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Research article

Philosophy of Biorobotics: Translating and Composing Bio-hybrid Forms[1]

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Abstract

In this paper, I explore how bio-hybrid forms can be created and combined when starting out from organic forms. The thesis I advance here is epistemological: the combinatorial practice of bionics, biomimetics, biorobotics, and all design strategies inspired by nature is based not on biomimetic inspiration (i.e., on a kind of imitation of nature) but on a practice of translation. To develop this thesis, I focus on the practices of contemporary biorobotics. I examine the practice of translating natural forms into technical artifacts, as developed by Raoul Heinrich Francé during the early 20th century. I then analyze the making of robots capable of replicating complex systems of locomotion. Finally, I investigate the interaction between robots and living organisms (fish). In the concluding part of the paper, I reflect on the philosophical payoff and broader conditions of possibility for this translational practice. I discuss when and to what extent a translation of biological forms into biotechnical ones is acceptable, and also highlight the conception of form that underlies this practice. I additionally seek to draw attention to the need to philosophically investigate what happens between different domains of knowledge – especially between science and technology. Thus, this article invites philosophers to develop a philosophy in the interstices of knowledge production.

Keywords: Form; Biorobotics; Organism; Philosophy of science and technology; Biomimetics; Technoscience

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Научная статья

Философия биоробототехники: Перевод и композиция биогибридных форм[2]

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Аннотация
В данной статье я исследую, как можно создавать и комбинировать биогибридные формы, начиная с органических форм. Тезис, который я здесь выдвигаю, – эпистемологический: комбинаторная практика бионики, биомиметики, биоробототехники и всех стратегий дизайна, вдохновленных природой, основана не на биомиметическом вдохновении (т.е. на подражании природе), а на практике перевода. Чтобы развить этот тезис, я сосредоточусь на практиках современной биоробототехники. Я исследую практику перевода природных форм в технические артефакты, разработанную Раулем Генрихом Франсе в начале 20 века. Затем я анализирую создание роботов, способных воспроизводить сложные системы передвижения. В итоге я исследую взаимодействие между роботами и живыми организмами (рыбами). В заключительной части статьи я рассуждаю над философским значением и более широкими возможностями для этой практики перевода. Я обсуждаю, когда и до какой степени перевод биологических форм в биотехнические приемлем, и также выделяю концепцию формы, лежащей в основе этой практики. Кроме того, я стремлюсь привлечь внимание к необходимости философского исследования происходящего между различными областями знаний – особенно между наукой и техникой. Таким образом, данная статья предлагает развитие философии в пробелах преумножения знаний.

Ключевые слова: Форма; Биоробототехника; Организм; Философия науки и техники; Биомиметика; Технонаука

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[2] Статья представляет собой сокращенную версию работы на немецком языке в *Deutsche Zeitschrift für Philosophie* (Tamborini, in press).

INTRODUCTION

In *Le vite de' piu eccellenti pittori, scultori, et architettori* (1568) [The lives of the most eminent painters, sculptors and architects] Giorgio Vasari described the life and work of the great artists, sculptors and architects. Having examined the life of Leon Battista Alberti, Botticelli, Perugino and others in the first volume, Vasari began the second by discussing the life of a painter *sui generis*: Leonardo da Vinci.[3] As is well known, unlike many other figures described by Vasari, Leonardo da Vinci used a combination of technical and artistic procedures to investigate nature and ultimately to master it by means of technology. I would like to quote just a few emblematic statements from Vasari's description which are useful for the thesis presented in this paper.

Vasari tells us that Leonardo came into possession of a kind of little wheel. Once he had polished and smoothed it, he decided to use it to paint something new, a "fabulous monster" (Vasari, 1886, p. 195). To this end, as Vasari tells it, Leonardo stepped into a particular room, "which nobody apart from him ever entered, with all kinds of lizards, crickets, snakes, locusts, moths, bats and similar repulsive creatures, and made out of this whole pile a truly hideous monster" (Vasari, 2020, p. 380). "From all these many creatures", writes Vasari, "which Leonardo had combined in different ways, he created a truly dreadful and fearsome animal whose breath poisoned the air and turned it into fire" (Vasari, 1886, p. 195).

