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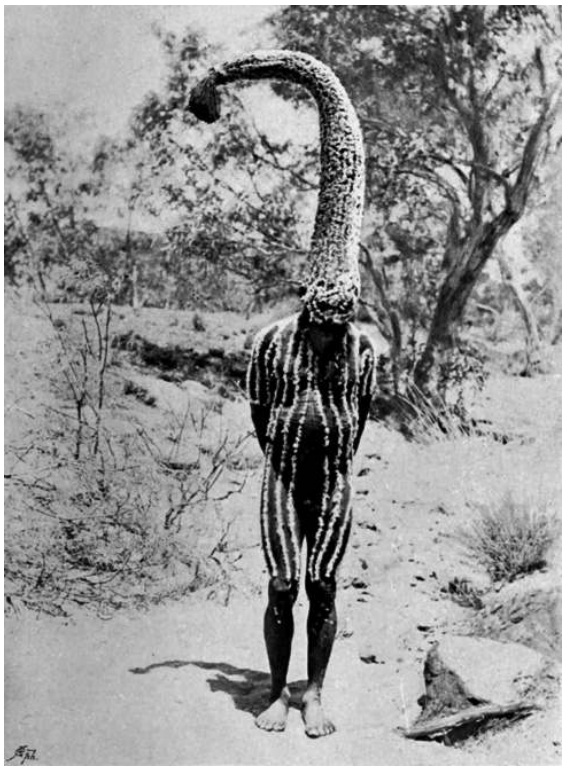
Arunta ceremony of the emu clan.



The headdress, made from bird's down, represents the head and neck of the emu.

Spencer, B. & F. J. Gillen 1912 *Across Australia* vol. II. Londres : Macmillan. University of Toronto / Internet archive

At our meetings in Marseille, during which we began preparations for this issue of *Techniques&Culture*, we heard multiple scientists and researchers who were working on building objects and processes by imitating nature and living systems say that they had done biomimicry spontaneously, "without knowing it"—only realizing "after the fact" that they had adopted this approach. There is nothing exceptional about this type of discourse; it is frequently found in the testimony of those who identify with the biomimetic approach. What status should be given to a process that one only becomes aware of *a posteriori*? Isn't there a tension between the promotion of biomimicry as a new method for studying organisms and producing objects—even as a new paradigm—and the observation that it is based on procedures whose steps and operations are not totally explicit?

1 Attempts have been made to set forth the "principles" of biomimicry and bioinspiration (Benyus 1997) and to present the methodologies that should guide future research.[1] According to its etymology, the word "method" (*meta hodos*) refers to a path that has already been taken: after some piece of knowledge has been discovered, a reflexive look back explains how the discovery was made, and how other discoveries could be made by repeating the procedures used. Since biomimicry intends to change how we think about and do things, its promoters, not surprisingly, are intent on establishing a methodology, on presenting a formalized method that will standardize the work of scientists and engineers. But we must be careful not to confuse the formalization of a process, which seeks to organize the steps for producing an object, with a properly scientific methodology. A scientific methodology is defined by its ability to identify sets of facts and to create conditions in which experiments can be

carried out to prove or disprove theories—eventually leading to their reformulation. The standardization of the biomimetic approach seems to be more of an attempt to establish procedures, rather than experimental protocols.

2 Our intention here is not to take part in these attempts at standardization, but rather to show how the human and social sciences help us understand a phenomenon such as biomimicry. In our introduction (Pitrou, Kamili, Provost 2020), we explain that in bringing together articles that look at diverse sociotechnical contexts, we hoped to conduct an epistemological experiment, by including in our analytical model sets of facts one does not usually think of when thinking about biomimicry. Our goal is to construct an anthropological concept of biomimicry that is broader than the one found in recent Western discourse, and better suited to studying variations in technical relations to nature across time and space. It is too early to draw conclusions from this undertaking. For the moment, we will simply make a few methodological remarks that can help guide studies of biomimicry within the human and social sciences.

