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Special issue on Scientific Process Ontology and Metaphysics

A Thematic Introduction

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Foreword. The reasons that encouraged me to propose a Special Issue for *Manuscrito* on processual thought in the philosophical-scientific perimeter are primarily rooted in the naturalist spirit intrinsic to process models. The appeal these models have had on my academic and research journey stems largely from their emphasis on the dynamism and relationality of entities, their mutual interdependence, and their contingency, which simultaneously allows for avoiding both reductionist and/or foundationalist approaches and those uncomfortable dualistic fragmentations or "bifurcations" of nature, as Whitehead (1920) would put it. Furthermore, in my view, processual thought revives the original core of the philosophical and scientific approach to understanding natural reality, which is essentially transient, transformative, and evolutionary.[2] Today, this kind of theoretical model plays an important role in the ongoing debate across many scientific disciplines, from physics (Rovelli, 2016) to biology (Dupré, 2012; Landa et al., 2024), chemistry (Stein, 2004; Córdoba et al., 2024), and cognitive and psychological sciences (Bickhard, 2024), to name just a few examples. In short, the processual approach is increasingly recognized as a capable and suitable conceptual framework for describing complex and inherently dynamic, interactive natural phenomena.

For these reasons, together with the entire Editorial Board of *Manuscrito*, and in collaboration with all the authors who participated in the Call for Papers for this Special Issue, as well as all the reviewers involved—to whom I extend my heartfelt thanks and my apologies for my inexperience and any mistakes—we aimed to offer a modest contribution to the processual philosophical-scientific thought.

The following thematic introduction is intended to offer some general coordinates, to provide the interested scholar with the conceptual framework necessary for a proper understanding of the contributions in this volume.[3]

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[2] It is worth noting that the Latin term "natura-ae" derives from the Latin root *gna* (in Greek *gen*), which means *generation*, from which the Latin verb "nasci", *to be born*, originates. Similarly, the Greek word "physis" belongs to the root of the verb "phyo" (φύω), meaning *to generate*, *to grow*. Thus, the term "physis" encapsulates the idea that all natural entities come into existence, that change and transform, that are born and die, and whose existence, therefore, is intrinsically transient and in becoming.

[3] There are two points I would like to add before proceeding further. First, the following introduction is not intended to offer a historical-theoretical reconstruction of processual thought. For that purpose, I refer the reader to much more comprehensive texts, like (Rescher, 1996; 2000; Seibt, 2024; Winters, 2017). I must also say that the introduction does not aim for completeness, whether thematic, argumentative, or bibliographic. The main reason for this is twofold. First, my goal has been to pique the reader's interest and provide him the bases for self-orientation, rather than to inform comprehensively. Second, the volume itself is composed of qualified, technical, and specialized contributions which thoroughly and independently address the various topics introduced here, as well

1. Processual models and the dynamic constitution of entities[4]

Unlike traditional metaphysics, which focuses on being or substance as either the starting point or the endpoint of its reflection,[5] process metaphysics primarily focuses on the relations, activities, and interactions that constitute all those specific differences or asymmetries that differentiate natural phenomena from one another.[6]

Processual models, in this sense, invert the substantialist view of reality, which prioritizes being over becoming, or self-contained, self-sustaining, and static substances rather than dynamic interactions.[7] Naturalistic substance metaphysics has always sought to explain and model the world, its dynamics, and its complexity, starting from the hypothesis of the existence of one or more fundamental realities made up of simple, isolated, static—non-dynamic and non-internally organized—primitive entities upon which everything else somehow depends—to the point of making this latter losing genuine ontological status and metaphysical power. In contrast, process metaphysics focuses solely on the transformative interactions that characterize the internal dynamics of natural reality, without any claim to touch upon being, which, if it indeed exists, transcends continuous becoming and, with this, all of nature.

For the processual approach, being is nothing but a chimera. If the being transcends nature hypothetically, then the self-sustaining entity or substance transcends it as well, along with every capacity we have for inquiry into it—be this empirical or theoretical. Thus, dynamic relations, interactions, and, more generally, dependency relations among entities, especially those observable in nature, are all we have to define the very existence of those: nothing exists in isolation or by itself, and nothing is self-sufficient.

What would an animal be without its environment? Certainly, it would not exist; it would die, cease to exist. Diachronically, it would migrate in search of a sufficiently suitable environment and then adapt to it, eventually changing its own identity—first as an individual and then, over generations, even its own species identity. However, while adapting, it also

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as others I have intentionally omitted for reasons of economy and appropriateness. I believe that the interested scholar will find satisfaction in reading the volume.

[4] Since, at the time of writing this introduction, I did not have access to all the contributions to the volume, I have chosen not to reference the authors' works here in order to avoid any unintended omissions.

[5] For an introduction, see the work of Loux and Crisp (2017) as well as that of Marmodoro and Mayr (2019). It is noteworthy that these texts make no mention of process metaphysics. The reason for this exclusion primarily stems from the fact that processes are traditionally understood as secondary and/or "derivative" entities, constructed from particular substances and their states arranged in temporal sequences. Thus, the very existence of processes inevitably depends on the existence of the particulars involved, that is, those participating in the processes. In process metaphysics, this relationship of dependence is at least reversed. For an introduction to the metaphysics of processes, see the works of Rescher (1996, 2000).

[6] To understand how Western metaphysical thought has incidentally adhered to the substantialist hypothesis rather than the already available processual one, I suggest referring to (Winters, 2017: §1).

[7] By "substances," we refer to all *ontologically independent*, *fundamental* or *primitive*, and *non-relational* entities (Winters, 2017: §2), meaning *self-sufficient* entities, such as *particulars* (Seibt, 2010), whether they are material or abstract. It follows easily that the existence of substances is necessary. Surely substances can participate in relations but, on the other hand, it is difficult to attribute an ontological status to these latter from the substantialist standpoint since relations cannot be fundamental substances. On the one hand, you must have relations to make fundamental substances interact but, on the other hand, relations must be fundamental as well. So, to have ralations inhabiting the substantialist model, the the philosopher faces the risk of ontological dualism and, thus, of the irremediable fragmentation of nature. I will come back on this point later.

contributes to transforming the identity of its (new) environment. In evolution (not only) biological, life, and biodiversity emerge as the result of constant dynamic processes of interaction and transformation between systems and their specific environments.

However, asserting that nothing exists except in some relation of dependence, that absolute being is a mere illusion and a false problem, does not simultaneously mean renouncing the concept of existence. Rather, it means asserting that, by assumption, existence is a *contingent* fact. To say that reality is processual or that observable entities are processes means nothing other than that these cannot be fully understood if isolated from the context in which they occur, as they are constitutively contingent.