Leonardo attempted, then, to form and present a new animal. In other words, it was Leonardo's intention to compose organic forms in a different way. Doing so, as Vasari wrote, brought "constant pain", so much so that the "sickness of the dead animals was too gruesome, but this sickness was not perceived by Leonardo, on account of the great love he felt for art" (Vasari, 1886, p. 195).

This anecdote recounted by Vasari is quite telling, as it relates to the issue of the potential composition of natural and artificial forms: Leonardo was indeed experimenting with the possibility of creating a new composition in the animal world. As is well known, Leonardo attempted not only to compose new organisms out of natural forms but also to create biotechnical forms through a combination of biologically inspired artifacts and functional principles. The 'ornithopter', for example, was Leonardo's famous design of a possible bio-inspired air machine: in terms of form and function it was a precise copy of a bird in flight (Innocenzi, 2018; Moon, 2007).

Leonardo's key lines of inquiry are basically the same ones that characterize a particular engineering practice in relation to nature, as found nowadays in the fields of bionics, biomimicry and biorobotics.[4] These scientific practices require fundamental philosophical reflection if we are to better understand the significance and limitations of – and conditions for – these activities.

How can forms be composed? How does nature itself compose? Can the composition of nature be mimicked in order to create new forms? How can a living

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[3] See e.g. (Bredekamp, 2001; Fehrenbach, 2019; Franzini, 1987; Moon, 2007).

[4] See (Cordeschi, 2002; Datteri, 2020; Datteri and Tamburrini, 2007; Tamborini, 2021, 2022a; Tamborini and Datteri, 2023).

organism be created? What conception of form underlies this practice? How do we compose natural forms using technical artifacts to obtain bio-hybrid systems?

In this essay I shall address these questions from a very specific perspective. I will not ask how nature itself combines forms to create living beings[5], neither will I address the issue of how the transfer of natural forms into technical forms is possible in terms of ontology. Instead, I will ask *how new bio-hybrid forms can be created out of organic forms and can be combined*. The thesis I am advancing, then, is an epistemological one: the combinatorial praxis of bionics, biomimetics and biorobotics – that is, of all design strategies inspired by nature[6] – is based not on a kind of biomimetic inspiration (i.e., on a kind of imitation of nature[7]) but rather on a practice of translation.

In addition, by inquiring into the conditions for a possible translation from one domain to another, I seek to draw attention programmatically to the necessity of examining philosophically what happens *between* different domains of knowledge – in particular, *between* science and technology. This article is thus an invitation to philosophers to develop *a philosophy in the interstices of knowledge*.[8]

To develop my thesis, I will focus on the practices of contemporary biorobotics. In doing so I will apply the broader methodological paradigm of the philosophy of science *in practice*.[9] In the following, therefore, I would like to offer a brief account of three case studies. The first, based on 21st century biorobotics, relates to the practices of turning natural forms into technical artifacts, practices developed in the early 20th century by Raoul Heinrich Francé. The second case study is based on the manufacture of robots capable of reproducing complex systems of locomotion through space, while the third is based on the interaction between robots and living organisms (fish). To begin, however, I offer a brief excursus about the emergence of forms in nature.

THE THEORY OF THE COMPOSITION OF NATURAL FORMS

As already mentioned, I will not concern myself with the conditions of possibility for the composition of natural forms. However, given that natural forms constitute the starting point for the practice of composing biotechnical forms – engineering scientists use the organic forms found in nature as points of departure for their technical composition capabilities – a brief excursus on the mechanisms of composition in nature is necessary.

