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Beyond the adjacent possible: On the irreducibility of human creativity to biology and physics

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Abstract

In this article, the problem of understanding multiple layers of complexity in our universe is addressed, with particular emphasis on explaining creative evolutions in the material, biological, and psycho-social layers. Perspectives from physics, biology, psychology, and philosophy are utilized in the discussion. Process philosophy is used to justify the theoretical foundation of the dynamic universal creativity process. The concepts of unified and final theories are discussed from a position that criticizes reductionism. The concept of the adjacent possible is reviewed as introduced by Kauffman to exclude the possibility that a theory from physics could be extended to explain the biological layer. In a similar way, the adjacent possible is shown to be useful but insufficient to explain the psycho-social layer of complexity, missing fundamental human abilities such as thinking of long-term futures, wisdom, and dynamic creativity leaps that use the impossible as an inspiration.

Keywords

Adjacent possible, complexity, consilience, cosmology, creativity, dynamic universal creativity process, final theory, process philosophy, unified theory

An expanding universe: Interpretations from physics and philosophy

The human species has access to a negligibly small portion of the universe, the visible part; hence, we know very little of the associated possibilities that existed, exist today and could develop in the future of our expanding cosmos (Frieman et al., 2008). This is not only due to our limited (albeit constantly improving) observation capabilities (Perlmutter, 2003), but more fundamentally to the fact that according to extant models of universe composition only 4% is made of visible matter, the rest being 20% of dark matter and 76% of dark energy (Frieman et al., 2008). Nonetheless, the human species is able to elaborate explanatory theories corroborated by experimental observations, that allow us for example to build models of the cosmic evolution after the Big-Bang that are coherent with measurements we can make today (Chaisson, 2009), although the field of theoretical physics cannot find a universally agreed interpretation: several alternative theories will remain possible (Peebles & Nusser, 2010), due to the intrinsic limitations in the extent of our observations.

It is evident that the fundamental problem of understanding our universe has also been the subject of extensive philosophical debate (Ellis, 2014). In fact, in order to answer ultimate

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questions about the existence and uniqueness of our universe, theories and measurements from physics cannot suffice, for they are not able to explain (at least not in a complete way) mind, thought, purpose, ethics, esthetics, and creativity. Given that we have first-hand anthropic experience of these phenomena, as a minimum on Earth, they are *possible* in the universe, and no complete cosmological explanation can avoid discussing them. Therefore, there is an unavoidable role for philosophy, as well as for psychology and sociology, in this discussion (Ellis, 2014).

In particular, I want to mention here the philosophical approach to cosmology identified as *process philosophy*, introduced by Whitehead (1929), especially for its simplicity and elegance of explanation. In fact, in process philosophy there are only three ultimate notions (Whitehead, 1929, pp. 21–22): many, one, creativity. The term "many" conveys the notion of "disjunctive diversity," representing the multitude of entities in the universe at any time instant, including all visible/dark particles and quanta of energy. The term "one" represents the universe in its effective entirety, as an integrated whole, which could also be extended to the notion of collection of universes under the multiverse hypothesis (Carr & Ellis, 2008). The term "creativity" is, in process philosophy, the universal of universals by which the many, which are the universe disjunctively, become the one actual occasion, which is the universe conjunctively. The universe is constantly changing and evolving, expanding and generating original galaxies, stars, and planets with possibility for life, and all of this can be read as the fascinating and awe-inspiring result of an ultimate form of cosmologic creativity.

Creativity at different layers of complexity: The DUCP

The fundamental consequence of accepting the above premises of process philosophy is therefore that creativity exists at all layers of complexity that can be identified in the universe, and in particular on our planet (Henriques, 2003). In (Corazza, 2019), it is shown how creativity at four layers of complexity can be addressed: fundamentally unpredictable trajectories of matter evolution at the *material layer* (Prigogine, 1967, 1996), species evolution at the *biological layer* (Darwin, 2004), dynamic human creativity at the *psycho-social layer* (Corazza, 2016; Kaufman & Sternberg, 2010), and computing-based innovation at the *artificial layer* (Colton et al., 2009).