This is the intrinsic naturalism of process ontology and metaphysics: everything is within the becoming nature, including the notion of existence itself, and therefore, existence also has a dynamic constitution. What exists—i.e., entities—always exists within a complex network of relations and through it. Only by including this network and its dynamic constitutions can the nature of entities be adequately understood. Thus, adequately modeling natural systems is possible only by incorporating a multiplicity of interactions with other processes and also by including the surrounding relevant specific environment.

The relational and open aspect of entities is crucial to understanding the ontological role of dynamics: a process is not simply a (temporal) sequence of states, as it is traditionally understood. Rather, a processual entity is a phenomenon in continuous transformation and evolution, whose identity is intrinsically linked to the achievement of those parameters that stabilize its dynamics and which are determined by both "external" and "internal" factors of the system that, by interacting appropriately, enable development and maintenance. The identity and existence of processes are thus fundamentally given by the organization of such dynamics.

A paradigmatic example of how organization is an essential component for the identity and (maintenance of) existence of a physical system (even a non-biological one) is found in *far from thermodynamic equilibrium* systems, such as the flame of a lit candle (Campbell & Bickhard, 2011). Without considering the organization of the convective motions generated by the flame for its self-maintenance, defining this system by identifying all the material components that make up the flame—such as the molecules of wax, the gaseous molecules of oxygen required for combustion, and the carbon dioxide emitted, etc.—would be impossible. For the flame to remain lit, a complete list of all these components is not enough; it is also necessary to order their interactions in a specific way to prevent, for example, currents of carbon dioxide from saturating the surrounding environment at the bottom of the flame or replacing the “reservoir” of oxygen that fuels it. Breaking this fundamental top-bottom asymmetry between the flows of oxygen and carbon dioxide, for example by blowing on the candle, means interrupting the combustion process, inevitably extinguishing the flame and causing it to cease to exist.

In other words, every process is not only essentially organized, but organization serves as a "unifying principle" of the system as a whole, defining the system's maintenance potential (existence) and its identity, but always in relation to an appropriate environment. In a processual and evolutionary cosmos, the very notion of existence, therefore, essentially depends on that of organization, that is, on the stabilization of dynamic asymmetries through which each system-environment pair emerges,[8] and for this reason, it is intrinsically contingent.

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[8] Not coincidentally, the notion of *metaphysical emergence*, which we will discuss shortly, generally implies a relation of asymmetric dependence.

2. Structures *vs* organizations: identity and existence

Unlike the particular objects of traditional naturalistic metaphysics—such as monistic and particularistic ones, like materialism—processes, being organized and open, are certainly relational entities. However, defining processes as essentially relational entities is not sufficient to characterize them appropriately, namely *qua* processes. For instance, other relational entities are structures, which are characteristic of ontic structural realism.[9]

Yet, structures and organizations are very different entities.[10] Unlike organizations, which are dynamic systems—i.e., asymmetric, variable, and open—structures, as well as particulars (whether abstract or concrete), are by definition symmetric and invariant entities. As in the case of particularist or objectualist ontologies, the identity and existence of structures are fixed once and for all through the assumption, more or less implicit, of a *primitive* equivalence relation—namely, one defined across the whole model and that, therefore, "generates" (specifies) all the denumerably infinite structures belonging to this latter. In the case of structures, this primitive relation is an isomorphic function; in the case of particulars, this role is fulfilled by "logical" identity.[11] In this sense, structural models are just as substantialist as particularist ones, despite their emphasis on relationality.

In processual models, instead, identity is dynamic and contingent. It is not only relational and relative—in the sense of being relative to a context and, so, specific to each type of object—but also *non-primitive*, namely not given in advance, set once and for all, as it is an essentially *constructive* notion. Indeed, the identity of an organization depends on its interactions with other processes and on the stabilization of these latter. This stabilization can be achieved or lost, and thus the identity of organizations is essentially "transformative" and can change over time. This contrasts with structural identity which is invariant by definition.

So, how could we ever hope to model organizations using structures adequately? How could we transform something that is, by definition, invariant? Processual identity requires less rigid and static notions than those characteristic of substances and structures. One example is that of a homomorphic function, a functional relation that is not necessarily pointwise symmetric and reflexive—i.e., not a bijective function. We will return succinctly to this point in Section 4. It may be useful to provide an example of the structure-organization difference in modeling change to help the reader understand the general point at stake.

A classic example of the problem that substantialist metaphysics faces regarding identity and change (or transformation) is the so-called *ship of Theseus problem* (Marmodoro & Mayr, 2019, 39-40). The ship of Theseus, like any other entity, is subject to

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[9] In particular, so-called "relational structures" dispense with objects to model the (internal) nodes of structures. See the work of Ainsworth (2010) for an introductory account of ontological structuralism and the various types of structures.

[10] A previous article of mine published in this journal, (Ferrari, 2021), mistakenly identifies relational structures with organizations and, consequently, with processes. This certainly applies to the first contemporary processualist project, the one originally formulated by Whitehead in 1929 in *Process and Reality* (1978), which I indeed discuss in that work, but it does not hold for processualism in general, and even less for the more recent, explicitly non-Whiteheadian versions. If, in fact, the structuralist thesis were an inevitable presupposition of processualism, (strong) ontic structural realism and processualism would coincide. However, among the many issues that would arise from this, processualism would risk being incompatible with a strong notion of metaphysical emergence, a concept we will introduce shortly, because structures are rigid, abstract entities, fixed once and for all.

[11] The second part of Section 4. discuss this topic further, although, for reasons of economy and simplicity, we do not discuss here the very idea of "logicality". For a discussion of this latter, see (Dutilh Novaes, 2014; Ferrari, 2022).

decay due to the constant pressure of events. To continue to be admired as a *memorandum* of the liberation of Athens by Theseus from Cretan domination, the ship must therefore be repaired whenever a part deteriorates. If one or all parts of the ship of Theseus are gradually replaced, can it still be considered the same ship? For the ship's identity to be preserved despite the changes, the substantialist view requires that there be something immutable within it—its essence. Accordingly, the process of transformation is conceived as a series of discrete states incapable of affecting that essence, and thus accidental.[12] At this point, it becomes difficult to understand how to identify such an essence, that is, what makes the ship of Theseus what it is *qua* The-Ship-of-Theseus. For example, from a materialist perspective, once a single material element of the ship is changed, or in the extreme, all of them, it would cease to be what it was because the particular material components are all that matter for defining its identity. But this clearly goes against common intuition: changing only the helm of the ship of Theseus does not seem sufficient to any longer recognize it as that very unique entity (The-Ship-of-Theseus). Even changing just two or three elements does not seem to alter its identity. Is there a limit to the number of replaceable parts? How many times can this occur?

To overcome these boundary problems, the structuralist view proposes the idea that the essence of the ship of Theseus is its (formal) structure, that is, the complete and rigidly ordered set of relations between its material components, whatever they may be. Until that is preserved, the identity of the ship is preserved.