The main mechanisms of the formation of forms were established by Charles Darwin in his 1859 book *On the Origin of Species* and were expanded upon in the course of the modern synthesis of evolutionary theory, that is, the synthesis of Darwin's theory of evolution and Mendelian genetics.[10] Put succinctly, new forms arise through a process

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[5] On this, see (Benyus, 2002; Dicks, 2016; Gutmann, 2017).
[6] See (Bensaude-Vincent, 2019; Knippers and Speck, 2012; Mazzolai et. al., 2014; Tamborini, 2021; 2022b).
[7] For this, see e.g. (Dicks; 2016; Hood, 2004; Drack et al., 2017).
[8] For this, see (Tamborini, 2022a).
[9] Cf. (Chang, 2012, 2011; Leonelli, 2016; Tamborini, 2022a).
[10] See (Corning, 2020; Huneman, 2019; Huneman and Walsh, 2017).

of random mutation of DNA and of natural selection. This explanation, heavily influenced by genetics and microevolutionary thinking, was joined in the 1960s and 1970s by a view that emphasized the macroevolutionary and interspecific structures of evolution. I would like to mention in particular the dynamics and structures of mass extinction, which can reverse microevolutionary mechanisms.[11] Additionally, a view has developed since the 1960s (brought about by a synthesis and circulation of knowledge and practices from architecture to evolutionary theory and *vice versa*) that has culminated in today's "extended evolutionary synthesis:"[12] there are certain form constraints which only particular evolutionary paths enable and others do not.[13] The contextual link between constraints and evolvability is emphasized more strongly in current evolutionary research. These constraints should no longer be understood as factors that limit the power of natural selection but rather as "enabling factors inherent in the process of development during morphological evolution." As biologist Gerhard Müller reminds us, nowadays these elements are the most important points of access for grappling with the problem of evolution: "The nature of the determinants and rules for the organization of design elements constitutes one of the greatest unsolved problems in the scientific explanation of the form displayed by organisms" (Müller & Newman, 2003, p. 5). Hence, constraints, evolvability, phenotypical plasticity and niche construction are the key mechanisms for the emergence of natural forms.

BIOROBOTICS

After this brief excursus I can now pose my main question: *How can* new forms be created, or rather, *how can* biological and technical forms be combined in order to obtain bio-hybrid forms?

As we can see, the question has a definite Kantian flavor to it[14]. Viewed in Kantian terms this possibility is given on two levels: *de facto* and *de jure*. *De facto* there are certain disciplines that are following "the secure course of a science" (Kant 1998, B VII). These disciplines are no longer "merely groping about" (Kant 1998, B VII), rather they are in a position to produce knowledge.

Indeed, in the 20th century especially, knowledge and practices were codified with regard to the potential production of biotechnical forms, and this has led to the production of functioning bio-inspired artifacts and automatons. As mentioned at the start of this essay, ideas about the possibility of biotechnology (i.e., the possible composition and creation of biotechnical forms) have always been part of the history of Western philosophy of technology (we might think here of Aristotelian ideas about technology as imitating nature, or of Ernst Kapp's notion of organ projection[15]) and of the history of the

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[11] Cf. (Eldredge, 2014; Raup and Sepkoski, 1984; Sepkoski, 2020).
[12] See (Pigliucci, 2007; Pigliucci and Müller, 2010).
[13] See (Tamborini, 2023).
[14] It is no coincidence that Chang supports Kantian and neo-Kantian philosophy as a valid instrument for understanding scientific practices. See (Chang, 2011; 2017).
[15] For an overview, see (Liggieri and Müller, 2019; Liggieri and Tamborini, 2021; Müggenburg, 2019; Tamborini, 2022a;).

engineering sciences themselves.[16] In the 18th century, for example, machines were built that imitated organisms, such as the famous automata of French designer Jacques de Vaucanson (the “flute player”) and of the Swiss clockmaker family Jaquet-Droz (see the “writer,” the “draughtsman” and the “musician”) (Riskin, 2003, 2016; Voskuhl, 2013). However, this practice and the implicit knowledge it entailed were not codified until the early years of the 20th century.