3 Drawing on research carried out in France, Japan, Siberia, Mexico, the United States, New Guinea, and Ethiopia, the texts published here shed light on what humans do when they imitate. Reading them together brings out traits common to very different situations, within the laboratory and without, in traditional societies as well as in the Western world. Four aspects of practices of imitating living beings and modeling life have emerged as significant: the selection of relevant characteristics of the relations between organisms (and objects) and their milieus; the use of analogies between living beings and techniques; processes of learning that make clear the circularity between a technicist view of nature and the fabrication of biomimetic artifacts; and the role of imitation in building collectives.

Imitation as the objectivization of organisms and milieus

In both laboratories and traditional societies, imitating a living being never means duplicating it. Every act of imitation is based on a selection: a certain trait is identified and judged relevant in an organism or living system that is perceived or modelled in such a way that it can be integrated into objects or body techniques. Although such operations isolate biological functions in order to replicate them in objects, in most cases, this isolation takes into account the milieu within which an organism lives.

4 Experiments in robotics offer good examples of this double operation—objectivizing a function and making the connection to a milieu—at work in constructing bioinspired systems: Elizabeth Johnson studies the case of the robot lobster built at the initiative of the United States Department of Defense. While the robot's morphology replicates the lobster's, the marine arthropod's material, physiological, and sensory complexity take a backseat to its neurology. This choice was guided by its creators' objective: to explore inaccessible regions of the ocean in order to deactivate mines there. By coding neurological traits into the robot's programming language, they created a machine capable of walking the ocean floors like a lobster.

5 This kind of double operation can also be found in the text by Stéphane Viollet, Julien Dupeyroux, and Julien Serres from the Étienne-Jules Marey Institute for the Sciences of Movement. These roboticists focus on the sensory organs of the desert ant *Cataglyphis*

in order to create a "navigation strategy" for their robot Antbot. *Cataglyphis* is known among biologists for being able to explore its environment without spreading pheromones, as other ants do, and for returning to its starting point in a straight line. *Cataglyphis* is capable of perceiving the polarization of light by means of organs located in its dorsal rim area. The great accomplishment of the ISM researchers is to have transposed this physiological particularity onto a "celestial compass," a tool based on polarization sensors and a set of equations. This "compass" is mounted onto the Antbot, which can move using articulated legs. Thus, we see that here, imitation of an organism takes place at two complementary levels: the level of the morphology of certain organs and that of systems of co-ordination.

6 These experiments compel us to go beyond a binary approach that would see imitation as merely copying a living being onto a technical object. A more complex schema must be explored, in which the milieu and the relations that are established within it are taken into account, constituting a third term on the basis of which the relation between living beings and artifacts are established. A milieu is not a uniform set of limitations but rather a system within which multiple relations can be established. This is true because for an organism, "to live is to radiate, it is to organize the milieu from and around a center of reference" (Canguilhem 2008 [1952]: 113-4). Similarly, technical objects can be neither conceived nor created without taking into account the relations that they establish with their "associated milieus" (Simondon 2017 [1958]; on this topic, see for example C. Sautchuk's excellent analyses (2018) of the harpoon's capacity to "open" milieus to fishermen). The form and function of an object that imitates an organism are determined by a double relation. On the one hand, imitation must bring out the relations between this organism and its milieu. On the other, the construction of the object must take material constraints into account.

Miro Robot Fish

Marketed by the Korean company Airo, these artificial fish can evolve autonomously in an aquarium, or be remotely controlled.
Salon Innorobo 2017 © Joffrey Becker

7 In the Chemfit project studied by Cyrille Jeancolas, the droplets of water produced by chemists at the Paris École supérieure de physique et de chimie industrielle (City of Paris Industrial Physics and Chemistry Higher Educational Institution) also shed light on the role of the milieu. These experiments in microfluidics reproduce the behavior of living cells in order to study the conditions under which the first cells appeared in the living world. These droplets cannot be considered "biological"; they are produced in a milieu so acidic that no known living being could survive there. But these experiments do more than imitate the functioning of elements of living beings: they model life. Just as an organism or its parts cannot be detached from a milieu, the microfluidic chip creates the environmental conditions in which the drops can "live" and evolve. Even if this technical device has no biological component, the fact that it creates a relation between an element and its milieu helps in thinking about the evolutionary mechanisms that may be at work in the transition from non-living to living systems.