Yet, this way of conceptualizing the problem tends to create a series of additional difficulties. For example, the structural idea overlooks the contingent aspect related to the very ontological constitution of entities. In fact, from a principled standpoint, the structure of the ship, being its essence, would not only be *necessary*, but *qua* structure, it would have a necessary *a priori* existence. On the contrary, as the starting evidence tells us, efforts must be made to preserve the identity of the ship and, therefore, that such identity is not a structural matter at all. If it were as the Structuralist claims, the ship would be invariant a priori. The contingency of entities tells us also that the ship of Theseus could have had a different structure and, more importantly, that it might not have existed at all. In other words, not only could Theseus have chosen another ship, but, above all, he might not have had one at all, and the one we attribute to Theseus might never have been built.

The problem for the Structuralist is thus twofold. On the one hand, since the existence of structures is necessary and a priori, the existence of the structure of the ship of Theseus would not be contingent, except in the linguistic sense where contingency would apply only to the act of associating a (pre-)existing structure with the label “The Ship of Theseus.” On the other hand, the structuralist stance cannot capture the fact that the ship of Theseus would not even exist—meaning it would not be a ship and would not belong to

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[12] Since Plato, traditional realist metaphysics has resorted to the strategy of introducing an additional hypothesis, alongside the existence of substances and properties, to resolve the problem of change: one of these is the distinction between essential and accidental properties. Of the two, accidental properties can change without altering the fundamental identity of a substance, while essential properties are those that cannot change without the substance itself ceasing to exist. However, this distinction has never been definitive, despite appearances. In fact, determining the boundary between these two types of properties, and thus the complete collection of essential properties, proves to be impossible. Another additional hypothesis for addressing substantial change is the existence of a substratum that persists and is thus common to the stages of substantial change. The problem with this latter solution is analogous to that just described. See (Winters, 2017: §3.3) on this topic. Fuzzy logics were invented to resolve logical problems analogous to that of the *Ship of Theseus*, precisely by “blurring” the boundaries of such distinctions.

Theseus—without presupposing a specific physical, biological, technological, and cultural context which is, in turn, difficult to define unequivocally, especially because it is inherently contingent and variable.

The notion of structure, in short, suffers from being strictly univocal and formal in principle, whose existence, serving as essence, would be as fundamental as it is a priori necessary—and thus intrinsically non-modal. This makes structures purely abstract, which the ship of Theseus is not, being an entity whose identity is both concrete and contingent, and therefore essentially modal as well as not univocally specifiable.

3. Transformative nature, emergence, and causality

One of the strengths of processual models comes straightforward from the fact that they do not need to explain change as such.[13] Rather, their task is to describe the modes and possibilities of specific changes, that is, those related to specific categories of entities. Indeed, modeling the constitutive dynamics of entities differs from category to category in terms of their specific organization. At the same time, however, this requires introducing new organizations, previously absent, within the domain of existence specified by the model since entities transform into something genuinely new.

Processual models are thus *open* because they naturally incorporate ontological *novelty*—the (contingent) generation of new, irreducible existences. Substantialist models, instead, hardly support ontological novelty without resorting to *epistemic* interventions that reinterpret "novelty" in terms of "informational surprise"—for example, relative to prior knowledge—or ontological miracles, such as creation *ex nihilo*. For processual models, on the other hand, ontological novelty is completely natural.

Transformations are not simply transitions from one state to another of something maintained underneath but, also, *constructions* of new organizations that *emerge* in the network of interactions between processes. Biological evolution, for instance, is a (complex) process through which new forms of life (organisms) emerge within the complex and dynamic network of interactions between organisms and their environments (Duprè, 2012).[14] There is no need to hypothesize predefined essences or fixed forms, like universals or Platonic substances, as well as a common invariant substrate to explain change.

Quite the opposite: new species are the result of contingent and relational processes that have interactively stabilized. The evolution of the entire cosmos, from the diversification of different states of matter-energy to life, with empirically associated laws with each stage is an open process. Albeit with the due differences, this holds at all levels of complexity, from the macro-level of thermodynamic, biological, and psychological-social processes to the micro-level of subatomic physical processes. For instance, in quantum field theory, particles (quanta) themselves emerge from interactions between fields as quantized oscillations, whose properties, far from being predetermined and rigid units, are specified by the interactions that progressively stabilize as the "particle" emerges (Bickhard, 2011; Seibt, 2002).[15]

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[13] Recall that process theories adopt a transformative perspective from the outset. This means that transformation (becoming and change) primitive or fundamental while what requires explanation is the nature of objects or objectuality.

[14] The transition from physicochemical activities to life is also the result of a network of complex and highly unstable interactions that ultimately stabilized sufficiently to emerge and sustain itself in existence, always evolving over time.

[15] Another paradigmatic example is human consciousness: it cannot be reduced to a series of interactions between neurons, but rather emerges as a new and "qualitatively" distinct property that arises from the complex organization of the human body.

The process-based model, therefore, aims to describe and articulate becoming in its multiple specificities, each one involving equally specific notions of emergence, thus describing and explaining as many categories of entities. The problem of the dynamic constitution of entities is the problem of understanding the stabilization of specific dynamic conditions that allow for equally specific organizations to be constituted. As mentioned earlier, the identity and existence of entities are tied to the specific dynamic conditions that constitute each organization. To specify this constitutive "mechanism," Processualists employ the notion of *emergence*, which thus becomes a fundamental component of the processual theory. There is no process of dynamic constitution of organizations without emergence (Bickhard, 2009; Campbell, 2009; Seibt, 2009).

In contrast to the processual context where emergence is the rule, the notion of emergence leads traditional substantialism to some of the strongest and most insurmountable tensions. Here, the introduction of genuinely new entities and properties is often seen as an anomaly or exception. If emergent entities and properties cannot be reduced to the components from which they arise,[16] then the question of their causal contribution arises. Let's briefly examine why.

According to traditional conceptualization, every effect or manifestation of change must have at most one cause, or rather a unique *sufficient* causal contribution (or chain) that can be traced precisely and *unequivocally*. Ultimately, the sufficient causal contribution is attributed to a "more fundamental" level of natural reality than the emergent one. In contrast, the idea that emergent entities and properties can be causally efficacious—that is, capable of producing effects—implies that causes at a higher level of ontological complexity can "influence" the underlying causal dynamics at lower ontological levels. To avoid contradictions between fundamental and emergent sufficient causes, traditional naturalist metaphysics has proposed two main solutions:

(1) To consider emergent causality as unreal or *epiphenomenal*, generally attributing it a merely "epistemic" status (Kim, 2005);

(2) To consider emergent causality as genuinely ontological but stripping it of distinctive causal contributions, that is, depriving it of causal powers (Wilson, 2021).

