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ORIGINAL RESEARCH

Exploring the transition: biology, technology, and epistemic activities

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Abstract
By focusing on biorobotics, this article explores the epistemological foundations necessary to support the transition from biological models to technological artifacts. To address this transition, I analyze the position of the German philosopher Thomas Fuchs, who represents one possible approach to the problem of the relationship between bio-inspired technology and biology. While Fuchs defends the idea of a unique ontological space for humans, this article contends that his categorical distinctions face challenges in establishing a robust epistemic foundation necessary to ground the transition from biology to technology. After identifying at least three interwoven reasons for rejecting Fuchs' epistemic foundation, I ask how, through what methods, and by means of which practices the newly bio-inspired object is accessed and shaped. Expanding on philosophy of science and technology in practice, I argue that the plurality of answers to this question provides a possible epistemological foundation *within* the different frameworks of practices that produce the bio-inspired object. In addressing the potential epistemological foundation for pluralistically grounding the transition from biological models to technological ones, my approach helps us: (i) concretize and examine the relationship between biological and technological models, and (ii) investigate the features and validity of bio-inspired objects, effectively offering a more concrete and pluralistic picture of what bio-inspired sciences and technologies are and what they can (or cannot) do.

Keywords Biorobotics · Robotics · AI · Biology and technology · Philosophy of science and technology in practice · Technology games

The analysis of the relationship between biology and technology has become increasingly important due to the recent rush development of artificial intelligence-based

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technologies as well as bio-inspired disciplines (Floridi, 2020; Dicks, 2023; Tamborini, 2022a; Mazzolai and Laschi 2020; Mazzolai et al., 2022; Giordano et al., 2023; Blok, 2023; Köchy, 2022; Grunwald, 2008, 2011; Gutmann, 2017; Misselhorn, 2021, 2009; Freyberg and Hauser 2023; Geiszler, 2023; Tamborini, 2024a; Datteri et al., 2022). The ability to simulate and develop neural networks that mimic intelligence processes has sparked a deep cultural and philosophical debate. At the same time, the design of bio-inspired robots paves the way for asking new research questions (Tamborini, 2021; Datteri, 2020b). Positions vary from a strong exaltation for possibilities opened up by new technologies to a rejection of them as producing illusory relationships (Bostrom, 2014; Turkle, 2011).

In this article, I will explore the possible epistemological foundation necessary to ground the transition from biological models to technological artifacts, as is occurring in current bio-inspired technologies, especially biorobotics. Departing from the features of bio-inspired robotics, I will ask which broader set of assumptions might justify the validity of bio-robotics knowledge production and the transition between biological models and bio-inspired technological production. Following the recent methodological insights of the philosophy of science and technology in practice[1] (Chang, 2011, 2022; Ankeny et al., 2011; Massimi, 2022; Leonelli, 2016; Rheinberger, 2010; Boon, 2017; Boumans and Leonelli 2013; Poliseli et al., 2022; Tamborini, 2023b, 2024a), I will show that this basis can be found *within* the plurality of types of diverse and situated activities used to generate bio-inspired knowledge. As I argue in Sect. 3, the question to be posed to tackle the possible epistemological foundation is: how, through what methods, and by means of which practices is the newly bio-inspired object accessed and shaped? The plurality of answers to this question provides a possible epistemological foundation *within* the different frameworks of practices that produce the bio-inspired object.

To address this transition, I will analyze the position of the German philosopher Thomas Fuchs, who represents one possible approach to the problem of the relationship between bio-inspired technology and biology. In his most recent book *In Defence of the Human Being: Foundational Questions of an Embodied Anthropology* (Fuchs, 2021), Fuchs emphasizes the (ontological) sharp distinction between human intelligence and artificial intelligence as well as between organisms and other bio-robotic artifacts. Although he is not pessimistic about technological development, Fuchs is sharply critical of philosophical and other theories that tend to blur the boundaries between biology, anthropology, and technology. He extraneously opposes these theories and admits that the union of the biological and the technological is an "oxymoron" (Fuchs, 2021, p. 42). In fact, Fuchs notes that, this oxymoron is epistemologically based on the "projection of our own intelligent abilities" onto technological systems (Fuchs, 2021, p. 42). However, despite Fuchs' valuable contributions in revealing the limitations of certain philosophical theories in grasping the distinct disparities between various phenomena (such as the distinction between human beings and robots, organisms and machines), Fuchs' categorical differentia-

[1] This approach has certainly deeper roots in the history of philosophy and in the history of philosophy of science. For an overview of how the seek for epistemological foundation has been variously shaped in the post-positivist philosophy of science see (Zammito, 2004).

tion falls short of establishing a robust *epistemic* foundation for grounding how the transition from biological forms to technological artifacts might be possible, as it is happing in bio-inspired technologies (like biorobotics).

Indeed, as I will address in the following sections, there are at least three interwoven reasons behind my rejection of Fuchs' epistemic foundation. Firstly, his starting point is too narrow, and sometimes he uses a definition of science, technology, and biorobotics that does neither fit nor represent what is happening in twenty-first-century bio-inspired technology and science. This is mirrored in the examples Fuchs chooses to address the transition between nature and technology. For instance, he focuses on the anthropomorphic robot Sophia as an example of bio-inspired robotics, forgetting that the motivation to build Sophia is very different from other bio-inspired robots (Sophia's main goal is to attract media attention rather than providing scientific breakthroughs[2]). Therefore, Sophia cannot be used as a representative case for bio-inspired robotics nor compared with other bio-inspired robots used in scientific settings. The recognition of the right object of investigation is, however, essential for correctly tackling broader epistemic questions like the transition from biology to technology.