In his books *Die technischen Leistungen der Pflanzen* (“The technical achievements of plants,” 1919) and *Die Pflanze als Erfinder* (“Plants as inventors,” 1920), Austro-Hungarian botanist, microbiologist, scientist and philosopher Raoul Heinrich Francé outlined a theory of “biotechnology” as a synthesis between biology and technology. This was a program involving the deliberate imitation of the “technical forms” of nature. For Francé all natural forms are technical to the extent that they perform a function completely. That is why, wrote Francé, “there is no form of technology which cannot be inferred from the forms of nature” (Francé, 1920, p. 20). Long before humans lived on the Earth, says Francé, plants had already anticipated humans’ tools, machines and architecture.”[17].With our simple constructions, we limited human beings are unconsciously mimicking the forms that plants have designed in such a flawless way that they are at once more rational, more sustainable and aesthetically more pleasing than our own. Francé‘s books contain comparisons between underwater algae and torpedoes, pine pollen and hot air balloons, tree roots and water pipes, and between liverwort and a Taylorist factory. When we look closely at the plant, the botanist says, “*the plant* turns out to be *a veritable industrial city”* (Francé, 1920, p. 51). In the industrial city of plants there are “drawworks here and tubular coolers there” in operation. Thus, Francé notes, “the more expert knowledge one has, the more one comes across technical terms in this domain” (p. 51).

Since the research findings from cybernetics, bionics, biomimetics and artificial intelligence that reached a high point during the 1960s and 1980s, Francé’s biotechnology has now developed into biorobotics. Biorobotics practices are many and varied.[18] Here I shall highlight just one area of biorobotics studies and practices, namely, the production of bio-inspired robots.

One of the most pressing problems in biorobotics and biology is trying to understand the mechanisms of locomotion. The “movements of animals are extremely hard to analyse and imitate because locomotion is the outcome of a complex interplay among many different components: the central and peripheral nervous system, the musculoskeletal system and the environment” (Ijspeert, 2014, p. 196).[19] In a groundbreaking study Auke Jan Ijspeert and colleagues chose a robot strategy to understand locomotion and realize it. Their strategy involved taking the salamander as a model animal and recombining matter and form in order to obtain a new organism. To achieve this, the scientists devised a numerical model of the salamander’s spinal cord.

[16] See for example (Drux, 1994; Heßler, 2015).
[17] See (Tamborini, 2020a; Vollgraff, 2021).
[18] See (Datteri and Schiaffonati, 2019; Datteri, 2021).
[19] See also (Nyakatura et al., 2019; Tamborini, 2021).

They then implemented and tested it using a salamander-like robot that can swim and walk (Ijspeert et al., 2007).

Figure 1. The robot developed by Auke Jan Ijspeert and colleagues, which walks and swims like a salamander. Credits: Kostas Karakasiliotis, Biorobotics Laboratory, EPFL, Lausanne.

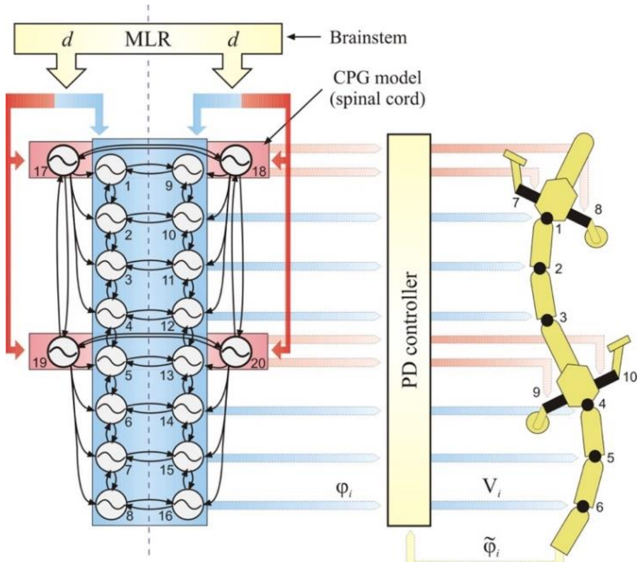

Figure 2. Implementation o the salamander model into a salamander robot. Figure by A. Ijspeert, courtesy Biorobotics Laboratory EPEL, Lausanne.

Another example: Scientists Donato Romano and Cesare Stefanini took the shoaling fish *Paracheirodon innesi* as an example to study the dynamics of social distancing toward potentially infected members of the same species. To study this issue in more depth they developed "a robotic replica of a fish that simulates a healthy P. innesi subject, and another that simulates P. innesi with morphological and/or mobility anomalies" (Romano and Stefanini, 2021, p. 1). What they found was that "P. innesi individuals were attracted by the healthy fish replica, whereas they avoided the replica with morphological anomalies, just as they did the replica with an intact appearance but mobility anomalies" (p. 1).