Despite the inner differences, both solutions are rather explicit in rejecting the idea of emergent causal efficacy. However, the first approach seems to be intellectually more honest in this regard. Unsurprisingly, the second proposal offers an ontological reinterpretation of the same notion of weak emergence that traditionally received exclusively epistemic interpretations. The attribution of ontological status to weak emergence seems to be merely stipulative (Ferrari & Bickhard, 2023).

It follows from that, however, that the very notion of causality inherent in the traditional view cannot be adequate for the emergentist and, more specifically, processual perspective (Campbell, 2009, 2015)—at the very least, in the sense that causal contribution is *not univocal*. This is not due to epistemic limitations, perhaps related to methods of inquiry, but rather to the non-univocal or equivocal/analogical nature of processual entities, as their

[16] In brief, this is the core idea of ontological and metaphysical reductionism: complex phenomena can be fully explained in terms of simpler parts or fundamental components. In other words, everything that exists, along with their causal powers—meaning the powers to generate effects and bring about changes in the world—can be reduced to underlying "basal" entities, such as elementary particles or fundamental physical units, and their causal powers.

existence and identity are “split” between what we have referred to as the system-environment pair.

Without delving into the complex details of the issue, the crucial point is that the possibility itself of distinguishing unambiguously between the system and its environment is essentially impossible. This is because determining, once and for all, the boundary between what constitutes the system and what constitutes *the environment for that system* is generally an unsolvable task for two reasons. One is that the system actively engages with its environment by adapting to and modifying it. Similarly, the environment, while adapting to the system, actively modifies the system itself.[17] Therefore, the ontological system-environment pair maintains an intrinsic equivocation that, when modeled using the resources of traditional metaphysics, can only generate *impredicative circularities* and other problems (Campbell & Bickhard 2011; Winters, 2017)—the *Ship of Theseus* problem being among them. Clearly, the processual perspective requires an organization-driven redefinition of the very notion of cause (Campbell & Bickhard, 2011).

4. Formal process-based models: ampliative logics and contextual identity

Theories are formal models[18] through which we describe various aspects of reality, and if adequate, they provide a representation of the behavior or nature of these latter.[19] Without postulating theories, we would not be able to specify models, make them available for empirical or formal testing to assess their adequacy, coherence, and utility, or even engage in debates about them. This holds for all theories—scientific, philosophical, as well as historical and hermeneutical ones. Process theory is no exception.

Of course, theories, viewed as languages, are collections of statements about a specific content or field. However, the inclusion in a theory of statements about specific and characteristic aspects of reality is not always sufficient to ensure that the model specified by the theory behaves in conformity with the desired one, the so-called “intended model.”

For instance, merely including a statement about the possibility of metaphysical emergence among a theory's hypotheses does not automatically mean that the theory can provide an emergentist model. In fact, linguistic stipulations alone have no direct grip on reality. In other words, to obtain the desired model, it is also necessary to intervene in the deeper formal elements of theories, such as the underlying logic and the relations that specify the nature of the entities inhabiting the model.

If the formal model is not appropriate, then notions like metaphysical emergence, even if linguistically stipulated, will not be supported by the model specified by the theory. This is what happens, for example, with substantialist models that distinguish between levels or domains of entities (objects) and properties (Ferrari & Bickhard, 2023). The mismatch between the specified and intended model clearly forces a conceptual shift in the underlying framework of such models and, thus, also a revision of the notions involved. An example commonly solicited by Processualists is the shift from the notion of “emergence from” lower-level properties to that of “emergence (of more or less complex organizations) within" the processual fabric itself (Bickhard, 2009).

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[17] For a detailed discussion and examples, see (Winters, 2017; Dupré, 2012). Regarding the broader issue of the failure to distinguish absolutely and unambiguously between internal and external relations, see (Rojek, 2022).

[18] Even if not necessarily formalized, that is, regimented through so-called formal languages.

[19] Nothing prevents such a representation from being non-definitive. For example, the criteria for adequacy of a representation can change, as they have indeed changed throughout the history of human evolution. Therefore, a representation that is adequate today may no longer be such as our knowledge evolve.

More generally, Process Philosophers call for a revision of the reference naturalistic model that accounts for the fundamental evolutionary and, therefore, transformative nature of reality which, on the contrary, the traditional model is arguably unable to support. In other words, Processualists alert that the ontological components of transformative models cannot be invariant or fixed once and for all, as it happens in substance-oriented models; otherwise, notions such as existence, organization, and even the information generated by interactions could not transform, and the model could not expand or evolve.[20]

In contrast to the various articulations of the notion of substance, process theories thus require a flexibilization of the interaction between traditional notions of existence and identity, rendering natural entities always dependent on the interactions through which they have been dynamically constructed and that maintain their stability. Similarly, the processual theory, as a logically articulated language, must leave open the possibility of generating informational novelty in order to account for the emergence itself even from the formal standpoint. With some approximation, we can say that two of the essential ingredients for constructing formal process models are:

I. The *contextualization* of the notions of identity and existence, and

II. Equipping the theory with genuinely *ampliative* logics, rules, and methods,

as proposed by Cellucci (2013; 2017, 2022). Let us begin by clarifying the latter.

Ampliative logics, unlike traditional deductive logics—which are informationally conservative[21]—allow the informational content of the theory to increase through heuristics, that is, rules of discovery. In other words, these are rules for enriching theories by introducing *plausible* premises (hypotheses). The introduction and formulation of new hypotheses depend on theoretical-empirical contexts based on *plausibility criteria*, which, being essentially pragmatic and inductive elements, will never be definitive nor unequivocal.

Through ampliative logics, not only the theory itself but also the logical-formal space that it models—i.e., the model it specifies—is constructed dynamically and step by step through the interaction between the newly introduced hypotheses and those already present, as well as those from other theories that delimit its *context of plausibility*, perhaps remaining "in the background." In this way, the interaction between old and new information transforms the informational space of the theory at each new step, altering its topology and metric, and consequently changing the organization of the ontological model so specified. Indeed, the models of ampliative theories are dynamic and interactive in the sense that they *cannot* precede the construction of the theory, as this is an indefinite process, and in this sense, also *open*.[22]

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[20] While remaining consistent with the principles of conservation of energy and matter.

[21] For these, that is, the informational content of the premises (hypotheses) is always preserved in the conclusions through simple symbolic-syntactic manipulation. In this way, the model of theories adopting such logics is not generative, as it neither produces new informational content nor explains how to introduce new hypotheses when needed.

[22] In this sense, ampliative logics must necessarily be weaker than classical logic, much like *intuitionistic* logics. Indeed, if the model is open, it is never complete, and thus classical principles that assume the completeness of the (canonical) model—such as the *laws of excluded middle*, *disjunctive syllogism*, and *reductio ad absurdum*, all based on the classical negation operator—do not hold unless, of course, it is confirmed that certain appropriate conditions apply.

