" with each other. This is precisely what Simondon criticizes: anything determined "prior to the generative process making the individual" can only have "secondary or external relation to the remainder of the individual" (ibid, 509). With the help of DiFrisco, we can summarize:

> "A generative relation, on the contrary, is internal to the terms related. In the context of minimal living systems, this means that a determinate material component specifies the types of interaction it may enter into with other determinate material components. If this is the case, there should be an intermediary order of processes between the extremes of the abstract relational form and the atomistic component, one which may be more essential for the explanation of living organization than either extreme alone. This intermediary order does not exist within the autopoietic theory." (ibid, 509.)

(M, R) systems theory, developed by Robert Rosen, consist also a top-down model that focuses on the form. Rosen builds theory of categories that is "supposed to provide a language for modelling the organization of systems" (DiFrisco 2014, 511). These systems "produce certain general kinds of effects which are, to some degree, independent of the particular material realization of the system" (ibid, 512). The theory strives to update the autopoietic by introducing a relation to the environment. DiFrisco summarizes that (M, R) system overcomes some problems of autopoiesis, like "its separation between the material parts of the system and its relational organization, which lay behind its recourse to formal causality and explanations by definition" (2014, 513). Thus, there is "a division between the whole formal system of parts and relations, [...] and its realization" (ibid, 513–514). However, the problem, for Simondonian perspective, is that between the "terms there is, moreover, a secondary, extrinsic, or 'arbitrary' relation […] because the particularities of the realization are not 'entailed relationally'" (ibid, 514). "[T]he elements of Rosen's notation are indifferently connectible combinatorial objects, which can thus be defined as forming the organization one likes independently of any material specificities" (ibid). Thus, "[w]hile there is little by way of formal causality in the theory, there is certainly a strong separation between the form and the matter, conceived here as formalism and material realization" (ibid, 515). In (M, R) systems the form is static and not generative.

Finally, DiFrisco gives Tibor Gánti's the chemoton as an example of bottom-up model. The term comes from "chemical automata" and, again, strives to give an account of "minimal life" (2014, 515). At the centre is the minimal metabolic system and, implicitly, the theory defines "the living system by a kind of closure – or rather by the 'autocatalyticity' – of chemical reaction cycles" (ibid). However, the theory acknowledges material constitution of the living and their chemical and fluid nature. "In living systems […], the driving force is the chemical energy of reactions proceeding in a fluid phase, where the relevant factors are not extensive, but intensive and qualitative—e.g., chemical

concentration and affinity" (ibid, 516). The chemoton begins its determination of a system from "bottom-up", that is, from materiality or chemical material composition. In the chematon, "the 'form' […] is nothing other than the chemical equation giving the reaction specificities which determine the network" (ibid, 517). This "form" – understood as its relational organization – is "only the set of relations internal to its matter" (ibid). The chematon is "composed of three […] autocatalytic cycles coupled to each other stoichiometrically", from which "[t]he first and most fundamental of these is the metabolic subsystem, which is the non-equilibrium chemical 'motor' of the chemoton, providing material to the other subsystems and maintaining the homeostatic stability of the whole". This is connected to "an information subsystem which produces larger template polymers using materials from the metabolism". Thirdly, "a membrane system is coupled to both of these which encloses the informational and metabolic cycles within their suitable range of chemical interaction". (Ibid, 518.) The starting point of the chemoton is, thus, more lifelike matter with intermediary order.[21]

From the Simondonian analysis of DiFrisco it seems that the top-down models give us only a static rather than "generative" notion of form (2014, 521). In these cases, the matter does not enter into the determination of the form (ibid, 522). To summarize, the generative position gets

> "…expressed in Simondon's generalized model of individuation via the conjunction of three necessary individuating factors—a 'pre-individual', metastable source of potential energy that interacts with an 'informed' matter to produce the eventual, formed individual. Whatever the specific model of individuation it may be, with a generative notion of form, understanding the form requires placing it within such a generative field, where it loses its independence and autonomy and becomes one potential result among many. The 'essence' of the individual becomes of necessity partially ambiguous because it includes more than what belongs properly to 'itself', and certainly more than its form." (ibid, 522.)