What is the theoretical basis of this practice of composing using forms from nature? In 21st-century biorobotics, as in the 18th and early 20th century, a function of an organism is isolated, defined and re-assembled in a different scenario. But what are the differences between these practices? And, in particular, which epistemological principle underlies them? In the section that follows, I shall make the transition from a *de facto* to a *de jure* study of biotechnology.

FROM COMPOSITION TO COMPOSING AND TRANSLATING

As already mentioned, my response to the questions just articulated will be an epistemological one. I will not look in detail at what nature itself is or what makes this shift towards biorobotics possible, but rather how we human beings manipulate and compose nature and can thus control it to an extent. This is not simply a return to Kant but a way of using Kant to think beyond him – in other words, for me it is not "composition" per se that is interesting, but rather how *we* are able to *compose* it. The focus here is on the verb, on the "activity" of composing, rather than on the end product, as is argued in the *Philosophy of Science in Practice.*[20]

On one level, this major shift was made possible by a change in the more general heuristic and metaphysical principles that guide biotechnological research. Francé – and then, increasingly, 1960s bionics and 1980s biorobotics – no longer asked whether organisms should be regarded in some way as machines.[21] During the first half of the twentieth century biology as a whole had been geared towards either denying or affirming a potential analogy between machine and organism. In contrast to this, the key metaphysical question underlying the new, biotechnological perspective on nature is about exploring the very converse of the previous approach. The question is no longer whether organisms are machines but whether machines are organisms. In his well-known publication "Machine and Organism", French philosopher Georges Canguilhem identified this transformative shift as the main reason for the new biotechnological research program pursued in 20th-century biology. He sums up this transformation in the following sentence: "Technology must be regarded as a universal biological phenomenon, and not just as an intellectual human pursuit". "As a result," wrote Canguilhem (2007), "we can inscribe the mechanical onto the organic" (p. 206). "Of course" he continued, "the question is now no longer to what extent the organism can or must be regarded as a machine, be it with regard to its structure or its functions" (p. 206).

On another level, this process by which the mechanical is inscribed onto the organic is a work of composition. The latter, in turn, takes shape through a very specific practice, namely, the practice of translation. The purpose of this practice is to transform something into something else. This involves transferring a meaning and a designation from one domain to another in order make it accessible to people with no access to the first domain. The practice of translation transfers, for example, the complexity of a salamander's locomotion into the artificial structures of a robot. The process of socialization and of social distancing in fish is translated using a robot; the shape of a poppy seed capsule is translated into a salt shaker, etc. In the course of this process of translation – as with any translation – some elements are retained, others are changed, others simplified, others circumscribed and others left out completely. When transferring the salamander organism

[20] See (Ankeny et al., 2011; Chang, 2011; 2012; Dresow, 2020; Soler et al., 2014).
[21] Cf. (Baedke, 2019; Esposito, 2016; Nicholson, 2014; Nicholson and Gawne, 2015; Tamborini, 2023).

to the salamander robot, for example, a number of morphological, social and environmental elements are left out in order to concentrate on a single element, namely, the form-function complex responsible for locomotion. This is isolated, disassembled, and reassembled in the robot.

We can identify three possible translation processes and practices within this practice of isolation, bracketing out and re-assembling: 1) Only function is translated (we might think of the "Canard Digérateur" machine, which simulates the digestive process of ducks); 2) Only form is translated (many experiments conducted by Leonardo da Vinci and by Francé were mere re-assemblages of natural forms); 3) The form-function complex is translated (as in the example of the salamander and the robot fish). This last translation exercise is emblematic because in this case the mere act of translating and reassembling form or function provides a complete picture of the complexity and meaning of the original organism. The function, for example, has been re-worked and rendered in mathematical terms so that a potential mathematical conversion schema emerges. This schema is very important because it enables the engineer in his or her role as translator to find elements that enable them to read nature in line with their conceptual schema.[22] As Canguilhem would say, however, the point of studying and of thus mastering the problem of locomotion is to "create" the craftsman – in other words, to convert function into potential (technological) form.