Second, due to the narrow definition of the scopes and characteristics of twenty-first-century science and technology, Fuchs addresses the shift from biology to technology too hastily, bypassing a meticulous commitment to the phenomenological principle of returning to and describing the things themselves[3]– a commitment that should be central in the epistemological and phenomenologically oriented framework he proposes. The phenomenological principle of returning to the things themselves entails a comprehensive examination of all the possible various sorts of bio-inspired objects as they emerge from diverse design processes[4]. However, Fuchs does not analyze what is proper to the different bio-robotic objects designed and used in various epistemic settings. Instead, he defends a monistic as well as context- and object-independent justification of bio-inspired technology.

Third and consequently, as I will elaborate in Sect. 1, Fuchs sees robots only as machines that *simulate* organisms based on the epistemic principle of human organs projection. According to this principle, the transition from biological models into technological ones is the result of a projection of human organs: "human technology", writes Fuchs, "is basically created as a projection and extension of the body, its limbs, and capabilities" (Fuchs, 2021, p. 42). And he elaborates further: "Artificial intelligence is also an "organ projection," albeit one that has been pushed to the extreme: from the abacus to *Deep Blue*, calculating machines are ultimately nothing more than extensions of our ability to count with our fingers—an ability that we have, of course, abstracted into logical-mathematical thinking and finally formalized in algorithms" (Fuchs, 2021, p. 42). Fuchs explicitly links to and based this epistemic

[2] I thank one anonymous referee for pointing this out to me. See also (Lemmen, 2023).

[3] (Husserl, 2013; Zahavi, 2003).

[4] Beyond the terminology of Husserl, this principle entails examining and investigating all the specific features and details associated with the diverse contexts in which the bio-inspired object is created. It emphasizes the contextual dependence of bio-inspired objects.

foundation of the transition between biology and technology on German philosopher Ernst Kapp (1808–1896). This in turn is a very problematic move.

In Sect. 2, I will tackle Fuchs' main epistemological cornerstone: Kapp's philosophy. I will address several deep concerns with Kapp's philosophical underpinning of technology (his Platonic and typological notion of form, organic projection as primarily associated with the human organism, the ambiguity between the projection of form of possible technical activities) and showed why Kapp's idea of technology as organ projection cannot be used as a solid epistemic framework for understanding the transition from biological models into technological ones[5].

In Sect. 3, following various proponents of the philosophy of science and technology in practice (Chang, 2011, 2022; Ankeny et al., 2011; Massimi, 2022; Leonelli, 2016; Rheinberger, 2010; Boon, 2017; Boumans and Leonelli 2013; Poliseli et al., 2022; Tamborini, 2023b, 2024a), I propose to focus on the role of epistemic activities *within* the realm of bio-inspired disciplines. Stressing the vital importance of scrutinizing the practices and language employed in conceptualizing and creating biotechnological entities, I will argue that bio-inspired technology should be regarded as an autonomous domain that generates its unique forms and functions with its distinct language and grammar (sense (Chang, 2011; Coeckelbergh, 2018; Wittgenstein, 2009; Tamborini, 2024a) and not as a mere simulation of organisms based on a metaphysical and highly problematic process of human organic projection.

1 Projection and technology: Thomas Fuchs' critique of bio-inspired technologies

In this section, I will focus on the arguments Fuchs raises in his latest book. This is aptly called *In Defence of the Human Being: Foundational Questions of an Embodied Anthropology* and was published in German in 2020 and translated in English in 2021 (Fuchs, 2021). Before tackling it in detail, I would like to state Fuchs' main argument directly quoting him: "The current reductionism is no longer based on the crude mechanism of the eighteenth or nineteenth centuries; it presents itself in the more elegant guise of bio-cybernetics and bio-informatics[6]. But, in principle, nothing has changed. The characteristic of life as we know it from our own experience, namely experience or inwardness, is still ignored: sensing, feeling, striving, perceiving, thinking" (Fuchs, 2021, p. 21).

The fundamental goal of the book is to debunk today's ontological and epistemological claims where distinctions between human beings and technological artifacts seem to have become obsolete. Fuchs identifies three basic pillars in today's lack

[5] As Fuchs several contemporary philosophers are relying on Kapp to epistemologically ground their notion of technology. See, for instance, (Stiegler, 1998; Pieper, 2024; Greguric & Džinić, 2021; Hoquet, 2018).

[6] I agree with one anonymous referee of this paper in saying that the term "bio-informatic" is used incorrectly here. Indeed, bioinformatics is not connected to the topic of the relationship between biology and technology as addressed by Fuchs and in my paper. Indeed, from a historical (and epistemological) point of view, bioinformatics does not play any role at all in the design of bio-inspired machines. See (Cordeschi, 2002; Tamborini, 2024a; Stevens, 2013).

of distinction between the biological and the technological: reductionist naturalism, elimination of the living, and functionalism.

