5
Interspecies communication and performance

In a now classic definition, Hal Foster characterizes the 'anti-aesthetic' art that breaks with modernism as a cross-disciplinary practice that is open to 'forms that deny the idea of a privileged aesthetic realm'.[1] The art–science projects explored in this chapter expand our understanding of the 'anti-aesthetic' through a radical reworking of notions of artistic autonomy. They do this not only by incorporating in art some of the disciplinary practices of science, but also by staging the intelligence and creativity of non-human species. Curating forms of interspecies encounter shifts the focus away from human ingenuity and allows us to observe some of the ways in which other species perceive, communicate and create. The projects gathered here forge means of interaction between humans and a range of other forms of life, including plants, marine mammals, bacteria and slime mould. They draw on surprising recent discoveries made by biologists and plant scientists concerning perception and cognition in other species. They challenge long-held (Aristotelian) convictions regarding the unassailable superiority of the human species and encourage us to rethink our interactions with other species within a common world.

These recent works have antecedents in electronic art as well as bioart. In Argentina, for example, where electronic art is a highly developed field, several multisensory installations created from 2005 onwards extended the possibilities of generative and interactive art to explore the dynamics of growth, order and evolution in nature. In Mariano Sardón's *Cultivos estocásticos* (*Stochastic Cultures*, 2005), which was installed in the Museo de Arte Latinoamericano de Buenos Aires (MALBA), data generated by computer keyboards and mice used by employees in other parts of the Museum created the basis for an

immersive multisensory environment. The algorithms that translated the data into sounds and images modelled ways in which organic systems create order and structure out of aleatory events.[2] *Sensible* (2006), developed by Proyecto Biopus, allowed participants to create a virtual ecosystem by balancing the needs of different organisms; these interventions also generated a real-time musical composition based on the ecosystem's configuration.[3] In Martín Bonadeo's *Pasto termosintético* (Thermosynthetic Grass, 2008), artificial grass appeared to grow when the light and the temperature inside the gallery increased, partly as a result of the presence of human visitors in the space.[4]

These works exemplify a growing interest in creating interactive installations and responsive environments that mimic the complex dynamics of an evolving ecosystem. However, although some of these works use Petri dishes, depict growing plants or configure entire ecosystems, the only organisms being cultivated here are virtual ones. In contrast, many of the works discussed in this chapter and in Chapter Six comprise real plants, animals and other organisms, demonstrating how these respond to different variables in their environment and how they act upon those environments themselves. At least two important implications arise from these differences. First, the participants' attention is focused not on the power of computing and human programming to create a multisensory environment, but on the multisensory faculties of plants themselves, which communicate with their environment in sophisticated ways that scientists are only beginning to understand. And second, participants do not primarily understand their role in these installations as agents, whose decisions may cause plants and ecosystems to flourish or not, but as part of a medium in which multiple agencies are at work.

George Gessert finds that bioart tends to 'challenge anthropocentrism', as the presence of living things often reminds us that 'nonhuman forms of life are not simply raw materials but entities that do not need us for validation or improvement'.[5] In fact, bioart may work equally effectively to shore up anthropocentrism, either through experimenting with prostheses to extend humans' perceptual and cognitive powers, or by parading before us the superior creative intelligence of the human artist who has successfully coaxed living matter into an aesthetic work or performance. In Eduardo Kac's *Natural History of the Enigma* (2009), the insertion of the artist's genes into a petunia arguably reveals little about the plant and more about the increasing capacity of humans to intervene in the genetic code of living things for a variety of purposes, some of them purely aesthetic. His

work has invited widespread criticism for its sensationalism, with many scholars denouncing its superficial treatment of bioethics. Writing on Kac's infamous green fluorescent *GFP Bunny* (2000), Manuela de Barros finds that there is no real questioning of the biotechnologies used: 'han sido domesticadas artísticamente y esterilizadas intelectualmente' (they have been tamed artistically and sterilized intellectually).[6] Gessert's more positive characterization of bioart certainly holds true for the great majority of contemporary bioart projects developed in Latin America, however. Mariela Yeregui finds in this corpus a consistent attempt to divert attention from the human creator, emerging from artistic practices that she considers to be 'decolonizing' in their overturning of hegemonic Western perspectives on nature.[7]