The theories describing the exponential growth of complexity in our cosmos (Chaisson, 2009), and in particular of the development of life on earth (Judson, 2017), show how expansion of our reality at all layers of complexity is based on mutually concatenated events: all creativity episodes are interconnected, either directly or through (possibly immensely long) chains of associations, that can occur within a single layer of complexity or interlace multiple layers (e.g. an episode at the material layer can spur an episode at the biological layer, as in the example given below). On these grounds, in 2019 the concept of the *Dynamic Universal Creativity Process* (DUCP) was introduced (Corazza, 2019; Corazza & Lubart, 2020) as the "*active ensemble of all creativity episodes in the course of cosmic evolution.*" The dynamic nature of the DUCP descends as a consequence of the adoption of the dynamic definition of creativity (Corazza, 2016), foreseeing the requirement for potential originality and effectiveness. The concept of potential in creativity can be shown to be related to individual, social, and material perspectives (Corazza & Glăveanu, 2020). The four layers of complexity in the DUCP are reported in Table 1. The distinction between wide-sense vs. strict-sense creativity depends on the absence vs. presence of consciousness in the involved actors.

An example of cross-layer concatenation in the DUCP is in order here. About 10 million years ago an unpredictable novelty emerged at the material layer on Earth: the Western and Eastern tectonic plates underneath Africa were displaced in opposite directions, producing a

Table 1. DUCP forms in the four layers of existence.

Layer of complexity	DUCP form	Creativity form
Material	Material Dynamic Creativity Process	Wide-sense
Biological	Biological Dynamic Creativity Process	Wide-sense
Psycho-Social	Psycho-Social Dynamic Creativity Process	Strict-sense
Artificial	Artificial Dynamic Creativity Process	Wide-sense

dramatic reconfiguration of the orography: the Great Rift Valley was generated, with its 6,000 km of linear extension from North to South. The mountain chains surrounding the Rift Valley became effective obstacles to Atlantic atmospheric perturbations, progressively drying out the Eastern territories of the African continent. This episode at the material layer was soon concatenated to a drastic novelty at the biological layer: the rainforest was largely reduced in vast areas, which in turn opened the possibility for a new ecosystem: the savanna. Concatenated episodes at the psycho-social layer now enter this historical account. Before these events, hominids lived of fruits and roots in the forest; but new sources of food became necessary as forests disappeared, and the possibility for hunting other animals started to be considered. Human weakness with respect to other animals became crudely apparent. It was in these conditions that a great novelty at the psycho-social layer emerged: bipedalism, and the consequent freeing of our hands. This was a crucial step in our evolution, as underlined by Gallagher (2015), as well as by Vaughan (2003, p. 99): "*If humans had not attained the upright posture […], the human brain would likely be much smaller, our sensory and motor systems would be different (more attuned to the olfactory than to vision), and none of it would function in the specific way it functions now. Indeed, we would likely have to redefine what we mean by rationality*." And, I can add, we would have to redefine creativity at the psycho-social layer.

The concatenated consequences of this early human evolution were clearly extraordinary and manifold, and include the advent of *Homo Sapiens* (Stringer, 2016), the exponential growth of our culture (Enquist et al., 2008; Lehman, 1947), and the modern generation of the fourth layer of complexity in the DUCP, that is the domain of artificial intelligence. Our minds are now significantly extended by new technologies (Menary, 2010), and our societies are undergoing radical transformations at a very high pace (Brynjolfsson & McAfee, 2014).

The quest for unified and final theories: the adjacent possible

How can we deal with the vast complexity of the universe and of the associated DUCP? A classic approach is to segment our understanding into disciplines, and then into smaller and smaller sub-fields, allowing the reach for very high spikes of expertise over very narrow domains. Whereas the pursuit of this approach has clear advantages, it also brings as a consequence a progressively finer fragmentation of knowledge into small parts with weak interconnections, which was already identified as a major problem for the progress of science by Henri Poincaré, at the start of the XX century (Corazza & Lubart, 2019).

In the opposite direction, attempts exist to search for unified theories that strive for general understanding. To be more precise, a distinction should be made between unified vs. final theories. Unified theories aim at reconciling disparate (and sometimes opposite) theoretical positions into a single and coherent framework, no matter how complex the result might be. Viceversa, final theories are more ambitious as they aim at finding ultimate principles which are sufficient to explain all reality through their (certainly complex) consequences. On the one hand, there is no need to claim that a unified theory be final: as soon as a new theoretical explanation arises and is accepted as valid, a unified theory should be modified to incorporate it. A unified theory can evolve as culture

grows, as long as it is able to maintain internal coherence. On the other hand, a final theory is also necessarily unified: otherwise, it would not be possible to claim that its principles are actually ultimate. Therefore, if a new domain of knowledge arises, either the final theory is able to provide inclusive explanations, or it its claim of being final is falsified, and it should be abandoned.