Of course, top-down and bottom-up (downward/upward) models of hierarchy of living have been common in biological theory. Already Donald T. Campbell (1974a) described "downward causation" which strived to show that "all processes at the lower levels of a hierarchy are restrained by and act in conformity to the laws of the higher levels" (ibid, 180; also, Heil 2017, 43). The organization and levels reflected biological systems, that is molecules, cells, tissue, organs, organisms, population, species, and even society (Heil 2017, 43). The key element was that the lower and higher levels became dependent on each other (also, Dupré 2021, 10)[22]. This leads already to – or assumes – emergent systems, which are combination of upward and downward processes – they "consist of several organizational levels, which often are interdependent in different ways" (Boi 2017, 182, 185).

The downward/top-down causation can be thought through information control, which can be "found in biological organisms already at the most elementary bio-molecular level, suggesting that there is not the possibility to reinterpret these results in reductionist terms" (Auletta & al. 2008, 4–5). In this model, the "higher-level instance exercises control of lower-level causal processes through feedback control loops making use of functional equivalence classes of operations" (ibid). Thus, higher-levels signals control the actions of lower levels[23]. What is interesting is that the model includes, in addition

[21] In additon, for example, another mechanistic viewpoint, that of "a program" can be also criticized. As Barthélémy summarizes, "[f]ollowing François Jacob [...] many biologists have used the term program to designate the action of genes in the development of living organisms", but "[t]his is to forget the hierarchical organization of the living being" (2015, 34, note 33).

[22] See also, for critique of "talk of levels", Dupré 2021, 6; Longo & al. 2012, 2.

[23] "Here, a signal is any variation or pattern in a physical or chemical medium that can convey information or be treated as a sign" (Auletta & al. 2008, 5).

to influence of noise, information selection or "a guess" (ibid, 12), thus giving some randomness to the system.

However, many of these models seem to be quite rigid and convey hylomorphism. The organism can be thought or studied from two perspectives. First, through "the ontogenetic process by which the sequence of forms that comprise an individual's life history come into being"; and secondly, as "the phylogenetic process by which species as collective entities form and change based on the variations among the individuals that make them up" (Lewontin 2001, 60–64). In general, Simondon too sees the organism and its development from these perspectives (Fagot-Largeault 1994, 37). In addition, and in line with beforementioned DST, Simondon can be also considered to understand *developmental system* "as an organism-environment system" (Griffiths & Stotz 2018, 232). Although he does have more general conception of development (in the guise of individuation) and more general understanding of environment (that is, milieu). Yet, it can be said that Simondon also thinks that "aspects of the developmental environment are part of the developmental system" (ibid, 235).[24] (See also, Miquel & Hwang 2016a; Miquel & Hwang 2016b.) Finally, as Susan Oyama underlines, nature and "nurture" (e.g., 2000) do not exists separately. This is also in line with Simondon's thinking: already pre-individual "nature" co-individuates with individuals, but in addition biological individuation is continued at psychic and collective level. Oyama continues that the "separation of form and matter [that] underlies all the versions of the nature–nurture antithesis that have so persistently informed our philosophical and scientific approaches to the phenomena of life" (2000, 1; also, Venn 2010, 140).

The "Triplex" of Information

As the communication is the key element of individuation[25] by putting into work and requiring two orders or systems, the information also appears as a foundational element. To individuate, the orders must be different, that is, disparate (e.g., Choukah & Theophanidis 2016, 292). Simondon gives us as an example the plants: they "come to exist as a link – or a communication [..] – between a cosmic order (the sun and the solar energy it provides) and an infra-molecular order" (ibid; ILFI, 383, note 9, 384, note 16). At any rate, Simondon underlines that "information is not a thing, but the operation of a thing arriving in a system and producing a transformation", and that "[t]he information cannot be defined outside this transformational impact act and the receiving operation" (CI, 60; translation by Thomas-Vaslin 2020, 177; see also, Choukah & Theophanidis 2016, 294.) Simondon wants to overcome, on the one hand, what he calls "technological" conception of information, that is, the Shannon-Weaver model. On the other hand, he thinks that the cybernetic information is not enough either. (E.g., ILFI, 245.) However, it is worth to press that Simondon do not think that these two conceptions are wrong, only that they do not think information with enough complexity – or along the line of generative process of forms. The key element is "the fact that low-energy incidences can establish couplings, amplifying effects occurring between different orders of magnitude in the same metastable system or between different metastable systems" (CI, 60; translation by Choukah & Theophanidis 2016, 294). For Simondon important is not the classical emitter-receiver model in general or even the property of the message. Although these are important aspects of quantitative