This practice of composing and translating, then, is based on regarding the forms of nature as *a complex language* and developing tools for translating this language into other forms.

Since the reassembling of biotechnological forms is a translation practice, the additional question arises whether there is any one translation that is better than another. A translation is better than another if it enables me to switch between two languages '*salva veritate*' (i.e., with unharmed truth). This process can even lead to a certain identity. As Leibniz famously wrote: "*Eadem sunt quorum unum in alteris locum substitui posset, salva veritate, ut Triangulum et Trilaterum, Quadrangulum et Quadrilaterum"* (Leibniz, 1890, 7:219) ["Those are the same of which one could take the place of the other, with truth unharmed, such as triangle and three-sided figure, quadrangle and four-sided figure"].

Two expressions are the same[23] if they can be mutually substituted without prejudice to the truth, such as "triangle" and "trilateral figure", "four-sided figure" and "quadrangle". Albeit this presupposes another step: the principle of reversibility. A given text A, in German, for example, is translated into text B (Italian). In order to check whether it is a good translation, I can translate text B back into text A (without knowing it in advance) and end up with another text C. If this text C is sufficiently similar to text A *salva veritate*, then it is a good translation.[24]

[22] On this issue see (Quine, 1960).
[23] It is important to note that what we have here is the identity of two expressions, i.e., the issue is how we perceive and categorize the world rather than one of an identity of the same thing, as Leibniz believed. To put it differently (and as I will show in the conclusion) the practice of translation is based on an epistemic and not on an ontological foundation.
[24] Cf. (Eco, 2016). See also (Baker, 2003).

I can change the words (or the materials and the physical appearance in the case of biorobotics), but reversibility must still be given. A joke, a turn of phrase or a tongue-twister must be capable of being translated back into the original with no loss of meaning. One example of this is Alessandro Manzoni's famous historical novel *I promessi sposi* [*The Betrothed*] (1840–1842), in which the author describes the events surrounding the betrothed couple Renzo and Lucia. At the end of the book the author spells out the message of the story by calling it the "sugo della storia", "sugo of the story." The Italian word "sugo" means "sauce". Manzoni uses this word to convey even more effectively his message of divine providence to the poor and uneducated classes in Italian society in the second half of the 19th century. Just as the sauce spread over pasta gives the dish its flavor and rounds it off, so the sauce of the story is the meaning that gives the whole story its flavor and meaning. In some translations we now read:

- "Questa conclusione, benchè trovata da povera gente, c'è parsa così giusta, che abbiam pensato di metterla qui, come il **sugo di tutta la storia**" (Manzoni, 1997, p. 558)**.**

- English translation: "Although this was said by poor peasants, it appears to us so just, that we offer it here as the **moral of our story**" (Manzoni, 1856, p.452).

- German translation: „Dieser Schluß, obwohl von einfachen Leuten gefunden, hat uns so richtig geschienen, daß wir ihn als den **Kern der ganzen Geschichte** hierher zu setzen gedacht haben" (Manzoni, 1879, p. 320).

- Spanish translation: "Esta conclusión, aunque hallada por pobre gente, nos ha parecido tan justa, que hemos pensado en ponerla aquí, como **el jugo de toda la historia**" (Manzoni, 2015).

All three translations are very good, but in my opinion the Spanish one is the best, because although the English and German versions capture the meaning of the words (i.e. the overarching lesson the author seeks to convey), they fail to put over the visual aspect. By using the word 'jugo', i.e. 'juice', the translator gets very close to the Italian word 'sugo', as he gives the reader a visual impression of the meaning of the expression in a *possible world* that is comparable to the original world given in the text.

To return to the salamander, clearly I cannot translate the salamander robot back and recombine it to obtain a living organism again. What remains, though, is the complex form and function of the salamander organism. In order to check whether the translation is correct, we just have to insert the robot into the salamander 'life form' and see whether it moves exactly the same in a possible environment.

The case of fish (i.e. in the case of so-called interactive biorobotics) is even more symbolically laden. Here, the robots enter into cooperation and connection with the life form fish, which proves that the translation is correct, as it allows me to study another life form which would be unknown to me without the translation and practice of composition.