A theoretical framework could claim to address a single layer of complexity, for example the material layer or the biological layer, or multiple layers. Crossing layers requires to address the problem of reduction. For example, the biological layer is based on the material layer, but can it be *reduced* to it? In other words, can a theory derived from physics be sufficient to fully explain the biological layer? The answer bears fundamental consequences, and it is often determined by the point of view the theorist starts from.

Note that the DUCP should be considered a unified theory for the creativity phenomenon, encompassing four layers of complexity, but always recognizing that a higher layer cannot be reduced to a lower layer. Therefore, in the DUCP it is implied that creativity for humans cannot be fully explained only resorting to, say, an explanation derived from evolutionary biology (Corazza, 2019).

Viceversa, it is not infrequent to see physicists show preference for a reductionist approach, based on the desire that a complete theory in physics could also extend its reach to explain the biological layer; on the other hand, biologists typically claim that this is impossible, because "life" introduces a fundamental and irreducible discontinuity between the material and the biological layers. Note that the idea that a theory in physics could be final and explain all of reality is identified as a *materialist* approach.

As observed by Kauffman (2014), Newton and Laplace had created the basis for modern reductive materialism, based on the laws and equations of classical physics: given initial and boundary conditions, solving a system of differential equations would predict the trajectories of all the involved bodies without uncertainty. In a celebration of determinism by Laplace, the idea was that "*were we to know the positions and momenta of all the particles in the universe, a vast calculating engine, Laplace's demon, could use Newton's laws to calculate the entire entailed becoming of the universe forward and backward in time*" (Kauffman, 2014, p. 4). As we know, classic determinism was broken into pieces by Einstein's theory of relativity at macroscopic level, and by the introduction of quantum mechanics at microscopic level.

Still, the dream of a final theory is not dead, as Weinberg's (1992) testifies, in which the author explains how humanity would be coming close to finding the essential laws of physics governing the universe, while harshly criticizing philosophic approaches at the same time. Even more ambitious was the attempt by Wilson (1998) to find a theory of consilience based on the laws of physics, that would be both final and unitary across all fields of knowledge. This approach was criticized by many, including Henriques (2003, p. 158): "*Although genes are coordinated populations of molecules, individual molecules are not "small" genes. Genes are irreducible points of complexity*." Two essential problems appear to prevent unification: the irreducibility of disciplines from higher layers into lower layers of complexity, and the impossibility to predict exactly the domains of future evolution of existence.

Both questions form the basis for the arguments that Stuart Kauffman used to introduce the concept of the *adjacent possible* in the domain of evolutionary biology (Bjorneborn, 2020; Kauffman, 2000, 2014). In Kauffman's view, physics is the realm of "happenings," whereas biology is the realm of "functions." And functions are not reduceable to happenings. As an example, the function of the heart is to pump blood, but it also produces side-effects such as its beating sound. In terms of Darwinian evolution, the selective advantage was the function of pumping blood, and not the sound: this distinction of importance is

obvious in biology, but unattainable in physics (Kauffman, 2014). Second, and equally fundamental, in the evolution of living organisms new functions can and do arise, but we cannot "prestate" (predict) the possibilities for these new functions, the potential number of which is indefinite. In Kauffman's (2014, p. 8): "*New in the universe "Actuals" are new boundary conditions that are enabling constraints that literally create new adjacent possible phase spaces or opportunities […] Then, some new Actual arises in the unprestatable adjacent possible and evolution continues to become, in a radically emergent way*." The concept of the adjacent possible is a powerful explanatory framework at the biological level of complexity, clearly arguing against any attempt to reduce it to the material layer.

The adjacent possible: Sufficient at the psycho-social layer?

However useful the concept of the adjacent possible is at the biological layer, it can be argued that its extension above and beyond that realm suffers from the same critical problem that was used against the upward stretch of theories from physics into biology: it is an instance of reductionism. This is indeed what appears to be happening when the concept of the adjacent possible is applied "as is" to fields of human endeavor, such as design, economy, and culture in general (Björneborn, 2020; Cazzolla Gatti et al., 2020; Gravino et al., 2016). The question is not whether the adjacent possible is still a useful concept when we discuss about creativity and innovation at the psycho-social layer of complexity. It certainly is interesting, and it can be of use. But the question is whether it is *sufficient* as an explanatory model, or if it misses any fundamental element that renders the layer of human culture, and specifically the disciplines of psychology and sociology, irreducible to biology (Henriques, 2003) and, even more so, to physics (Ellis, 2014).