1. Reductionist Naturalism: This perspective contends that every phenomenon can be fully expounded through scientific methodologies. It asserts that subjectivity, mind, and consciousness emerge from specific neuronal processes, lacking autonomous effectiveness in the world.
2. Elimination of the Living: The second perspective views organisms as essentially biological machines governed by genetic programs. Within this paradigm, concepts like selfhood, experience, and subjectivity are excluded. Consequently, it becomes conceivable to engineer living machines within a laboratory setting.
3. Functionalism: The third perspective places emphasis on the functionality of organisms, particularly data processing and its resulting output, as the defining characteristics of the mind (Fuchs, 2021, 3–4).

Identifying the broader framework, which can be variously found in the entire history of western science and technology (Tamborini, 2022a), Fuchs isolates the peculiarity of today's technology: the possibility of *simulating* organisms[7]. He notes that biology, AI, and other bio-inspired disciplines are up "to replace the living with an external structure and then reconstruct it as a program—in other words, to *simulate* it" (Fuchs, 2021, p. 21 italics in original).

Thus, Fuchs recognizes the sole business of today's bio-inspired technologies in *simulating* external features of biological organisms (i.e., their form and function), in this way scientists design products able to fulfill similar tasks. Eventually, bio-inspired products would replace the truly biological ones. In this task, Fuchs goes on, "the inwardness is ignored, and the place of the expressions of the living is taken by the output of a system" (Fuchs, 2021, p. 21). In light of this process of simulation, a broader (ontological) question may be asked: "What distinguishes life from its simulation? Does the well-known principle really apply here: "If something looks like a duck, swims like a duck and quacks like a duck, then it is a duck"?" (Fuchs, 2021, p. 21).

Fuchs responds to this question straightforwardly. Although progress in recent bio-inspired disciplines enable scientists to design robots that look like and behave like organisms, "the increasingly perfected *simulation* of such a unity demands that we […] take [the words of the bio-inspired and human-like robot] Sophia for what they actually are: mere hollow sounds, like those of a parrot (or not even that, since a parrot at least experiences its sounds). Otherwise, we give ourselves over to appearances and, like Nathaniel or Theodore, simply give up the "as-if," the distinction between virtuality and reality" (Fuchs, 2021, p. 23).

Sophia is a social humanoid robot designed to interact with people and hold conversations. Sophia is well known in the robotics community as being an example of

[7] This argument has deep roots within the history of philosophy, reaching its peak in the second half of the twentieth century. I thank one anonymous referee for bringing up this point. On the history of this definition see among others (Cordeschi, 2002; Liggieri & Tamborini, 2021; Geiszler, 2024; Riskin, 2016; Tamborini, 2024a).

robots that are overhyped (Lemmen, 2023). Fuchs argues that even though robots like Sophia can produce speech and actions that seem lifelike, we should not mistake these behaviors for genuine consciousness or subjective experience. According to Fuchs, the same goes for all the bio-inspired robots design for biological experiments. The iconic salamander-robot developed at the EPFL is merely a tool that is faking us in its behavior (Auke Jan Ijspeert et al., 2007; Ijspeert, 2014). As parrots can mimic human speech, but they do not possess true understanding or consciousness of the words they repeat, Fuchs suggests that robots like Sophia may be similar in that they can *imitate* certain human-like behaviors without actually having consciousness or subjective experience.

Taking Sophia as a case of bio-inspired robotics overlooks the fact that Sophia's primary purpose is to attract media attention rather than contribute to scientific advancements. While Sophia's goal is to appear human, which is just one aspect of bio-inspiration (and not the most common one), the motivation behind building Sophia differs significantly from other bio-inspired robots, such as the salamander-robot developed at EPFL, which was designed to ask and validate scientific questions through bio-inspired design. Hence, Fuchs departs from a too narrow definition and characterization of science and technology in this and other examples. As I will show in Sect. 2, this starting point poses significant problems in grounding the epistemic transition between biology and technology.

Fuchs bases his notion that contemporary bio-inspired technologies aim to simulate external characteristics of biological organisms on both ontological and epistemological reasoning. I will briefly mention the first point. According to Fuchs the self-modeling capability of a robot, where the robot can create an internal model or representation of itself, should not be confused with self-awareness or consciousness. The distinction is made by pointing out that a robot's self-modeling does not equate to true self-awareness because it lacks the essential element of conscious self-reference.

Second, living being, such as biological organisms, are characterized by their ability to self-organize and essentially create themselves. This means that they have the capacity to come into existence and develop autonomously. This autonomy is a fundamental aspect of their nature. Indeed, "the characteristic feature of living beings is that at the moment of their creation they "tear themselves away" from their conditions of origin, and pursue an autonomous, autopoietic development" (Fuchs, 2021, p. 38).

Fuchs' ontological distinction between persons (and broadly organisms) and machines finds resonance among several contemporary philosophers (Nicholson, 2013, 2014a, b, 2019; Lewens, 2004). However, as this paper does not focus on the ontological distinction between machines and organisms, further discussion on this topic will be omitted. Instead, this paper will concentrate on Fuchs' epistemological argument, which explores the transition from natural to technological forms and its philosophical underpinnings. In Fuchs' words: "What appears[8] intelligent in the per-

[8] One anonymous referee pointed out to me that Fuchs employs two concepts of projection. Firstly, akin to Kapp's concept, we project our own intelligent abilities onto technical systems. Secondly, we project our performance categories to evaluate AI and technological systems. Yet Fuchs neither recognize nor explain this possible tension. I agree with the referee (and thank them for this insight). Indeed, this presents another issue stemming from: (1) a departure from a narrow notion of twenty-first century science

formance of AI systems is only a *projection of our own intelligent abilities*" (Fuchs, 2021, p. 42 italics mine). In other words, bio-inspired machines execute tasks based on the goals, problems, solutions, and evaluations that humans have meticulously encoded into their programming through a sort of projection.