OUTLOOK

In the practice of composing and constructing, then, a conceptual plan of a form comes about as an emergent arrangement of various factors, an arrangement perhaps better understood in terms of a construction.[25] This realization is of both historical and theoretical significance. It suggests a further genealogy of the Kantian-Romantic paradigm of morphology. This paradigm which has privileged, among others, the concept of gestalt and the intrinsic properties of form, was taken up by the 20th-century organic movement.[26]

In this case, however, the point at issue is not the actual properties of matter but rather the emphasis on (and translation of) the elements that connect and hold together the parts of the original form. The composition is thus based on a *translation practice*[27] that takes into account what is to be translated. In other words, the point of departure is Francé's definition of the organism:

"The meaning of the term organism and organisation is nothing other than the *law-based unification of parts* [...] Accordingly, no function exists on its own but rather always in interaction with others. An organ effects other organs, their functions interlock with one another like the teeth in a cogwheel and all of them together are regulated by the whole to which they belong" (Francé, 1928, p. 262).

The key question is how both this "*law-based unification"* as well as the "parts" that form a whole can be translated and composed. It is on this basis that engineers negotiate and make decisions by *hermeneutically interpreting*[28] nature and categorizing the forms of nature into possible worlds of interpretation, in order to extrapolate from there what needs to be varied. In accepting this perspective, my study has established a connection and an encounter with linguistic studies in the philosophy of technology as represented, for example, by Mark Coeckelbergh and Alfred Nordmann.[29]

In addition, this case study brings us face to face with the famous problem articulated by Quine (1960, 1969), namely, that of radical translation.[30] Here too a profound indeterminacy and determinacy of translation becomes apparent. In a translation manual consisting of words and options used by engineers, we are entirely determined. To the outside, this translation remains utterly indeterminate. If we accept this conclusion, we can also extend it to the understanding of the relation between nature and technology. The approach I have put forward and developed in this article rejects any identity or

[25] On this, see (Tamborini, 2022a, 2020b).
[26] Cf. (Friedman and Krauthausen, 2022; Tamborini, 2022a, 2022b).
[27] Although it is not the aim of this article to do so, I would like to remark that the emphasis on the translation practice of engineers implies drawing attention to an ontological difference between nature and technology, a different that is bridged epistemologically. On this topic see (Speck et al., 2022; Tamborini, 2022a).
[28] On this see (Grunwald, 2015; Sand, 2019; Schmidt, 2021).
[29] See (Coeckelbergh, 2011, 2017a, 2017b; Nordmann, 2002).
[30] The solution to this dilemma lies in the principle of relativity: "reference is nonsense except relative to a coordinate system". Accordingly, Goodman (1978) writes, "not *what* is given but *how* it is *given*" is key (p. 6). Or, as Cassirer (2000) noted from a different perspective: "We thus do not recognize ‹objects' — as if they were already previously and independently determined and given as objects —, but rather we recognize objectively by creating certain demarcations within the uniform course of a set of experiences and fix in place certain lasting elements and contexts of interconnection" (p. 403).

dichotomy between nature and technology. On the contrary, by placing the emphasis on translation practices, we can see the significance of a holistic treatment of both domains which, as Quine himself observed, highlights the background theories, nature and technology, which are connected only by the network of acts of translation (ontological relativity), which in turn are based on principles that are always capable of being revised and (re-)negotiated.

By concentrating on this practice of translation from one domain to another, I am ultimately drawing attention to the need to study philosophically what happens *between different scientific domains* and especially *between science and technology*. Given that this process is not simply about some kind of takeover, a solid philosophy of the technosciences should be developed in order to understand what is happening with these cross-cutting movements. This paper therefore throws down the challenge to philosophers to develop a philosophy of knowledge in the interstices.[31]

The compositional practice of biorobotics is thus not biomimicry (i.e., a mere mimetic copying of the forms of nature), but a *translation practice* based on the general metaphysical paradigm of an inscription of the mechanical onto the organic. As a result, within this practice, the scientist becomes *homo translator* for they shifts between different media of representation to express the biological into the mechanical and vice versa.

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[31] See on this (Tamborini, 2022a, 2020b).

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