Obviously, this means that the entities composing the model of the theory are not fixed once and for all, which implies a revision of the traditional interaction between identity and existence. This brings us to the first point.

It has always been unquestionable that the notions of identity and existence are closely linked. As the Quinean slogan goes, *no entity without identity*. However, the idea that both of these notions must be fixed once and for all—categorically and in such a way as to render the ontological units in the model of the theory static—is precisely what processual thinking firmly rejects. Rather, process theorists recognize that *changing the identity changes the entities* (Ferrari, 2022), and they are, of course, seeking notions of identity that are far more flexible than the traditional ones, and that are adequate to their own transformative and emergentist view. Let's explore why.

The idea that identity is a rigid or invariant notion has a long tradition, which in recent centuries has been redefined in terms of its *logicality* or *a priori* nature, i.e., *invariance* (Rodin, 2007; 2017). For example, the "analytic" approach to philosophy, certainly inaugurated by Wittgenstein but whose foundational elements were derived from earlier reflections by Frege, Whitehead, and Russell—just to name a few—and from their *logicist* approach later assimilated by logical empiricism, embraces this idea.

Now, conceiving identity as a *logical*, *a priori*, or *invariant* relation implies not only that the ontological units of the theoretical model are themselves rigid and invariant, but also that the model of the theory is similarly rigid and invariant, as it would be already *fully* formed. Indeed, the existential domain of the model M of the theory can be defined using the identity relation ($x = x$) specified by the *Classical Theory of Identity* (CTI)[23]—formally, $M_{\exists} = \{x: x = x\}$. According to this conception of identity, $M_{\exists}$ includes everything that exists according to the theory, as everything that exists is identical to itself—this is the axiom of *reflexivity of identity* (R). It is also worth noting that the CTI leads the theoretical model to restrict the notion of entity to that of objectual substance, as it establishes that all entities x of $M_{\exists}$ are *context-independent*—this is the axiom of *substitutivity of identicals* (S), *salva veritate*.[24]

To realize that this conception of identity is *not* universally valid, one need only reflect for a moment on the fact that the invariance of identity holds only if the objects composing the model exhibit certain characteristics (Dutilh Novaes, 2014): the objects must be *discrete*; they must *endure* (temporal insensitivity); they must not merge (i.e., two objects becoming one); they must not spontaneously multiply (i.e., one object becoming two). In short, the CTI expresses a numerical and *particularist* conception of identity—as well as a rigid one of existence—since it imposes that the number of discrete (particular) objects in the domain remains stable; otherwise, the invariance of the relation collapses. The invariance of the identity relation and that of its extension or domain $M_{\exists}$, therefore, go hand in hand.

Yet, this clashes with processual intuition and, also, is inadequate for modeling natural reality. Indeed, there are numerous natural processes where this conception of identity and existence does not apply. For instance, the communication of ideas and concepts, their formation and sharing,[25] cellular multiplication, chemical reactions, the division or fusion of

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[23] The CTI consists of only two axioms: the axiom of reflexivity (R) and the axiom of substitutability (S)—the logical counterpart to the principle of the indiscernibility of identicals, which together form a special equivalence relation (reflexive, symmetric, and transitive) defined over the entire model (Ahrenhart et al., 2019). Formally, (R) states that for every x, $(x = x)$ while (S) states that if $x = y$ then $(\varphi x \leftrightarrow \varphi y)$, where φ is a schematic letter for well-formed open formulas (from first-order languages).

[24] And for this reason, they are substitutable (in different contexts, including propositional ones) salva veritate.

[25] Let us recall that Quine believed that concepts and intentions are non-extensional entities and therefore should be rejected as ontological components because they do not meet the criteria of

fires, or even the separation or fusion of clouds. In all these cases, the number of natural entities does not remain invariant. Another example—perhaps the most paradigmatic—of how the CTI is inadequate from an empirical-natural point of view, and not only on macroscopic scales, is provided by the evidence of non-local quantum entanglement phenomena. In fact, if indiscernibility does not entail numerical identity, then the entities in the model are not necessarily objects in the sense of the CTI: that of entities capable of preserving a defined numerical identity, like substances or particles (Ahrenhart et al., 2019; Catren, 2022, 2023; French & Krause, 2006). More generally, quantum particles are not substances (particulars) precisely because they are oscillations of fields, that is, non-local and thus non-discrete entities obtained by interaction (Bickhard, 2011).

As Seibt (2002, 2010) pointed out, the great problem of traditional naturalistic metaphysics is indeed its tendency to indissolubly tie the concept of an *individual* to that of a *particular* — either concrete or material.[26] In models of this type—those naturally induced by an interpretive misuse of the syntax of classical predicate logic, which distinguishes between subjects (objects) and predicates (properties)—metaphysical emergence, as well as evolution, are in principle impossible (Seibt, 2009). Instead, processes are generic individuals, that is, *schematic* individuals (Seibt, 2004, 2009), due to their organizational and interactive nature (Bickhard, 2009; Campbell, 2009), and whose numerical identity is entirely irrelevant.

The problem of the identity of processes is undoubtedly one of the most challenging to resolve. However, the processualist theory currently finds itself in a favorable position. Nonetheless, it is conceptually unclear why the theory of identity typically adopted in ontology and metaphysics should be the substantialist one, essentially corresponding to the CTI.

Even excluding issues of empirical relevance, there are already alternative formal models to the CTI in the scientific literature, based on theories of identity that we might call “contextual.” This is so, if for no other reason than because they reject the generality of the principle of the *indiscernibility of identicals*—which corresponds to the context-independence or axiom (S) of the CTI. In fact, in *category-based* formal contexts (Heller, 2016), two identities (objects), although equal, can still be distinguished by looking at their internal composition, or by observing how each has been constructed through morphisms. Although two objects may be equal, it is not necessarily the case that they are always equal in every context in which they interact.[27]

In the category-based domain of Homotopy Type Theory, some geometric interpretations of Martin-Löf's Constructive Type Theory are currently being articulated and developed (Rodin, 2017). Here, we can only briefly mention these alternative developments; however, we wish to indicate their utility and conceptual coherence. Category-based entities are, in fact, non-rigid or “variable” entities, that is, inherently relational or dynamic, rather than simple static extensions made up of invariant individuals—such as structures. It is no coincidence that Heller (2016) proposes a non-objectual or non-substantial formal ontology for these entities.

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identity imposed by the CTI. For an analysis of the notion of identity upheld by Quine, see (Béziau, 2003). It is also worth to note that the CTI is *non-categorical*, in the precise meaning that it does not specify a unique model (up to isomorphism) for the identity concept. For a discussion of this result see (Arenhart, et al. 2019; Béziau, 2003). For a discussion of non-categoricity and its impact on the intended model, see (Klenk, 1976).