[24] However, some elements of evolution and development are problematic or criticized by Simondon. For example, adaptation – although not, again, discarded by Simondon – appears as substantialism. Barthélémy (2015, 28) summarizes: "The biological concept of adaptation is based on a subtle and concealed substantialism which Simondon, with reference to the great philosophical tradition deriving from Aristotle, calls 'hylomorphism': 'biologism of adaptation' is based on the idea of an encounter between an already given individual and an already given environment, each of which sometimes takes the role of 'form' and sometimes 'matter'. But nothing is given and, moreover, genesis extends even beyond adaptation, as we see with the living being that has become psycho-social, which rebels rather than adapts itself." Simondon writes that "[d]evelopment could [...] appear as successive inventions of functions and structures that resolve, step by step, the internal problematic carried by the individual as a message" (also, ILFI, 226).

[25] E.g., also, Vitas & Dobovišek 2019, 84. ("...communication is the main characteristic of life".)

model of information (Shannon-Weaver model), the importance lies in the "state of the receiver, which Simondon qualifies as 'metastable' because it is charged with potentiality so as to make becoming-informed possible" (Barthélémy 2015, 36). Here we have certain chronology, as "there is a 'first information' in which emitter and receiver do not yet exist" (ibid). The first point of genesis can be placed somewhere here, where the metastable system, full of potentials, picks up the information "when the information is message transmission" (ibid).

In the end Simondon wants to replace the concept of form with that of information (ILFI, 16, 235; also, Venn 2010, 146). If the technological model of information focuses on quantity of information and cybernetics on the quality of information[26], then Simondon presents that we need the concept of information *as intensity*. What this means is that "the intensity of information can be increased using a voluntary reduction of the quantity of signals or of the quality of the forms" (ILFI, 268). The organism must be understood as a whole and as integrated into the world, and thus intensity means almost dialectical fusion of quality and quantity of information that gives rise to third term. Simondon writes that "the information is that through which the non-resolved system's incompatibility becomes an organizational dimension in the resolution" (ILFI, 11). Intensity, thus, means a kind of *meaningful dimension of this organization*. Organism orients relative to the world through this dimension – intensity is "the information potential of a situation" (ILFI, 269). This order of intensity increases the potentiality, that is, energy. The process moves from pre-individual "energetic potential to an individualizing formatting and signification" (Garelli 1994, 60). All in all, information can be thought as "singular or critical points and micro-level properties" (DiFrisco 2014, 505).

Although Simondon brings out the novel conception of information, he does not completely replace the concept of form. The form is "a condition of information; it is what receives information, the a priori that receives information" (MEOT, 150). Thus, he continues, that the information is not a form, but "it is the variability of forms", and this is, to be precise, "the unpredictability of a variation of form, not pure unpredictability of all variation" (ibid). Forming of a form is also "a correlate of the progressive degradation of potential energy" (ILFI, xxi; Garelli 1994, 59). That is, the generative dimension degrades and requires new information process to variate. In addition, signal can be, simply, underlined as "that which is transmitted" and, finally, "information properly speaking that which is effectively integrated into the functioning of the receiver after the experience of disparation involving the extrinsic signal and the intrinsic form" (ILFI, 249). However, this process is more complex as it involves already introduced concept of transduction as well as *modulation* and *organization*. In the light of information these can be understood as "amplifications" – that is, as transductive amplification, modulatory amplification, and organizational amplification (AMP).

The transductive amplification can be seen as a singular event that changes the structure of the system. It requires two disparate orders (or systems). For example, in living beings the transductive process is hierarchized because of different orders of magnitude, that is, physical and biological (vital) (see, e.g., ILFI 171). In physical systems transduction happens at single level. Simondon's often quoted example is a crystallization of a solution. The germ seed, introduced to the liquid, is considered an informational event, which triggers crystallization and, thus, gives rise to *a structure (form)* (e.g., see Carrozzini 2015, 36) – the initial germ is amplified to a formed individual crystal. (See, also DiFrisco 2014, 505.) The transduction can be understood as a passage, that is amplification, of information that leads to differentiation and integration (organization) (ibid). The key element, in the organism, is that the transduction "allows the change of order of magnitude" (API, 171). This change can be