Kac's transgenic art may indeed offer a useful point of contrast with the great majority of recent bioart projects developed in Latin America. In creating the transgenic petunia (called 'Edunia', to signal its dual genetic heritage) and *GFP Bunny* (Alba), for which a jellyfish gene was inserted into a rabbit embryo, Kac transferred genes from one species to another to create hybrid organisms. Whether for financial, political or ethical reasons, there is little interest among most contemporary bioartists in Latin America in performing transgenic procedures of this kind. Instead, their work is directed towards exploring possible means of communication between species that already exist. This is a crucial difference. Transgenic manipulation takes commonality as its starting point, relying on the universality and exchangeability of the genomes of all living creatures, as gene transfers are only possible because of the large proportion of genes shared between animals, plants, insects and bacteria. Interspecies communication, in contrast, starts with a notion of difference, and works towards overcoming it through increasing our awareness of diversity in non-human perception and cognition. One relies on an impoverished idea of commonality based on genetic similarity, while the other recognizes the challenge of constructing a common world in which multiple species may thrive. In an important sense, the projects of Colectivo Electrobiota, Ivan Henriques, Guto Nóbrega, Ariel Guzik and Interspecifics discussed in this chapter – as well as artists throughout this book who work with organic material – are not incursions into biology so much as interventions in culture, addressing the urgent need to find new ways of relating to other species.

To learn to apprehend the myriad life forms that surround us – many of which evade ordinary human perception – and to start to understand how they relate to their environment are crucial steps in building a world marked not just by the coexistence of humans and non-humans but by

increasing collaboration and even co-creation. Bruno Latour asks, 'How can one take new beings into account if one cannot radically change the position of one's gaze?'[8] Here, the sciences offer instruments, methods and skills to help us record and listen to 'the swarming of different imperceptible propositions that demand to be taken into account'. In this sense, as Latour contends, science does not present the illusion of a 'detached' perspective, 'a view from nowhere'. Quite the reverse: by means of specialized instruments and models, it constantly shifts between different viewpoints, allowing the world 'to speak, write, hold forth'.[9] If many of us lack the training and the equipment required to decipher such languages, art may play a significant role in rendering them visible, tangible or audible to a wider audience. Interspecies interactions are made possible and enhanced by art's capacity not simply to record or to translate, but also to stage affective encounters that deepen our embodied understanding of the subjectivity and agency of other forms of life.

I. Plantbots and the logic of vegetal life

Julien Offray de La Mettrie, physician and philosopher of the French Enlightenment, found many continuities between man and animals but very few between man and plants. In *L'Homme-plante* (*Man as Plant*, first published in 1748), La Mettrie defined the plant as 'an immobile animal' that has no soul and lacks feeling; as plants have 'no needs' and 'no desires', even the slightest trace of intelligence would be 'as superfluous for them as light for a blind man'.[10] In more recent decades, the agency and autonomy of plants have been widely debated among plant physiologists and philosophers. There is a growing consensus among scientists that plants demonstrate capacities – such as intelligence, sentience, perception, purpose, mobility, and the ability to respond with discretion to different stimuli and even to learn – that are consistent with many definitions of autonomy and intelligence.[11]

Matthew Hall points out, however, that these recent advances in scientific knowledge have had little bearing on contemporary Western practices with respect to plants. Remaining wholly instrumental, these have led to widespread deforestation, soil erosion, the devastating introduction of invasive species or monocultures for commercial profit, and, as a result, the highest rates of habitat destruction ever known.[12] The use of plants in the artworks explored in this section emphasizes the subjectivity, agency and autonomy of plants in ways that challenge this reckless subjection of them to human purposes. None of the artists whose

work I discuss advocate some kind of purist 'return to nature', however, in which we would abandon agriculture or the use of plants for biofuels or desist from any technological intervention into natural processes. Instead, they imagine new, more horizontal relationships between humans and plants, in which technology is more respectful of the natural life cycles of plants (or fungi, or bacteria) and the complex ecosystems in which they participate, allowing us to become more conscious of plants as subjects and as our potential collaborators.