Let's start with two definitions for the adjacent possible, as reported in (Björneborn, 2020). (D1) The adjacent possible is "the set of possibilities available to individuals, communities, institutions, organisms, productive processes, etc., at a given point in time during their evolution" (Loreto, 2015, p. 9). (D2) The adjacent possible is "the set of things – could be molecules, organisms, technological products, ideas, etc. – that are one step away from what actually exists and that could be reached by the incremental recombination of the existing elements" (Gravino et al., 2019, p. 2). Clearly, both definitions refer to the "possible," but not to "the entire possible" at the psycho-social layer. In fact, D1 emphasizes "possibilities available at any given point in time": what remains excluded are therefore possibilities that might materialize in the future, but that are not available at that specific point in time. They could only be imagined, and there is no guarantee that they will indeed materialize. On the other hand, D2 clearly confines the adjacent possible to the realm of incremental innovation, "one step away from what actually exists." What appears to be excluded from D2 is disruptive innovation, that is the form of innovation that requires discontinuity, leading to totally unexpected events that have the potential to shift paradigms.

Both future-thinking and disruptive innovation are fundamental elements to understand how humans create. In other words, at the psycho-social layer there exist both "adjacent" and "non-adjacent possibles," the latter including future possibilities and disruptive innovations. Plus, we can add, the adjacent possible for humans includes both a "wise adjacent possible" and an "unwise adjacent possible." This wisdom-based distinction is meaningless at the biological layer. Finally, neither D1 nor D2 include the "impossible," which however is a very important conceptual tool at the psych-social layer. Let's enter into more details, considering in particular three elements: sustainable futures, wisdom and creative leaps into the impossible

As seen from definitions D1 and D2, the adjacent possible essentially represents all innovations that can be directly achieved via

transformation of the extant state-of-the-art (Björneborn, 2020). In nature, these innovations pertain to new characteristics in living organisms, possibly selected by the environment if they lead to enhanced fitness (Darwin, 2004). In biology, there is no reason to consider any specific possibility for evolution as "good" or "bad." Anything that is possible in nature has an intrinsic positive value, in the sense that it strives to contribute to the perpetuation of living ecosystems which might be in equilibrium, or even far from it (Sprugel, 1991). If an innovation fails, it will soon disappear from the environment.

However, considering humans and the corresponding psycho-social layer of complexity, it must be recognized that the scenario is fundamentally different. Our conscious mind enters critically and irreducibly in the decision making process, and its role cannot be understood by resorting solely to the adjacent possible. Limiting our understanding to this biological metaphor could actually lead to severe problems for humanity, as discussed in the following.

First, consider that from the very beginning of the industrial revolution in the XVIII century, humanity has been evolving technology in all its possible directions, without any real concern for possible side effects. Whereas the enormous progress we brought about in almost 300 years provided many benefits to our societies, today we also witness the damage we have inferred onto the Earth environment, with changes to climate as its most dangerous signature. We are rapidly running toward an end point, although the very mild political decisions that continue to be taken at world environmental summits do not seem to reflect this urgency. We simply cannot keep innovating in an incremental way, trying all solutions only because they belong to an adjacent possible. Tools from future studies and anticipation (Poli, 2019) must be used in order to project our thinking ahead of several tens of years, much beyond the adjacent possible, in order to make decisions today that have the highest chance to change our path and save our planet. In other words, we cannot only explore the adjacent possible, but rather we should design sustainable futures with a long-term perspective. There is no equivalent to this discussion in the biological layer of complexity, as we represent apparently the only living entities that have the ability to imagine and work with long-term futures.