As in the case of Sophia, Fuchs again adheres to a too narrow definition of science and technology, failing to explore the full range of potential bio-inspired objects. Indeed, robotics encompasses various approaches that rely on emergent solutions[9] rather than predefined programming, such as swarm robotics, evolutionary robotics, and self-assembly robotics (Floreano and Mattiussi 2008; Yang et al., 2013; Blackiston et al., 2023; Endo & Sugiyama, 2018). Similarly, unsupervised or semi-supervised machine learning methods generate unexpected solutions that are not explicitly encoded by humans into their programming (Ramdya and Ijspeert 2023).

Fuchs' acceptance of only a particular view on today's science and technology brings him grounding the relationship between biology and technology on the epistemological principle of organ projection[10]. To illustrate his point, Fuchs draws an analogy to a clock that measures time: the clock "measures time for us because we have outsourced our own experience of regular natural processes and represented it in a useful mechanism. Intelligent is not the watch but the watchmaker alone. And as nonsensical as it would be to attribute knowledge of time to the clock, it is just as nonsensical to attribute the perception of danger to an "intelligent car" or the understanding of language to an "intelligent robot"" (Fuchs, 2021, p. 42). Hence, we perceive robots and AI intelligence only as manifestation of human intelligence and design for we *projected some* features into the technical objects. The process of organ projection is responsible for the transition from natural to technological forms and is at the base of Fuchs's epistemological grounding of bio-inspired technology. Indeed,

and technology, (2) the lack of clarity regarding the similarities and differences between bio-inspired technological systems, and (3) basing the process of transition from biology to technology on the problematic notion of organic projection.

[9] I thank an anonymous referee for pointing out the following point, which in turn supports my argument for closely analyzing what scientists are doing. In summary, the referee notes that since some types of simulations can also show emergent behavior, the gap between simulation and bio-inspired technologies could be bridged. In this case, Fuchs' thesis would be correct. I agree with the referee that the gap between simulation and biorobotic construction can be narrowed (I bracket here all the problems associated with the so-called reality gap). However, if placed under these conditions, the reduction of this gap would bring a new argument against Fuchs and other philosophers who advocate similar ideas. Indeed, Fuchs has too narrow a concept of simulation that fails to capture the emergent formation of behavior. As I showed in the body of the paper, Fuchs uses the concept of simulation in a pejorative tone, as a false image of an initial process based on the projection of external features. Therefore, to reduce the gap between simulation and construction, one would need to examine what scientists do when they simulate. In doing so, the plurality of meanings and actions related to simulation emerges — a point I am advocating in this paper. Regarding the broader debate on the notion of simulation (and the plurality of meanings) used in biorobotics, I refer to the following papers and the literature they discuss: (Datteri and Schiaffonati 2019; 2023).

[10] It is important to note that the epistemological principle of organic projection does not imply that intelligence, for instance, in a technological artifact, is subjective or depends solely on the observer's perspective. As I will elucidate in the following pages, the principle of organic projection does not concern the attribution of intelligence or of other biological proprieties to technological systems, but rather it signifies that we project elements of our bodily forms and being into technical production to create technological artifacts.

Fuchs explicitly links this to the philosophical foundation of technology proposed by German philosopher Ernst Kapp. As Fuchs puts it, “Human technology, as Ernst Kapp already showed in his philosophy of technology (1877), is basically created by “organ projection,” namely as projection and extension of the body, its limbs, and capabilities” (Fuchs, 2021, p. 42).

Hence, Fuchs argues that artificial life “without life and consciousness”, i.e., “i.e., without *experience* [ohne *Erleben*] (Fuchs, 2021, p. 16 italics in original)” is “self-contradictory”. “At best”, Fuchs goes on, “it is a *simulation* of narrowly defined areas of human intelligence” (Fuchs, 2021, p. 31 italics in original) and it was produced by projecting features of our bodies onto technological design. This projection of human attributes onto technical objects is a key element in the transition from natural to technological forms, as discussed in his work.

In the following sections I will address this epistemological justification. First, I will show that Kapp’s philosophy of technology does not help us grounding the transition biological models into technological ones. Second, I will propose a possible methodological way to address the epistemological justification and ground the transition from biology to technology.

2 Limitations in Ernst Kapp’s philosophy of organic projection

By publishing his book *Grundlinien einer Philosophie der Technik* (Elements of a Philosophy of Technology) in 1877, German philosopher Ernst Kapp laid the foundation for the emergence of philosophy of technology as a distinct philosophical field. His thesis, as discussed in the previous section, continues to hold significant philosophical relevance today (Kapp, 2008; Kirkwood and Weatherby 2018; Scholz and Maye 2019; Tamborini, 2022a; Vollgraff and Tamborini, 2023). Kapp sees the development of technology as a phenomenon of organic projection. The human being projects part of the forms of his body into technical production in order to develop technological artifacts. Kapp’s classic example is the hand. In the process of organic projection, the shape of the hand closed as a fist is transformed into the shape of a hammer. This can then take on further forms, such as the shape of an axe or a hatchet. Another example Kapp analyzed is about the invention of the camera obscura. According to Kapp, in a process of *unconscious* projection, its inventor projected the form and function of the human eye into the making of this technical instrument.