[26] Among these, particular absents specified by the monistic theory of *tropes* must also be included. For a discussion on the identity relation characteristic of tropes, see Ferrari (2024a).

[27] In this sense, category-based identity is not necessarily provided by isomorphisms.

To summarize before moving on, we might say that process metaphysics, in its attempt to describe the dynamic reality of objects, has found a significant ally in ampliative logics and category-based formal models that may help to describe the complex nature of contextual identities. Such formal tools allow for the representation of entities and models not as monolithic and unchanging entities but as transformative ones, with their identity being determined by the context in which they exist and the interactions they maintain with other processes.

5. Realism, (logical) empiricism, and nominalism

The epistemological stance of process philosophy is quite distinctive, as it can be situated between realism and empiricism. This is because the processual model is both monistic and non-particularist and, therefore, even non-nominalistic.[28] Let's begin by rejecting the realist hypothesis of an absolute and independent reality.[29]

Processualists reject epistemic realism because they also reject metaphysical realism. Metaphysical realism, akin to the neo-Aristotelian dualism of substance and property, posits the existence of entities that are both fundamental and independent of the mind—and of all its faculties, including languages—such as universals (aka, properties) to provide an *objective* foundation for the laws of nature formulated by various special sciences. According to realism, universals are indispensable for *objectively* differentiating and characterizing natural entities (substances) and their causal powers. Thus, real universals serve as the ontological ground for the empirical laws provided by sciences. Without the hypothesis of real universals, reality could not be independent of human observation and conceptualization.

In contrast, Processualists reject the idea of presupposing the existence of primitive natural properties, empirically specified by the laws of nature, to ascribe distinctive causal powers to kinds of natural substances. They argue that the necessity of such a presupposition arises simply from the ontological isolation of substances, whether they are concrete or material particulars, which otherwise would lack the resources to interact causally in a specific and necessary manner, precisely because they are ontologically closed units.[30] Properties and substances, being irreducible, must belong to two different ontological categories that are also mutually indispensable for a proper characterization of the model. Because of this, metaphysical realism struggles with the challenge of finding a coherent way to enable their interaction without rendering the model dualistic and, thus, fragmenting nature.[31]

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[28] For an introduction to Realism and Nominalism, see (Loux & Crisp, 2017).

[29] Both the epistemic position known as empiricism and the ontological nominalist hypothesis that underlies it arise and develop in opposition to the dualistic and thus anti-naturalist tendencies of ontological and metaphysical realism, with which nominalists nonetheless share the particularist or substantialist character of existence and identity. I have taken advantage of this reasoning to start the discussion from the critique of the realist hypothesis.

[30] For a critical discussion of metaphysical realism, particularly in its neo-Aristotelian form, see (Winters, 2017).

[31] Unfortunately, a coherent way to make real properties and substances interact has not yet been identified. To enable the interaction between universals and substances, it is necessary to introduce a third component in the model, such as a relation that is equally irreducible and equally ontological (as opposed to logical). To address this issue, tropes were introduced into the ontological space, which, being both particulars and properties, were supposed to resolve the problem of ontological and metaphysical dualism. Unfortunately, this hypothesis is also not immune to problems that some consider insurmountable (Ferrari, 2024a; Seibt, 2002, 2010).

Processualists, in their view, rather than attempting to find a highly implausible solution to this heavy problem, have focused on avoiding it altogether from the outset. From their perspective, constructing monistic models is not an issue, as organizations, rather than properties, serve as the privileged site of causation (Bickhard, 2009). Since organizations also play a role in constituting the existence of the ontological units within the processual model, the processual perspective does not need to attribute a fundamental and primitive role to properties. Instead, the properties of a system *emerge interactively*, that is, they emerge within the organization of the system in interaction with its environment—for example, with other entities. Processualists' evidence for this lies in the fact that, without interactions, there would be no possibility of even observing causal powers.

However, processualists also reject non-realist views of universals, such as those accommodated by (neo-)empiricism, surely of nominalistic inspiration. Empiricists indeed reject the realist concept of cause—and with it the notion of universals, both tied to the idea of ontological necessity—in favor of one specified by mere statistical correlations that are empirically supported and aligned with the scientific method. According to this epistemic approach, the natural laws established by the special sciences are nothing more than expressions of such correlations, whose necessity, rather than being grounded in the real nature of universal properties, depends on their logical-mathematical formal structure, which is therefore *a priori*. In this case, the foundation of the laws is merely epistemic, and the nature of universals is merely linguistic.[32]

Processualists, on the other hand, do not believe that the differences and similarities in the world, along with its asymmetries, have a purely linguistic nature and an exclusively epistemic (logical) foundation. They are fervent critics of logical empiricism and its tendency to associate empirical laws specifying sets of natural phenomena with equally arbitrary theoretical (non-logical) terms. Indeed, a committed processualist firmly rejects the idea that the organization of reality reflects the subject-predicate grammatical schema characteristic of predicative languages, precisely because they have reason to reject the neo-empiricist notion of grounding the necessity of the structure of reality in the formal and syntactic structure of mathematical logic—and, more in general, of predicate logic and its extensions, like modal logics. In other words, they reject the idea that the structure of reality corresponds to the “deep” logical structure of the formally regimented language (mostly mathematical) used to express the laws of nature. Therefore, Processualists have no reason to think like Nominalists since they do not believe that the emergence of asymmetries in nature, as well as the analysis of the properties of entities, is fundamentally a stipulative and arbitrary matter.

Processualists' ability to reject both the realist and the empiricist-nominalist stances stems from the recognition that the issues inherent in both these perspectives have a common source: the unjustified assumption that natural entities can only be particular substances as if this were an a priori, inalienable, and unavoidable fact of our modeling the world.

6. Ontological pluralism, reductive monism, and scientific metaphysics

An additional theme characterizing the adoption of the processual perspective is its tendency to promote a nuanced and equally integrated understanding of nature,

[32] This is what characterizes any nominalist ontology.

encouraging the overcoming of the limitations that inhere reductionist scientific metaphysics,[33] while respecting its complexity without sacrificing its intrinsic unity.

From a genuinely theoretical standpoint, the central issue for the processualist project is whether it is possible to counter the commonly reductionist attitude typical of traditional monistic models without simultaneously fragmenting nature into a plurality of domains that are not only mutually autonomous and irreducible but, also, ontologically self-sufficient. Processual thought claims to offer an “in-principle” solution to this significant dilemma.

Pluralism and ontological monism are traditionally viewed as incompatible. Pluralism holds that reality is composed of many different kinds of entities, all of which are both autonomous and ontologically primitive, though all necessary to represent the world. Monism, in contrast, asserts that among the many domains specified by the special sciences—from physics to psychology and sociology, as well as chemistry and biology—there is *only one* fundamental domain to which everything else can be somehow reduced.