Second, sustainability is not the only concern when it comes to a free exploration of the adjacent possible. Ethical dimensions also must come in when we try to imagine whether a specific creative idea would bring benefits or possibly be harmful to societies. There exist a dark side of creativity (Cropley et al., 2010), and in order to avoid that it prevails onto the bright side, elements of wisdom must enter into the picture. Distancing from one's point of view, humility, integration of different viewpoints, concern for ultimate questions, ethics: all of these elements compose the very complex picture of the wisdom construct (Corazza & Lubart, in print; Glück, 2020). When wisdom is used in deciding the next steps, the adjacent possible is useful but insufficient to project ourselves into any adjacent future. A possible idea that is potentially harmful to humanity, in other words an unwise idea, should be avoided, regulated out, or lead to severe punishment. Again, all these arguments cannot be reduced to the biological layer: there is no need for a living organism to be "wise," as all of its possible mutations are equally ethical (although they will not be equally fit to the environment).

The third consideration is even more fundamental to explain why the adjacent possible is not sufficient as a model for creativity and innovation at the psycho-social layer: human creativity is able to leap beyond the adjacent possible into the impossible, possibly leading to discontinuous innovation. This wonderous ability takes on many forms: achieve the impossible, narrate the impossible, or use the impossible as an inspiration.

For example, one can realize endeavors that are deemed to be impossible based on the shared extant knowledge at a certain time

epoch, because they are out of the shared notion of adjacent possible. A prominent example comes from Guglielmo Marconi: in 1901, when he was a 27 years old inventor and entrepreneur, he decided to try to cross the Atlantic Ocean from Poldhu to St. John's Newfoundland with a radio signal, while all the scientists had proven this to be mathematically impossible. Surprising the world, and against all odds, he succeeded: only later, the ionosphere was discovered to justify this outstanding achievement from the point of view of electromagnetism.

Further, one can imagine impossible worlds, that are clearly out of the adjacent possible, and use these dreams to narrate fantastic stories, or to create games in virtual reality. As an example, Italo Calvino's Cosmicomics (Calvino, 1968) start with a short story based on the idea that once the Moon was so close to the Earth that it would be possible to reach it with stairs, placed on a boat making its way into the water. Calvino's story is extremely fascinating, colorful and full of details, such as for example the fact that, in these out-of-the-world conditions, gravitation would be so large that all the small living fish and debris would rise out of the water and float around. So, people on the boat had the use large banana leaves to make their way through this strange fog… (Calvino, 1968).

Finally, imagining the impossible can also be used to generate creative ideas that are possible but non-adjacent: if realized, they could lead to discontinuous innovation. In other words, the impossible can be used as a valid source of inspiration with a high potential for originality and effectiveness, in accordance with the dynamic definition of creativity (Corazza, 2016) and the Da Vinci model for the creative thinking process (Corazza & Agnoli, 2022). There is evidently no equivalent to this phenomenon in the biological layer, for which the "impossible" has no place and the adjacent possible is sufficient.

As an example, the aforementioned fantastic short story by Italo Calvino could inspire the realistic idea that city debris could be lifted up from apartments and houses instead of being brought down to the street level. Imagine for example a scenario like Manhattan in New York. Why would this be an advantage? Given the extant rat infestation problem, forcing inhabitants to reduce the time during which trash can be brought to the streets (CNN, 2022), this could be a very effective solution; but then one should also find a way to collect debris from the skyscrapers' roofs. While this is very likely to be not feasible today, at least from an economical if not technical point of view, we can imagine a future in which fleets of drones designed for public services could perform this task quite efficiently. In other words, this simple idea inspired by an impossibility does not belong to the immediately adjacent possible, but it can be useful in terms of guiding innovation steps toward a desirable future (Voros, 2007). Perhaps even more convincing of the usefulness of the impossible in the human creative process is the example of Leonardo da Vinci, who was able to imagine and describe ideas that where absolutely impossible in his epoch, and that were turned into reality up to four centuries later, such as the helicopter or the tank.

Conclusions

Multiple layers of complexity can be identified in our universe. I have discussed here in particular the material, biological, psycho-social, and artificial layers. Although strongly interrelated, these layers are separate because higher layers are not reducible to lower ones. For this reason, a final theory appears to be unattainable, while a unified theory of knowledge should be formed as an integration of explanatory theories at the different layers, exploiting synergies but at the same time holding firm to non-reducible peculiarities. The adjacent possible is fit for the biological layer and useful at the psycho-social layer, but it is not sufficient as it misses fundamental elements in human thinking processes, such as thinking of long-term sustainable futures, wisdom, or exploiting the impossible for dynamic creativity leaps. On the other hand, the dynamic

universal creativity process (DUCP) is a unified theoretical framework that addresses creativity at different layers of complexity, always preserving the non-reducible peculiarities of each layer.

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