The process of organic projection, according to Kapp, is operative in all technical production. Drawing from late nineteenth-century advancements in mechanical engineering, including Reuleaux’s definition of a machine as a combination of resistant components, each performing a specific function under human control to harness energy and perform tasks (Reuleaux, 1894; Tamborini, 2022b), Kapp demonstrates that machines, too, fundamentally rely on the concept of organic projection: “the machine”, writes Kapp, is “is as much a continuation of the hand tool and of tools generally as the tool is the continuation of the hand and the organ” (Kapp, 2008, p. 147).

The process of organ projection is not to be understood in a teleological way; rather, Kapp describes it in as a dialectical development in which the initial moment, the form of the human body to be projected, is preserved throughout the process. Thus, Kapp remarks: “The machine should not be thought separately from its origin; it would cease to be a machine if it were thus disconnected. The kinematic train is the actual continuation of the vital organic kinesis that Reuleaux sharply distinguishes, as the living working machine, from that which is lifeless” (Kapp, 2008, p. 147).

By referring to the history of time displacement written by astronomer Julius Foerster, Kapp adds another element to the understanding of the relationship between technical and natural forms. Foerster “proceeds to trace the most relevant and also apparently contrasting moments in the history of timekeeping devices—from the pillar erected in the ancient public square, to the sundial, hourglass, water clock, weight- and spring-driven clocks, the pendulum, and the chronometer—in order to show how the science and art of measurement proceeded to develop, from pacing the length of a shadow to appending and recombining mechanisms that we already know to be projections of organic powers (levers, springs, pendula, etc.). He shows, moreover, how human beings had begun to measure calendrically not only astronomical time and space but even sensations and the formation of representations—a metamorphosis of the primordial human measure that really does border on the miraculous!” (Kapp, 2008, p. 59).

The relationship between technical forms and organic forms can thus be traced back to a process of continuous metamorphosis (on this see also (Tamborini, 2020, 2022a). In concrete realization, the original forms of the human body are projected into technical instruments and artifacts, which then metamorphose again and again into new forms. In this process of metamorphosis, however, the original idea is always present and comprehensible. Indeed, although the technical forms that emerge over time have nothing to do with what they originally emerged from, they are conceived as a continuation of it: “The hand hammer is a hand metamorphosized… [it] helps forge new hammers, erect entire hammer mills, and make world history” (Kapp, 2008, p. 78).

However, the greatest difficulty in Kapp’s theory lies in the fact that he advocates a *typological notion of form*. According to Kapp, there are basic organic forms or basic Platonic types that make technology possible. In describing the transition from simpler objects such as the hammer to more complex tools such as the axe, Kapp writes explicitly that “the crooked finger of the hand that plucks became the sickle, the sickle the scythe, the scythe the reaping machine; and […] the concept of an original activity, expressed in the tool’s basic form, is preserved throughout the entire series of its transformations” (Kapp, 2008, p. 46). And he goes on arguing that the “basic form of the hammer, in general capable of broad modifications depending on the material and intended use, *has been preserved unmodified* in, among others, blacksmithing and mining hammers and is recognizable still in the giant industrial steam hammer” (Kapp, 2008, p. 36 italics mine). The basic form plays the same role in metamorphic processes: it behaves like a Platonic idea that is instantiated in every possible concrete form. However, it remains unclear, first, how new basic forms arise and, second, whether and to what extent they can be related to each other. While acknowledging the metamorphosis of forms, Kapp maintains a completely static relationship between technology and the organic world. The basis of this relationship lies in the static nature of organic forms. The morphologist Kapp thus provides us with a *metamorphosis without morphogenesis*. He provides a concept of form as stable, but also as a static container: forms are rigid and timeless. In this way, Kapp approaches idealistic biological positions that explain form change on the basis of changes in typological paradigms.

Moreover, Kapp's concept of organic projection is primarily associated with the human organism, which serves as an intrinsic model for the development of technology. This model not only represents the ultimate goal of technology but also its most advanced realization and fundamental principle upon which it is based. Kapp's understanding of a possible organic projection underlying technology refers therefore completely to the organic projection of the human being. It is not possible to project nonhuman forms into technology. This thesis has been largely refuted by the development of biomimetic disciplines that rely precisely on a nonhuman, non-anthropocentric concept of technology (Pohl and Nachtigall 2015; Mazzoleni, 2013; Tamborini, 2022a). Moreover, there are some challenges in applying this human-based notion of organ projection to all technical objects, as in the case of designing a wheel. This is difficult to directly relate to human anatomy.

Last, there is a conceptual ambiguity about what is being projected - a point that will be explored in my proposal in the following section: is it the human organ itself or its function that is being unconsciously projected? For example, a hammer does not simply aim to imitate the shape of the hand, but rather the *act* of hammering with a closed fist. The same principle applies, according to Kapp, to the steam engine, which imitates metabolism. In sum, according to Kapp, although this aspect is not fully developed in his works, it might be argued that technology does not exactly imitate the human organism, but rather its *performances* and related practices. In this case, the distinction between organic and inorganic becomes less significant in practices.