8 Along similar lines, Lauren Kamili's study of a project to create a bioluminescent lamp shows that the relations between an organism and its milieu must be taken into account, even when doing so is not part of the initial project. She demonstrates how an attempt to reproduce a biological function taken in isolation—here, the bioluminescence of a mushroom—culminated in the exploration of a universe that exists between species, a relational universe that is built as the object is developed. This object, which has the form of a lamp in a jar, is not simply utilitarian: it is an artificial milieu that makes it possible for a symbiotic system to function. After some initial experiments, Helena Amalric, the designer, and her customers observed flies inside the

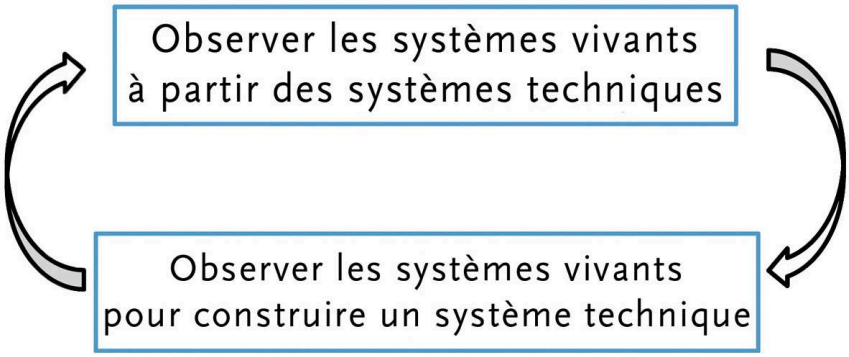
glass globe containing the mushrooms. At first, these flies were seen as intrusive, disruptive elements; as a sign of dysfunction. But they gave rise to a line of questioning that ultimately led Helena and Didier Blaha, her mycologist colleague, to a discovery: the symbiosis between the insects, the fungi, and trees. The light of the mushrooms attracts fruit flies, who lay their eggs in a piece of wood; in so doing, they facilitate its decomposition, which makes it easier for the mushroom to eat, so it can produce more light. The investigation progressed as the researchers' comprehension of the functioning of biological organisms increasingly took into account the relations between organisms: while the initial project was to replicate a function, in the end, it was an ecosystem that was recreated. Once again, the imitative process was based on an intersecting inquiry that looked both at relations between living beings and their milieus and at artifacts understood as tools and as milieus, or as elements of milieus.

9 Ultimately, what is imitated in biomimetic projects? An entire organism or one of its biological functions? A single vital process or an ecosystem as a whole? In what way is the milieu of the living model taken into account in the project to imitate it? And how is the biomimetic artifact connected to this milieu? Rather than simply affirming that objects imitate natural beings, one must detail how identifying a function within an organism implies taking into account its relations with a milieu. Symmetrically, an artifactual assemblage that is inspired by a living system cannot be conceived without some reflection on how it fits into a milieu, whether natural or artificial. Taking the milieu into consideration thus requires being attentive to what happens *after* an object is built—not only before and during.

Imitation as a search for analogies

The iconography that accompanies standard discourses on biomimicry usually involves an image of a living being that mirrors the technical creation it is supposed to have "directly" inspired, as if imitation were a term-to-term juxtaposition of biological and technical elements. The contributions to this issue demonstrate more complex technical and mental processes, and ask us to think through situations of circularity. Like the concept of the milieu, which serves as a third term for thinking the relations between a living being and an artifact, *analogies* serve to mediate between living and technical systems (Pitrou 2017). From this point of view, biomimicry is also technomimicry—or at least implies moments when nature is perceived through a technical analytical framework.

10 If analogy creates a chiasmus between organisms and artifacts, this intersection should be understood as a dynamic, by bringing out the circularity of the relations established with natural systems. Of course, biological knowledge presides over the construction of biomimetic technical systems but, at the same time, technical analogies are used as tools for thinking and perceiving living beings: thus, technical construction precedes the imitation of nature both chronologically and logically. The process of isolating a function or seeking to solve a practical problem emerges from a view of nature and of living systems that is oriented by an underlying technical project, whether that project is explicit or potential. Imitation never consists in a single operation: it is a reiterative process that compares and contrasts different systems.