[26] In addition, these forms of information are mainly hylomorphic. Thus, especially technological notion of information has no "true" novelty: "the apparently spontaneous emergence of new information, is in fact the revelation of that spatio-temporal information already present in the distribution of components and the network of signalling paths among them" (Farnsworth & al 2013, 211–212).

seen as an ontogenesis of, for example, a macrostructure from "germ-microstructure". The metabolism is an example of "an organism's capacity to build stable structures that increase the efficient exchange of energy with its environment" (Walsh & Wiebe 2021, 110; See also, Choukah & Theophanidis 2016, 293). The metabolism is a part of the systematic whole that, through transduction, individualizes a form, that is, a structure (e.g., Garelli 1994, 60). However, transduction – as a singular event that enables a new form to rise – requires the other amplifications.

The second amplification, a modulatory, is seen by Simondon as a scheme that "domesticates" singular transductive process. As modulation is established, it is possible to control and feed transduction under regular conditions. (API, 165.) In modulation no new structures (forms) are established, only domesticated, which in turn brings normativity to the system. If information can be said to be "variation of forms", then modulation is a constant flow of energy as a model of form that was established in singular point of transduction. As an example, Simondon offers self-regulation in organisms. In modulation the "macrophysical structures […] govern the fate of […] microphysical elements" (API, 171). Thus, as Bardin summarises (2015b, 8), in modulation "the individual itself is understood as a metastable system made of different 'phases', the result of a coupling of initially independent systems and 'processes of formation'" (ILFI, 225). As Simondon writes, "transduction is oriented towards the future", but "the modulation is a victory of the old over new, a recycling of the old structure" (API, 173). Modulation can only be in the system where there are structures, and these structures are created through transduction (API, 174). In general, the modulation is continuity, and transduction is a discontinuity (a phase change in a sense of quantum mechanics).

Finally, there is organizational amplification[27], in which the information is "not a given structure, but a framing of structures" and it "intervenes as a requirement" or "a problem posed" (API, 170). In organizational amplification information is expressed finally as "a system of compatibility to be invented by moving to a higher dimensional axiomatic" (ibid). Here, transductive and modulatory processes are correlated. In this case Simondon uses as an example the binocular perception: "the disparation of monocular images is what renders them incompatible" (ILFI, 711), but this is required for a three-dimensional image to emerge as a higher-level organization. In the example of crystalline solution, the germ becomes an organizing "link between past and present" – the transduction and modulation –, it is like "an agent" that "amplifies" the information (Fagot-Largeault 1994, 32).

Also, Simondon seem to describe organization as differentiation and integration (ILFI, 171–172; Venn 2010, 145).[28] This is clear if we break down "the dialectics": transduction differentiates, and modulation integrates. This organizational amplification of pre-individual germ potentiality launches singular event as transduction, to form a structure, which then modulates excessive information, and finally, amplifies differentiation-integration process as an organizational whole to receive higher-level. In the case of physical beings, the centre (crystal) is inert. However, the interiority of living beings, which has as a threshold a selective membrane, "is the place of topological differentiation and of chronological integration – that is, an autonomous spatio-temporal structuring". (Fagot-Largeault 1994, 24–25.) The living beings resolve tensions (or, at different level, problematics) by modifying their relation to the environment and by modifying themselves (by inventing new internal structures) (ibid, 25). Through this invention – of a function, a process of operation to structure and structure to operation – the individual – as organizing amplification – "becomes a 'communication node'": "this internal mediation can intervene as a relay in relation to the external mediation that the living

[27] Barthélémy underlines (2015, 35; also, in Iliadis & al. 2016, 278) that "what Simondon called 'information' [...] corresponds with what [Henri] Atlan calls 'organization'" (see also, Atlan 2006).

[28] Simondon (ILFI, 227), for example: "...the adult being is a dynamic web, an organization of separations and reunifications of structures and functions. A double movement of integration and differentiation constitutes this structural and functional web".

individual realizes, which allows living beings to communicate a cosmic order and an infra-molecular order" (ibid).[29]

Finally, the singular transductive process of realizing a new structure (a form) can be thought to include signification:

> The individual is the being that appears when there is signification; reciprocally, there is only signification when an individuated being appears or is prolonged in a being that is being individualized; the genesis of the individual corresponds to the resolution of a problem that could not be resolved by means of prior givens, because they did not have a common axiomatic: the individual is the auto-constitution of a topology of being that resolves a prior incompatibility through the appearance of a new systematic; that which was tension and incompatibility becomes functional structure. (Faucher 2013, 44.)