Hence, there are severe limitations to Kapp's philosophy. These limitations, in turn, apply to Fuchs' approach and its epistemic foundation since, as shown in Sect. 1, he relies on the very same definition of organic projection as developed by Kapp, without discussing, expanding or revising it. Therefore, Kapp's philosophy cannot be used as valid philosophical cornerstone to ground the transition from natural forms to technology. Building upon the idea that technology is more about practices and actions than the projection or replication of human forms, I will establish a framework to explore the shift from biology to technology.

3 Exploring epistemic activities in bio-inspired disciplines

So far, I have argued that (i) Fuchs' narrow starting point and his definition of science, technology, and biorobotics do not align with twenty-first-century bio-inspired technology and science, (ii) Fuchs does not investigate the full variety of bio-inspired objects, thereby neglecting the diverse characteristics of bio-robotic objects designed and used across different epistemic settings, and (iii) Fuchs grounds the possible transition from the realm of biology to that of technology in Kapp's concept of organic projection. However, this concept has notable limitations and does not ensure a smooth transition from biology to technology (see previous section).

In this section, I address the potential epistemological foundation for pluralistically grounding the transition from biological models to technological ones. This, in turn, helps us: (i) concretize and examine the relationship between biological and technological models, and (ii) investigate the features and validity of bio-inspired objects, effectively offering a more appropriate image of what bio-inspired science and technology are and what they can (or cannot) do. I propose to address these issues by exploring how knowledge in biorobotics is variously generated, validated, and applied. This involves closely analyzing the variety of methodologies, practices, and contexts that underpin and constrain the production and use of bio-inspired objects *within* a particular set of practices. Indeed, in the epistemological foundation I am putting forward here, the bio-inspired technological object, in this case the biorobot, has its validity *within* the set of practices and values used to create it.

My proposal can be developed by embracing specific methodological suggestions from philosophers like Ernst Cassirer, Mark Coeckelbergh, and various proponents of the philosophy of science and technology in practice (Chang, 2022; Ankeny et al., 2011; Massimi, 2022; Leonelli, 2016; Rheinberger, 2010).

First, Cassirer claims that science (including biologically inspired disciplines) consists of a set of actions. "The analysis of this action", adds Cassirer, "requires criteria and categories entirely different from those used for the analysis of natural entities" because scientific disciplines do not belong to the "world of things"; they are not a product of nature but of culture (Cassirer, 2011).

If we accept this premise, as contemporary philosophy of science in practice does (Chang, 2011, 2012, 2022; Ankeny et al., 2011), then we have to examine closely the features of scientific activity. Merely working with categories and concepts related to the object of technological knowledge (e.g., what are robots, cyborgs, machines etc.) is insufficient. It is not enough to point out the ontological differences between biological and technological domains. We need to illustrate *how* the object of the biotechnological disciplines is practically conceived, to what end, by what means, by whom, and so on. The focus is on the totality of epistemic activities used to coherently create the biotechnological object (Chang, 2011, 2022). In other words, the focus lies on two aspects: firstly, the actions that underpin Kapp's idea of metamorphosis, and secondly, the diverse actions that serve as the foundation for the shift from how biologists perceive and study natural forms to how these forms can be manipulated in the realm of engineering.

Merely asserting that robots simulate organisms based on the concept of human organic projection is inadequate, as (1) simulation is just one of the epistemic activities proper to biorobotics and (2) (human) organic projection cannot used as solid philosophical foundation (see previous section). The field of bio-robotics (and embodied artificial intelligence) encompasses a much wider variety than simply simulating organisms. For example, we can distinguish at least three different types of biorobotics (Tamborini and Datteri, 2023; Datteri and Tamburrini 2007; Datteri, 2020a; Tamborini, 2021, 2023b):

3.1 Classical biorobotics

In this field, robots serve as experimental tools to test theoretical hypotheses about the behavior of living organisms. The classic volume that marks the birth of biorobotics as an autonomous discipline in the 21st century is the text published in 2001 edited by Barbara Webb and Thomas R. Consi: *Biorobotics methods: and applications*. The two editors wrote that the object of study of biorobotics are "animal-like robots (termed biorobots in this book but also known as biomimetic or biomorphic robots)" (Webb & Consi, 2001, VII). From this starting point, it follows that the "biorobotics is a new multidisciplinary field that encompasses the dual uses of biorobots as tools for biologists studying animal behavior and as testbeds for the study and evaluation of biological algorithms for potential applications to engineering" (Webb & Consi, 2001, VII). For example, researchers have used biorobots to simulate bat navigation by mimicking their interaural comparison techniques. Or, to give another example, Auke Jan Ijspeert and a team of researchers adopted a robotic approach to comprehend and replicate locomotion. Their chosen approach involved using the salamander as a model organism. To accomplish this, they developed a digital model of the salamander's spinal cord, which they subsequently applied and assessed in a robot designed to mimic the salamander's ability to both swim and walk (Ijspeert, 2014; Auke Jan Ijspeert et al., 2007). In these cases, the robot simulates the form-function complex of an organism (Tamborini, 2021). Another main domain[11] in classical biorobotics revolves around the design of robots using soft materials such as gels, elastomers, and biological materials (Coyle et al., 2018; Mazzolai et al., 2022; Kim, et al., 2013; Laschi et al., 2016; Milana et al., 2019; Peerlinck et al., 2023; Speck et al., 2021). As has been noted, "much inspiration for soft robotic design comes from the actuation behavior of entirely soft bodied organisms such as earth- worms, jellyfish, and octopi. There are plenty of practical engineering designs that can be learned from the octopus's arm due to being a muscular hydrostat" (Coyle et al., 2018, p. 55). In this case, similar to the bio-hybrid robotic approach (Mazzolai and Laschi 2020; Guix et al. 2021; Webster-Wood et al. 2022; Xu et al., 2021; Tamborini, 2024a, b; Ricotti et al., 2017), where robots are created by hybridizing biological cells and synthetic materials, the soft or bio-hybrid robot does not simulate the form-function complex of an organism but rather endows "robots with new, bioinspired features that permit morphologically adaptive interactions with unpredictable environments[12]" (Coyle et al., 2018, p. 51).