11 Sacha Loeve demonstrates how the members of Jean-Pierre Sauvage's team bring a technicist view to bear on nature and living beings. In their department of synthetic chemistry, these scientists create molecules that are designed to act as "molecular machines" in order to meet topochemical challenges. Here, entities from the natural world comprise a catalogue that makes it possible, by means of a formal analogy, to requalify these "machines" that are *a priori* without utility. Sacha Loeve uses the expression "natural analogues." For example, in the capsid to the bacteriophage HK97, the chemists found a natural analogue to the "tetramer…of pseudorotaxane" that resulted from failed attempts to fabricate molecular chainmail. Or, in the protein known as chaperonin, a natural analogue to their "molecular press." We may draw two ideas from this. First, the analogies identified by these chemists are based on a biological mode of description of objects that operates, to use the author's words, "always already by analogy to techniques." Second, the act of drawing these analogies inaugurates a particular regime of relations between technique and biology that implies a formal and kinetic proximity—never an identity—between entities. Thus, in one and the same movement, resemblances requalify both the technical object and the biological object.

At Biomim'expo, a device that reduces evaporation is displayed alongside its inspiration, the water lens plant.

Senlis, 2017 © Lauren Kamili

12 Mathilde Gallay-Keller's article reveals this technicist lens at work in how living beings are entered into a database at the Muséum national d'histoire naturelle (French National Museum of Natural History). Whereas in the past the objective was to catalogue living beings in order to systematically analyze their traits and evolution, here, living beings are "tested" for how they might be able to serve human technology. Gallay-Keller studies an agro-industrial group trying to solve the problem of *Fusarium* head blight, a disease that affects wheat yields. Scientists at the Museum were contacted to take part in this effort and proposed a solution based on a process from the living world: symbiosis, a mode of interaction in which two organisms co-exist by providing mutually beneficial services to each other. By taking a series of samples from wheat fields, experts created a database of species in order to identify those that might be able to eradicate the *Fusarium* microfungi while living in symbiosis with wheat. Here, species are not observed for what they are, but rather for the already-identified potentials they contain as well as those that might be discovered. The ritual practices associated with agriculture among the Mixe, an Amerindian group in the Mexican state of Oaxaca, represent another occasion for tracing the porous boundaries between technical systems and living systems (Pitrou, this issue). The ceremonial deposits made to solicit the action of an entity known as "He, Who Makes Being Alive" indeed model an ecosystem. The ritual gestures of distribution, which are carried out from an overhead position on a demarcated surface, can be interpreted as analogues of a process that contributes to the growth of corn by distributing rainwater throughout a field. But this biomimetic translation of an ecological system itself depends heavily on a human agricultural project that understands the role of rainwater by analogy with a

technique for planting: both are operations of distribution. Within a regime of "co-activity" (Pitrou 2012), the imitation of nature is but one moment within a larger conceptual and pragmatic operation, in which analogy becomes a framework for thinking together phenomena that at first seem incommensurable: sowing and rain as acts of distribution.

13 In parallel with a line of inquiry that seeks to describe the natural and artificial milieus associated with biomimetic enterprises, it is thus relevant to develop another line in order to trace in detail the circularity of sequences in which humans look at living systems as technicians, or take inspiration from them to make artificial systems. The central role of analogies, which actors may use more or less explicitly, thus merits analysis in order to shed light on their intellectual workings: how do they translate one system into another? What elements are judged pertinent to this operation? At different moments within a biomimetic process, what is the system of reference? To what extent does an analogy bring out intermediary representations between two systems of reference? Insofar as analogies are also means of carrying out technical actions and instituting co-ordination between very different forms of agency, we must also catalog the kinds of collaboration and skill transfers that are established through biomimicry.