The signification comes to mean dimension of information that affects the other order/system ("the receiver") in that the system invents a new structure. (Hui 2019.) However, the signification (or "meaning") seems to have various modes. For example, the prior mentioned "tension of information" can be considered as meaning in the level of subjectivity. On the other hand, more formal processes of living beings can have significations. This seems to be Simondon's conception of development:

> "...a stage of development supplies the unique signification within which the pair of disparate elements constitutes a continuous system. Development is therefore neither pure analysis nor pure synthesis, nor a mixture of the two aspects; development is the discovery of significations, the structural and functional realization of significations." (ILFI, 228–229.)[30]

The pre-individual domain can be thought as a noise (or source of noise) "if we think" it is "characterized by the equal probability of all possible states, and thus rich in the greatest possible 'freedom of choice'" (Malaspina 2018, 48).[31] Thus, the pre-individual is "a positive ground for differentiation": it grounds the form and the transformation. In addition, the noise would company individuation and individual as a pre-individual load/excess. In any case, as a source of potentials, the milieu is inherently contaminated with noise. In addition, to Miquel & Hwang (2016b, 54) pre-individual seems to work as "recursive causality": it is a dimension of being that allows to it a certain degree of reflexivity. This Simondonian idea is in line with ideas presented by Flack (2014), who underlines that "complexity and the multi-scale structure of biological systems are the predictable outcome of evolutionary dynamics driven by uncertainty minimization" (ibid, 14). However, she seems to take quantitative form of information as basis, but "uncertainty minimization" could describe invention of (modulatory) structures. Still, the rigid form, that is, structure requires – in living beings – the dynamics of transduction, which is connected to metastability and pre-individuality. Flack points out that "biological systems manipulate spatial and temporal structure to produce order – low variance – at local scales" (ibid). With Simondon, the production of order (negentropy) accounts only

[29] Fagot-Largeault continues (ibid, 31) that the information "provides the key to autonomy" in that a "[a]utonomous being is the one that regulates its own development and stores the information and governs its action by means of this information".

[30] Fagot-Largeault (1994, 33) underlines that, in Simondon's thought, being, organism, is not pre-formed in "the germ" (or genes) but "invented at each stage of its development" – but not out of nothing. It "invents itself as a resolution to problematics posed by its informative schema" (ibid). Simondon: "In the course of an ontogenesis, the contributions of structural germs due to external circumstances can somewhat orient the structuration that comes after a dedifferentiation. But a structural germ that deviates too much from the characteristics of the structurable field no longer possesses any tension of information with respect to this field. Tension can only be defined in a field that can form a circuit. It is not a property of the isolated source, but of the source + receiver system." (ILFI, 692.)

[31] On noise see also, e.g., Lewontin 2001; Weinstein & Pavlic 2017, 182.

the modulation side of the triplex. The living beings *require the dynamics of information and noise, the order and disorder*. Although, she summarises nicely that a "new level of organization brings out new functionality", which is a "payoff for the system as a whole" (ibid). An adept wording of Simondonian triplex.

To Simondon, the "equilibrium between integration and differentiation is what characterizes life" (ILFI, 172). As mentioned earlier, in physical domain transduction happens at the "same level". But in living beings, the being itself is the transductive amplification, a bringing together of the different orders. On the other hand, the living beings is organizational amplification: it is "conditioned by the recurrence of causality due to which a process of integration and a process of differentiation can receive a coupling while remaining distinct in their structures" – "*life is not a distinct substance of matter; it supposes processes of integration and differentiation that cannot in any way be given by something other than physical structures*" (ILFI, 173, emphasis added).

From Matter to "Life"?