3.2 Interactive biorobotics

Interactive biorobots go a step further by actively *interacting* with living systems, often in real time. They collect data from the living system that can modulate their

[11] Furthermore, we can find several internal categories within classical biorobotics such as using robots as model for or of biology, copying features, replicating full animals/plants, etc. I thank one anonymous referee for this.

[12] Within this specific scientific context, matter is meant to be active and able to compute information. On the notion of morphological computing see (Müller and Hoffmann 2017; Freyberg and Hauser 2023; Harrison, et al., 2022; Tamborini, 2024a, c; Füchslin et al., 2013).

behavior via sensors and feedback systems. Interactive biorobotics takes therefore a different approach. The role of the robot is not to simulate the system under investigation, but to *stimulate* it (Datteri, 2020b; Tamborini and Datteri, 2023).

For instance, scientists Donato Romano and Cesare Stefanini conducted a study using the social fish *Paracheirodon innesi* to explore how these fish engage in social distancing from potentially infected group members. To delve deeper into this investigation, they designed two robotic fish replicas - one mimicking a healthy P. innesi specimen and the other imitating P. innesi with physical or movement irregularities. Their findings revealed that P. innesi individuals were drawn to the healthy fish replica, whereas they avoided both the fish replica displaying physical abnormalities and the one with normal appearance but locomotor issues (Romano and Stefanini 2021).

The use of a robotic fish to study the "social distancing, a behavior-based response to diseases" (Romano and Stefanini 2021), of the target population illustrates that this technological tool does not merely imitate nature. Its primary function is to act as a research tool and data collector, providing access to a population that would otherwise be inaccessible. In this context, the primary goal is to study emerging interactions and behaviors rather than simply imitate natural forms. Since we are dealing with biorobotics, it is obvious that a biological-imitative component is present, but it does not exhaust the meaning and epistemological value of the use of robots. In a constructive practice within a coherent set of practices, a bio-robotic object emerges with qualities of its own. A new form of life is being formed: the "fish-robot hybrid interaction" (Romano and Stefanini 2021). The same aim of achieving animal-robotic mixed societies is pursued in the "design of a robotic system capable of observing and modulating the bee cluster using an array of thermal sensors and actuators". This endeavor was undertaken also to "investigate collective behaviors of the western honeybee (*Apis mellifera*)" (Barmak et al., 2023; Romano, 2023).

3.3 Body-centered biorobotics

Biorobotics is more than just bio-inspired robots. It includes the planning and design of robots to collaborate in human environments, the development of exoskeletons to assist, rehabilitate, or augment human motor functions, and the creation of advanced robotic limbs. For example, when designing exoskeletons and robotic prosthetic hands, scientists start with the precise form and function of the human body, aiming for a deep relationship and symbiosis between the robotic prosthesis and the human user. Current biorobotics research focuses on the transition from exoskeletons to exosuits (Xiloyannis et al., 2021; Ding et al., 2018), which use tissues and metamaterials to support human limbs during actuation, moving away from the rigid joints found in traditional exoskeletons. This approach is highly effective in scenarios where human biomechanics provide structural support while robotic components handle torque and force transmission beyond human joint capabilities. In all these and many other cases, the purpose of building bio-inspired robots *is not to simulate* an organism and then ask further biological questions. On the contrary, it is about mimicking some parts of an organism to create a technological artifact that serves a purpose in itself and/or in possible interaction with a user. In fact, it is not about asking further scientific questions, testing a biological theory, or incorporating and materializing a biological mechanism, but simply about technically *mastering* a possible form-function complex of the source organism and making this complex technologically independent.

All these different types of biorobotics are in turn based on different concrete systems of practices that create objects that are valid only within the chosen system (Tamborini, 2023b).

Therefore, we need to take the phenomenological motto (supported also by some contemporary philosophies of technology (Ihde, 2009; Ihde and Malafouris 2019) seriously and return to the things themselves, in this case to the bio-technical things. Once their properties are examined, we need to address the technoscientific practices that produced them. These are understood as coherent systems. The central question arises then: how, through what methods, and by means of which practices is the newly bio-inspired object accessed and shaped? Through this approach, we can elucidate the *inherent epistemic distinctions* among various bio-inspired objects.

Returning to Fuchs's clock example: Firstly, a clock can certainly be viewed as an embodiment of theories, representing our comprehension and experience of the world. However, this interpretation should be understood as the actualization of *potential actions*. As philosopher Moritz Schlick notes, "We should not forget that observation and experiment are *actions*, whereby we enter into direct commerce with nature. The ties between reality and ourselves often emerge in the shape of propositions having the grammatical form of indicative sentences, but whose true meaning consists in furnishing directives for possible actions" (Schlick, 1979, p. 197).