Imitation as active learning

According to the logic of the bio-inspired process promoted by the organization co-founded by Janine Benyus, the Biomimicry Institute, or, in France, by the Centre européen d'excellence en biomimétisme de Senlis (Ceebios), observation is understood as a distinct, defined stage that precedes any technical intervention on or with a living being. But this ideal type does not match actual practices. The examples we have looked at demonstrate an iterative approach, in which biological knowledge informs the construction of technical systems, which in turn creates new knowledge about the imitated living beings. The development of a biomimetic artifact is not a linear process that transposes data from biological systems to technical systems: it is a process of co-construction in which technical knowledge orients one's perspective and isolates functions, while better observation of natural entities leads to refining the objects built. It is thus important to envision the circularity of this relation, by examining how, within iterative processes of learning, cycles of observation and technical experimentation are intertwined. But the biomimetic discourse on learning ignores the active role living beings play in the learning process. Many of the texts here emphasize that imitation is also an experience of cohabitation that leaves room for non-human otherness, and allows humans to learn from this.

14 Florence Brunois's studies among the Kasua of New Guinea highlight a form of knowledge sharing between humans and non-humans. The imitation practices of the Kasua are rooted in a cosmology in which each human being exists simultaneously in the visible world and in the invisible world of spirits. The forest where they live is teeming with a multitude of beings, each with its own point of view. Very early on, Kasua children learn to adopt these non-human perspectives, at the same time as they develop a refined ethology. This "interspecies empathy" opens the way to various forms of imitation, including body techniques (dances) and artifacts (ritual costumes),

as well as practices such as hunting, horticulture, or building homes, which the Kasua acknowledge having borrowed or learned from their animal neighbors.

15 Rather than imagining that humans are inspired by nature to develop techniques, Brunois provides examples in which animals are seen as already possessing technical knowledge: they are capable of peeling fruit, building homes, and healing themselves by selecting food with medicinal properties from within their milieu. We may thus consider that non-humans teach humans how to proceed, but without thereby adopting the position of the Biomimicry Institute, which sees nature as a "teacher." Different practices of imitating living beings open the way to diverse forms of learning, whether it is a matter of imitating a living being in order to understand it better or learning from a living being in order to imitate it better. Without humanizing or anthropizing the behaviors of animals and natural systems, imitation can be seen as a form of co-ordination and collaboration between humans and non-humans within an inter-species ecological community. A similar idea can be found in two articles in this issue dedicated to ecological projects that position nature as an organizing force, by letting natural systems "do their own thing"—a modality of indirect technical action described by André-Georges Haudricourt (1962).

16 Marie Lusson's text focuses on the environmental engineering techniques used to restore a river in the south of France. Within such projects, it has been learned that technical action is more effective when it grants greater agency to the river, recognizing the logic of the milieu's self-organization. The engineering teams of the Water Agency strive to re-establish the "natural" functioning of a river whose course has been repeatedly re-routed for agricultural purposes. Territorial planning techniques divide and reorganize the environment through technical operations such as digging ditches, planting trees, reintroducing species, etc. This anthropization of a milieu makes apparent that which resists the human effort to build an ecosystem as if one were putting together the pieces of a building block game. A bioinspired moment then occurs: actions based on the strategy of "doing" give way to other strategies based on the perspective of "letting do" [*laisser-faire*]. Imitation, which often involves specific actions, here takes the form of a decision to refrain from acting. As among the Kasua, a sort of transfer of skills takes place: humans do not impose their laws on nature, but rather learn by observing it. However, this practical knowledge is only gained because a technical project establishes observation at the beginning.

Dance of the tigers, Chilapa de Álvarez

In the festivities of many village communities in Mexico, the imitation of animals can be associated with several purposes: ritual staging of conflicts, initiation of young people, petition for rain.
CC by SA Brian Carmona León, Chilapa de Álvarez, Guerrero 2018

17 This dynamic is at the heart of experiments by Yoann Moreau and Masumi Oyadomari to explore relations between "doing" and "letting do" in the farmaculture Masumi practices in Japan. Masumi is a former engineer, with whom the anthropologist Moreau has carried out a collaborative study of relations between savoir-faire and milieus. This mode of agriculture takes inspiration from ecosystems in order to "grow edible plants without cultivating the land." This means not plowing, not weeding—in short, not relying on common agricultural techniques. Observing natural rhythms leads to "slowing down" human intervention in order to grow plants. A garden is thus conceived by balancing times of human action with times when it is suspended. Here, nature is not an engineer on a quest for profitability; instead, the image is of a nature that "does nothing," but *is*. Here again it is a matter of technical choices that emerge within an initial project to intervene on a cultivated plot of land.