Simondon's metastability is quite close to Vitas & Dobovišek's (2019, 78) "far from thermodynamic equilibrium", which in turn characterizes life (as a dynamic balance) to them. They also ask, "how information accumulation, processing and transformation appeared at the prebiotic level?" (ibid, 82). As a reference, they mention proto-organisms "with primitive biochemical networks", that did not store "information about properties of primitive proteins and catalysers [...] on a genome". Thus, they ask: "could the information just rise out of chemical reactions of matter?". (Ibid.) In line with Simondon, they show that there are cases of spontaneous organization of matter, which leads to systems that acquire their information from environment. This leads to information transmission from environment to the living organisms. The writers summarize:

> "'life' – in the broad sense of the term – is a complex collective network made out of self-reproducing autonomous agents whose basic organization is instructed by material records generated through the evolutionary-historical process of that collective network." (Ibid, 83.)

For Simondon, the whole project of ILFI seems to be – at least partially – striving to describe individuation that starts from physical and moves all the way to biological, psychic-collective, and finally even technical order (e.g., see ILFI, 168–169). He constantly underlines that biological or vital individuation is the continuation of initial individuation, that is, physical. Physical mechanisms have their effect on biological realm (e.g., Bechtel 2007). On the other hand, as it is shown earlier, " many a biologist rightfully regards the standard deterministic or statistical or probabilistic forms of physics as insufficient to explain life" (Annila & Kolehmainen 2015)[32]. The reality is made of elements (118 different), which can enter complex combination and form proteins. These, in turn, can combine to make cells and cells can make up organisms. (Walsh & Wiebe 2021, 112; also, Boi 2017, 181; Nottale 2019.)

The beforementioned "triplex of information" (amplification) is at the heart of this matter – at least for Simondon. However, it is not completely clear how the individuation – the initial individual (origin of physical matter) or the first vital individuation (origin of life) – "started". Simondon seems to, at least partly, evade this question, as Miquel & Hwang points out (2016b, 52): "when physical boundary conditions vary up to a critical point, an emergent property suddenly appear, and system drastically changes", which is not "deduction, because the emergence of the global constraint that will act downward on all system's components cannot be predicated at the beginning". Thus, *the*

[32] Although Ellis & Kopel stress (2019, 1), that "[b]iology differs fundamentally from the physics that underlies it".

origin cannot be individualized as a form a prior. It must be studied as individuation, as its ontogenesis – as Dupré says, "[t]he organism just is its life history" (2021, 19). As Ho summarises:

> "Life must therefore reside in the patterns of dynamic flows of matter and energy that somehow makes the organisms alive, enabling them to grow, develop and evolve. From this, one can see that the 'whole' does not refer to an isolated, monadic entity. On the contrary, it refers to a system open to the environment, that enstructures or organizes itself (and its environment) by simultaneously 'enfolding' the external environment and spontaneously 'unfolding' its potential into highly reproducible or dynamically stable forms." (1998, 6.)

Conclusions

In conclusion it is worth to note that, as Godfrey-Smith puts it, "it is tempting to offer a grand theory", and this is precisely what Simondon is doing. Even if more general analyses and theories are important, all-consuming conceptions and principles seem, in the light of various complex phenomena that they supposed to grab onto, ridiculous. At any rate, Simondon's theory of individuation and interesting notion of information can give tools to help, for example, organizing the processual metaphysics of biology, which Dupré demanded. In addition, none of the beforementioned theoretical models are useless, they just capture studied phenomenon from different perspectives. For example, we of course *can* study living beings as machines or even algorithms, but if one would *completely identify* these complex, open systems through these mechanical concepts, they would be wrong.

Finally, Simondon has, of course, been criticized. Fagot-Largeault, for example, ponders that "Simondon is perhaps saying nothing other than what contemporary theoretical biology says: living things are open systems in unstable equilibrium with its environment, which amplifies its organization thanks to its capacity to transform the information disorder" (1994, 27). In addition, she criticizes Simondon's insufficient knowledge of biology, or at least molecular biology (in Bardini 2014, 146). She continues that Simondon's intuitions remained Lamarckian, and he did not "come to terms with Darwin" (she also identifies individuation as "an evolutionary process", but this is not right) (also, Fagot-Largeault 1994; Barthélémy 2015, 18.) Barthélémy stresses the lack of DNA in Simondon's analysis (Barthélémy 2015, 18). However, Fagot-Largeault seems to identify "the germ" with genes (1994, 33), thus giving him some credit. Finally, mathematician René Thom offers (1994) robust criticism for some scientific points of Simondon, but also uses Simondon's concepts.

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