Now, ontological reduction surely represents the strongest form of *ontological dependence*, but it is not the only one. Weaker forms of dependence can also be conceived, perhaps, without necessarily sacrificing the monistic nature of the model. At least, this is what processual thinkers claim since they believe in having the resources to provide the right parameters to balance the ontological dependence of a plurality of ontic domains with monism. The Pluralist, instead, in order to avoid the fragmentation nature, can at best hierarchize the plurality of ontological models by assuming a relation of ontological dependence among the various domains and, then, “vertically” arranging them into ordered levels. However, the cost of such a non-reductionist approach, typical of non-reductive physicalism is that the hierarchy must still be rendered "well-founded" by presenting a single fundamental domain upon which everything else ontologically depends.

In this sense, “well-founded” ontological pluralism and traditional monism share a common trait: the need to establish a single fundamental domain. However, they diverge about how they characterize the form of ontological dependence that defines their respective views.

Understanding how to characterize this “univocal” dependence—which runs from the “top” or macroscopic to the “bottom” or microscopic, down to the fundamental (quantum) level—has proven problematic for pluralism. The root of this problem lies once again in the substantialist hypothesis. According to this view, the entities belonging to each specific domain are both primitive and dependent. Since they are ontologically primitive, they are

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[33] Unlike *methodological* reductionism, which is aimed at discovering genuinely novel and additional phenomena characterized by irreducible natural properties and interactions, *ontological* reductionism is based on the idea that complex phenomena and their dynamics—colloquially referred to as “high-level” phenomena—can be fully explained and modeled making exclusive reference to their constituent parts and the dynamics of those parts. If this were the case, clearly, such high-level phenomena would not be ontologically autonomous. A paradigmatic application of this approach is addressed to the *mind-body problem*, to which a solution that exclude the mind from the ontological and metaphysical domain is provided. A crucial component for the success of this position is the search for a general demonstration of the *functional* reduction of high-level properties to low-level properties (Kim, 2005, 2006). Otherwise, it involves proving that the notion of metaphysical emergence is inconsistent (Kim, 2005, 2006). Unfortunately, the first option has never been produced, and moreover, some criticize the very plausibility of the reductionist thesis (Lombardi and Pérez Ransanz, 2011) as I will brievly expose later. The second option, instead, is highly debated and criticized (Corry, 2013; Ferrari & Bickhard, 2023). An example of reductionist ontology is Kim's (2005) "ontological physicalism," whose formal and ontological limitations are extensively discussed in Ferrari (2024b).

irreducible, making it unclear how they can constitutively depend on entities from other (lower) levels. Rather, they should all be considered ontologically fundamental entities. As substances, their ontological constitution—identity and existence—is, by hypothesis, independent from everything else.

In this way, ontological pluralism becomes an extension of ontological dualism, as it systematically fails to address how to facilitate interactions between various domains since the existence of the entities that inhabit them is self-sufficient. Indeed, such interaction cannot be merely epistemic, nor *a fortiori* it can be purely logical:[34] it must be genuinely ontological. However, if the dependency is ontological *stricto sensu*, then the very existence of the entities inhabiting each level must depend on that of the entities of lower levels— and, in the case of the fundamental level, on itself. It becomes unclear, then, how each domain could be inhabited by ontologically primitive entities, being these substances.[35]

At this point, the reductive hypothesis presents itself as a workable solution to the fragmentation of nature. Buying that, the Ontological Monist aims to safeguard naturalism, that is, the idea that nature is not ontologically fragmented. However, by adhering to the substance-based hypothesis, the Ontological Monist can only eliminate the problem of how to coherently characterize the various forms of ontological dependency. To achieve this, it proposes the strongest form of such dependency: ontological reduction—via functional reduction. Yet, through the reduction conjecture, the Monist gives up the opportunity to account for the multi-colored characterization of nature, denying any ontological status to its many-sided complexity.

There is, however, no evidence for even the possibility of such a reduction, not even a functional one. In fact, the very possibility of arguing in favor of ontological reductionism by providing a general method for reducing higher-level properties to lower-level ones seems formally impossible—a clue is provided by (Ferrari, 2024b). Furthermore, the attempts to locate evidence for the reductionist hypothesis in *inter-theoretical laws* seem entirely *unmotivated* (Lombardi & Pérez Ransanz, 2011). Inter-theoretical are those empirical laws connecting two distinct domains from autonomous special sciences. It is precisely here that the processualist stance emerges as a plausible solution for a coherent integration of ontological pluralism and monism.

To better understand why the only viable solution to the problem of ontological monism in the metaphysics of science lies in the processualist hypothesis, It is worth taking a moment to further reflect on the reasons behind the unfounded nature of the reductionist hypothesis. In this regard, before leaving the reader to the various contributions in this volume, let us review the reasoning put forth by Lombardi and Pérez Ransanz (2011).

Let's imagine two autonomous theories, T1 and T2, each specifying two different models or domains, characterized by distinct empirical laws and deductively irreducible. T1 and T2 specify entities whose respective causal powers are in turn irreducible. After all, the properties bestowing such powers are defined by the theories' respective laws. Now, let's suppose we discover an empirical law that acts as a *bridge* between the variables or

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[34] Typically, such dependence is characterized in terms of a modal logical relationship: "b depends on a if and only if it is impossible for b to exist without a also existing." However, this approach, which clearly has empirical origins, encounters the issue that this notion of dependence is so austere that it coincides with a simple correlation, which certainly cannot resolve any genuinely ontological problems. The issue is not to determine the modality of the relationship between two existing entities. Rather, it is to characterize how the existence of one is possible as existence stemming from the other.

[35] Remember that substances are, by definition, ontologically independent and fundamental entities.

quantities defined by the laws of T1 and T2. It is also important to note that this *bridge law*, being empirical, does not imply any *deductive* reducibility of T1 to T2—or *vice versa*.

A paradigmatic example of a bridge or inter-theoretical law is the functional relation $T = (2/3k)\bar{E}_k = f(\bar{E}_k)$—where k is Bolzmann's constant—between the average kinetic energy per molecule ($\bar{E}$) in a system of molecules, specified in statistical mechanics (T1), and the temperature (T) of the system, conceived as a gas, from thermodynamics (T2). Clearly, as Lombardi and Pérez Ransanz emphasize, the law is a functional relation (R_f) of the form $y = R_f (x_1,\ldots x_n)$, where $x_i \in$ T1 and $y \in$ T2. It is important to note that T2 is a macroscopic theory, as the variable $y = T$ is a *global* variable that characterizes a multitude of molecules as a whole, whereas T1 is microscopic, as the quantities x_i pertain to the *components* of the system, specifically characterizing each of the gas molecules. R_f, instead, is a mathematical function or operation.