18 Observation thus emerges as a temporal process that implies leaving time for a living being to experiment and find its rhythms: the rhythm of human action and its suspension. Actual description of the conditions under which biomimetic projects are developed and completed leads to thinking in terms of long, slow processes—the kind of temporality natural processes may have. In order to imitate well, one must spend a long time co-existing with that which one seeks to imitate. This proximity, even intimacy, is present in all forms of savoir-faire and opens up experimental pathways that the engineer's plan, outlining all the stages ahead of time, could not possibly anticipate. What is the temporality of imitation? How many cycles of observation and experimentation must be completed? Who teaches whom—and at which moment? In seeking to answer these questions, the goal is to grasp in detail how a way of looking, knowledge, and savoir-faire are all constructed over the course of uninterrupted cycles

of observing and experimenting with ecosystems. If imitating living beings invites us to learn *from* them, it also implies learning *with* them, and thus, forming collectives.

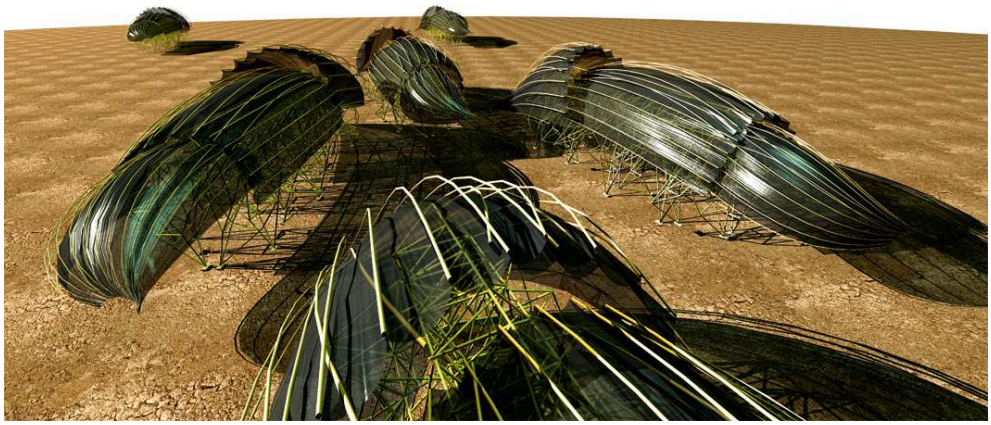
Imitation as the construction of collectives

Scientific experimentation does not consist in taking nature as a model; rather, it creates conditions for observing and interrogating it in a useful manner. This is also true of the experiments carried out in interactions with the living beings that populate natural environments—but the relations established in this context are motivated by criteria that are not only utilitarian: they may be ludic, ritual, or artistic, for example. This accounts for the fact that biomimicry is part of the construction of collectives, following logics that are not at all limited to the domains of science and engineering.

19 Games and rites are interesting practices for exploring biomimetic undertakings, as Roberte Hamayon's analyses remind us (*La Chasse à l'ame* [1990]; *Why We Play* [2016]; and her interview in this issue). Her work is based on her ethnographic studies among the Buryats, a people living on the shores of Lake Baikal in Siberia. Wrestling games played by Buryat youth and the dances that are part of nuptial ceremonies establish complex relations between humans and between humans and non-humans. Wrestling is a form of imitating the fights between young stags, and it develops qualities judged essential for men and indispensable to their marriages. At the same time, ritualizing wresting is a form of acting on a natural milieu: for example, fights that take place on a mountain summit might seek to encourage rain. The imitation of animals by shamans is another context in which one can trace the interlacing interactions that take place in the non-human sphere, where the shaman interacts with various animal entities, and in the human sphere, where the shaman intervenes to address misfortune. Mobilizing a large range of techniques (body, song, ritual objects), shamanic activity also participates in organizing a collective. Whereas in wrestling matches and dances, youth behave "like" animals, the imitation performed by shamans is carried out "as if" they are participating in interactions that take place in a supernatural space, and it constructs a fictional framework that opens onto new regimes of action.