Second, seeing it as the embodiment of a potential action, the clock does not represent anything beyond itself. As philosopher Alfred Nordmann notes, "Whoever makes something work makes no claim to truth, but creates a technical system that is measured by its performance, by what it can do and what it grants [….] But even a clockwork represents nothing, or at most itself, even if it can be assigned a representative function, for example, if it is to serve as a metaphor or model for natural phenomena" (Nordmann, 2012, p. 204).

Similarly, situated within a cohesive network of practices, a robot does not pertain to an external (ontological) domain, nor is it conceived through the projection of human or non-human forms. Instead, it possesses intrinsic validity and a mode of existence[13] within the framework of practices that brought it into being. Its assessment should be based on its performance, on what it is capable of achieving, particularly *within* the scientific context in which it was engineered– for instance, bio-hybrid robots are attributed ontological significance based on their functionality, beyond their role as mere representations.

Thus, as Mark Coeckelbergh has pointed out, robots are embedded in cultural wholes. Not only are they the objects of cultural practices (science is an act of culture, as argued by Cassirer and many others), but are also part of "larger sociotechnical systems: like other technologies, robots are intertwined with the social practices and systems of meaning of human beings" (Coeckelbergh, 2022).

Furthermore, Coeckelbergh notes that just as we use words within the framework of language games and as expressions of our cultural way of life, we also use technol-

[13] This links the approach I am proposing here to Simondon's investigations (Simondon, 2012, 2013; Liggieri, et al., 2023; Fabbro, 2021; Hoel and Van der Tuin 2013).

ogy, like robots, within the context of "technology games" and as part of our broader cultural form of life (Coeckelbergh, 2011, 2017b, 2018). Our activities with technology are not isolated but are deeply influenced by the cultural practices and meanings that surround them.

If a robot, and more generally a technological or a scientific object, makes sense within the set of practices and values used to create it (i.e., within a technological game), just as a word makes sense within a language game (Wittgenstein, 2009), the transition between the biological and technological domains is context-dependent and concerns a possible *translation* of language games and forms of life[14] and not a projection of organic forms.

Consequently, there are no abstract Platonic organic ideas (i.e., Kapp's typological forms) projected onto technological systems; instead, one finds a multitude of distinct forms of life that underlie various technological practices. These distinct forms of life, though inherently different, possess the capacity for communication and shared performance through the process of language translation. Therefore, a form of life, associated with a distinct language, acquires the precise character of a practical action. This perspective shifts the focus away from bodily or physiological attributes to the way we can structure, mold, and organize the material world and navigate between different language games and forms of life. In doing so, this approach enables a balanced comparison between different manifestations of the artificial and the organic realm itself.

4 Outlook

In this article, I have explored the evolving relationship between biology and technology, exploring its contemporary implications. I have delved into the philosophical viewpoint of German philosopher Thomas Fuchs, focusing on his critique of bio-inspired technologies. According to Fuchs these technologies only attempt to simulate various aspects of biological organisms. Moreover, these technologies, while exhibiting realistic behavior, lack true consciousness and subjective experience, and essentially serve as *projections* of human attributes onto technical objects.

Furthermore, I have also investigated the limitations of Fuchs' argument, particularly its dependence on the concept of organic projection as originally proposed by German philosopher Ernst Kapp. Kapp's philosophy of technology suggests that human technological development is rooted in the projection of bodily forms and functions into technical production. Although Kapp's ideas offer valuable insights into the continuity between human tools and technology, they cannot be used to ground the transition from biology to technology. Kapp's focus on idealized forms of the human body and his denial of genetic elements and natural forms outside human biology limit the applicability of his philosophy as a cornerstone for understanding the transition from natural forms to technology.

[14] On this see the detailed arguments presented in (Tamborini, 2023a, 2024a; Coeckelbergh, 2017a, b, 2018). On the notion of technology and language game in the animal-human relations see (Köchy, 2022).

Showing the limits of a bio-inspired philosophy of knowledge detached from an analysis of practices, I argued for the adoption of the methodology proposed by Cassirer, Coeckelbergh and proponents of the philosophy of science and technology in practice. This approach highlights the importance of examining the epistemic activities that underpin technological knowledge and emphasizes that scientific disciplines are products of culture, not the natural world. Thus, I have argued that robots and technological objects have *their validity and mode of existence within* the systems of practices that create them. Following Coeckelbergh and others, I have argued that robots, like words, exist within specific cultural and technological frameworks, and their meaning and validity are derived from the practices and values of these systems. This brought me to argue that the transition from biology to technology involves a *translation* of language games and forms of life rather than a projection of organic forms onto technology as Fuchs and other philosophers would argue.

Hence and to conclude, in this paper I have argued that technology should not solely be perceived as a "simulation" or "imitation" of nature, whether accurate or not. Instead, it can be seen as an independent realm that generates its unique forms and functions with its own language. This change in perspective helps us recognize the plurality of aims, practices, and values involved in the production of bio-inspired objects, effectively debunking the idea that the sole purpose of today's bio-inspired technologies is to simulate the external features of biological organisms. Furthermore, it provides us with a more concrete and pluralistic picture of what bio-inspired sciences and technologies are and what they can (or cannot) do. As a result, this paper emphasizes the importance of examining the epistemic practices that facilitate the intersection of biology and technology and the languages they employ.

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