In this scenario, the reductionist hypothesis takes advantage of the presence of the identity sign "=" in the expression that characterizes the functional relation, interpreting it as if the entities characterized by the functional relation were the same. However, Lombardi and Pérez Ransanz lucidly argue that this cannot be the case for two main reasons.

A. The symbol "=" that occurs in the functional expressions commonly used in physics *does not express logical identity*.

Specifically, the symbol "=" does not indicate that the thermodynamic term "T" and the statistical mechanics term "$(2/3k)\bar{E}_k$" refer to the same entity, just as it does not indicate that Newton's second law $F = ma$ identifies force F with mass m and acceleration a.[36]

B. The functional relation R_f specifies nothing more than *algebraic operations between numerical values* whose units of measurement differ.

Indeed, it makes no sense to apply algebraic operations to entities or concepts, especially when they are not quantitative. In other words, "despite the numerical coincidence, the concepts are genuinely different and, consequently, refer to ontologically irreducible elements" (p. 45, *my translation*). The binary predicate "=" in mathematics merely "indicates a numerical coincidence between numerical values" (p. 46). Therefore, Lombardi and Pérez Ransanz conclude that "[e]ach theory refers to its own ontology, and the coincidence of numerical values does not cancel this fact" (p. 46).

To further illustrate the falsification of the motivations supporting reductionist monism, one could continue Lombardi and Pérez Ransanz's reasoning by exploring, *by reductio*, whether reductionism might have a chance of success if mathematical identity were interpreted as logical identity. Unfortunately for the reductionist, we can already conclude that even if the predicate "=" in inter-theoretical physical laws were indeed a logical identity, no ontological reduction would still be possible. Let's see why.

As mentioned in a previous footnote (fn. 25), the CTI is non-categorical and, therefore, does not define, nor can it define, a single model (up to isomorphism) for the theory that employs it, whatever that may be. Thus, even if the identity were logical, we cannot infer the existence of a single ontological domain from it.[37] Strictly speaking, if there are many

[36] Newton's second law is an example of an intra-theoretical law, as it connects terms belonging to a single theory.

[37] This model-theoretic result is linked to the *Löwenheim-Skolem Theorem* concerning first-order theories with denumerably infinite languages and models. For a discussion of this result and of its

non-isomorphic ontological domains, how can we choose the “intended” or “standard” one to reduce everything to? Suppose T1 is the fundamental theory. The existence of non-standard and irreducible models of T1, for example, would support the pluralist hypothesis rather than the monistic one, as these could coincide with as many domains defined by other special sciences, such as T2, for which a bridging law with T1 has been formulated.

Furthermore, we should note that the relations of ontological dependence and reduction are clearly *asymmetric* — even if in opposite directions. Yet, if logical identity is symmetric, how can we infer, based on the existence of a bridge law, which between T1 and T2 is the (more) “fundamental” theory? Perhaps solely based on our pre-theoretical “intuitions” regarding the ontological asymmetry of the micro-macro pair? Clearly, if this were the case, such intuitions could only serve as *ad hoc* reasons, that is, assumptions that are certainly unprovable with the resources of either of the T1 and T2 and, even more so, with that of the “fundamental” one.[38] From an ontological perspective, the assumption of reductionism is both empirically and theoretically ungrounded and, therefore, represents an unjustified ontological *presupposition*.

On the contrary, the processual interpretation of bridge laws becomes certainly more tenable—not only in light of the failure of reductionism but also regarding the ontological fragmentation brought about by the pluralist stance, re-bolstered by the former’s shortcomings.[39] Indeed, processual models should have no difficulty in framing inter-theoretical functional relations as expressions of the emergence and mutual interdependence of the ontological and metaphysical—that is, causal—domains specified by the various sciences. This all, without implying any ontological self-sufficiency for the many domains, and while respecting their respective autonomy stemming from their deductive and formal irreducibility.

In this approach, empirically discovered and (mostly) mathematically formulated bridge laws between theories could specify as many fields of possible interactions among different domains. After all, each domain may be seen as a complex organization and thus an interactively open system. In this manner, ontological monism would emerge as inherently plural due to the interactive integration and causal contribution of other different fields—without imposing, among other things, any upper or lower limits, meaning that the processual view does not necessitate the existence of any (more) fundamental domain or, for that matter, the most complex one.

According to the processual view, the natural sciences, social sciences, and humanities all contribute to a comprehensive understanding of reality.

7. Concluding remark

Process-based metaphysics paves the way for a unified conception of reality, both plural and complex. It acknowledges that the various scientific disciplines offer different descriptions of as many aspects of reality which can be viewed as complementary and

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consequence, among which the mismatch between the intended model of a first-order theory and the model this specifyes, see (Klenk, 1976; van Dalen, 2004).

[38] Even if there were any chance for ontological reductionism, it would have to involve assuming an asymmetric and univocal ontological dependence of the non-fundamental theory on the fundamental one. However, when observing inter-theoretical laws among theories, we do not have this information at all, as the functional relations are symmetric, as previously mentioned.

[39] Not incidentally, at the same time, even the hypothesis of a well-founded ontological pluralism loses its coherence. If it is impossible to identify a single domain (up to isomorphism) from the appeal to logical identity, then it will likewise be impossible to determine which of the many domains is the fundamental one.

mutually integrative perspectives of a single, open, evolutionary, and dynamic reality. In this way, processual metaphysics provides a theoretical foundation for a consistent pluralistic monism, recognizing the complexity of reality without suffering from ontological fragmentation, and ontological dependence while avoiding ontological reductionism.

The processual view suggests multiple ways of being in interaction as part of an increasingly broader and dynamically interconnected network. Unification does not imply the disappearance of plurality but rather an understanding of how the various dimensions of reality are interrelated and coexisting.

The processual model is both dynamic and category-based. On the one hand, the model is inherently constructive, namely built step by step, modifying every step the very network just constructed at the previous one. On the other, it does not aspire to represent the being of reality but, rather, to build bridges to unify what the being of substances divides.

Nature and society are one, forming a dynamic and complex whole from which we cannot isolate ourselves. This approach not only enriches our understanding of reality but also encourages an ethical and responsible view of our interactions with the world: that is eco-processualism.

In conclusion, processual models are crucial for monistic and naturalistic ontology and scientifically oriented metaphysics. By offering a dynamic synthesis of monism and pluralism, recognizing the autonomy of scientific disciplines without risking the fragmentation of nature, and simultaneously overcoming reductionism, these models provide a coherent and rich framework for addressing the complexities of reality as a whole.

Thus, processual metaphysics invites deep reflection on how we perceive objects and their relations, emphasizing that reality is as interconnected as it is complex. Embracing this vision can only open new avenues for philosophical and scientific inquiry, and we hope that our Special Issue can contribute to this project.

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