20 In a similar manner, the imitation of cattle in the dances of the Mursi in Ethiopia, which Jean-Baptiste Eczet studies, is based on a double connection: by selecting behavioral traits of cattle to imitate through body techniques and ornamentation, men and women take part in building the social order. The dancers do not fully imitate the cattle—for example, by going on all fours and making movements with their heads. Rather, imitation is selective and focuses on qualities deemed essential depending on the dancer's age and gender: by miming the bellowing of bulls, young men represent their ability to fight; the women's skipping emphasizes the importance of successful pastoral activity; and the passivity of the elders before the dancers, which crystallizes the attitude expected of a cowherd with respect to his herd, demonstrates the Mursi political ideal. Imitation does more than make manifest interspecies relations: it participates in building a social hierarchy. Observing the imitation of living beings constitutes a precious tool for social anthropology—not just for the anthropology of techniques.

Theo Jansen is known for his wooden structures, imitating living forms, which he makes move on the beaches of the North Sea.



Gryllothalpa (1995) is a digital work featuring computer-generated virtual creatures whose genetic code is composed of zeros and ones.

1995 © Théo Jansen

21 Ludic, ritual, and poetic imitations are not only observable outside of the Western world. We find examples of it in contemporary art, within the domain of bioart for example. At the interface of art and science, the project of Lia Giraud, Térence Meunier, Philippe Marmottant, and Nathalie Henrich-Bernardoni is to artificially imitate "fish songs." Their work illustrates the plurality of views different disciplines take of living beings. In their experiments, the physicist of the group focuses on the frequency at which the fish bladder vibrates; the bio-acoustician looks at "sound landscapes"; the biologist draws attention to the fish's morphology; while the sound technician reproduces the fish song by focusing on its audio component. Imitation strategies make various dimensions of an organism apparent. The effort to imitate a vital phenomenon can serve very different purposes. Beyond the range of potential discoveries about an organism and the techniques used to carry out an investigation, this kind of research-creation reminds us that art and poetry are powerful engines for exploring the real. Socially, this process is part of constructing a space in which the actions of participants and the objects they make cannot be explained by utilitarian reasons, nor by the quest for functions and solutions within a living being. For anthropology, these practices confirm that a large palette of social customs for imitating living beings exists.

22 A change of scale is necessary to trace the integration of imitation into larger dynamics. As we analyze the sequences of technical operations necessary to ensure mediation between an organism and a milieu and between a living system and a technical system, operations of synthesis must also be examined. What attachments and communications does imitation encourage between humans and the beings they imitate? What type of community does it create? What are the normative and value systems that determine biomimetic enterprises, and how are these systems reinforced by imitation? In seeking to answer these questions, we have favored investigations

carried out within the domain of the social sciences, which shed new light on biomimicry. The goal here is not to understand how to build biomimetic artifacts, or to formalize procedures for doing so. Rather, it is to explore how, individually and collectively, human identity is constructed through the incorporation of otherness. In this way, we free ourselves from a binary approach that sees the imitation of living beings through techniques in terms of a copy seeking to reproduce an original. To imitate is always also to establish a connection and a relation, which is why, at several levels, biomimicry may be understood as a very particular means of communicating and constructing a shared world.

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NOTES

1. Although biomimicry and bio-inspiration are differentiated by some actors, who consider them to have distinct processes, methods, and goals, within the general anthropological perspective we take here, inspiration is understood as a form of imitation. See the following ISO standards: ISO 18458:2015 Biomimetics: Terminology, concepts, and methodology; ISO 18459:2015

Biomimetics: Biomimetic structural optimization and ISO 18457:2016 Biomimetics: Biomimetic materials, structures, and components.