One of the ways in which they do this is by rendering plant signals perceptible to the human eye or ear. Many art–science projects have sought to record, amplify, transduce and transmit the different signals emitted by the animal, vegetal and even mineral forms that compose this planet, often with the aim of bringing us into a closer encounter with other ways of being in the world. Some of these attempts merely translate different frequencies onto a scale that can be perceived by humans, in a way that does little to expand our understanding of the phenomena we are hearing. The plant behaviourist Monica Gagliano rails against the use of devices to make plants 'sing' by assigning musical notes to different ranges of voltage values measured by attaching multimeters to plants. These might appear to create 'a tangible connection' between the human and the plant, by claiming to offer us a direct experience of the plant's 'voice', and they may even give evidence of plant intelligence. But the assignation of musical notes is entirely arbitrary, as these are not sounds being emitted by the plant. It is an approach she dismisses as 'immature' and 'anthropocentric'.[13]

In the first part of this chapter, I will explore recent Latin American art–science projects that have developed hybrid technologies – coupling acoustic, electronic and/or telematic devices to living organisms – in order to stage more thoughtful encounters between humans and plants. My interest can be expressed in four questions. Firstly, how have artists attempted to give a 'voice' to other species without simply translating signals into a human register, which effectively strips plants of any real agency (as Gagliano suggests)? What may such projects reveal about the agency, cognition and communication of plants? What kind of relationships are they able to construct between plants, technologies and human participants? And lastly, how are the encounters they create enhanced by the sensorial, aesthetic and affective dimensions of art?

Hannah Stark observes that while animal studies often build arguments on the basis of commonalities between humans and animals, this closeness is not extended to plants, which are 'fundamentally foreign' to us in the nature of their being and the way they experience things.[14]

In different ways, the projects explored in the first part of this chapter form responses to the question posed by the philosopher Michael Marder in his book *Plant-Thinking: A philosophy of vegetal life*: 'How is it possible for us to encounter plants? And how can we maintain and nurture, without fetishizing it, their otherness in the course of this encounter?'[15] From different disciplinary perspectives, both Marder and the plant neurobiologist Stefano Mancuso call for a greater understanding of plant agency and autonomy, as well as for a serious re-evaluation of how plant ontologies may point the way to better technologies and forms of social organization than the ones that humans have developed to date. In the discussions below, I explore what Marder calls the 'logic of vegetal life' as a model of subjectivity and communication in a common world; in the next chapter, I explore this logic as a model for new sustainable technologies based on energy cycles in nature.

Communication in the rhizosphere

Colectivo Electrobiota is the collaborative endeavour of two Mexican artists, Gabriela Munguía and Guadalupe Chávez, who have lived in Buenos Aires since moving there as postgraduate students. Bioart was – and is – markedly less well developed as a field than electronic art in Argentina, but they were able to undertake research within the broad curriculum of the successful Master's in Electronic Arts at the Universidad de Tres de Febrero, and later to teach bioart as part of the same degree. Electrobiota has developed several projects that create interfaces between humans and plants; these draw on the personal knowledge and experimentation of the artists as well as on extensive reading in plant science. The collective's work has a strongly educational focus, often involving schools or local communities. Rather than bringing members of the general public into classrooms or organizing visits to university laboratories, the artists often use mobile labs for their projects and prefer to take participants out into forests and other sites that stimulate more of a sensitivity to nature. Territory and milieu are of the utmost importance to both artists, shaping the design of their projects from the start; even the works they exhibit in art galleries often have a strong grounding in the local environment.[16] I will show that this emphasis on milieu plays a significant role in the understanding of plant communication that their work promotes, which is based on multiple exchanges between plants, fungi and microbes within the rhizosphere.

In an earlier solo project, *Talking Green* (2012), Munguía placed a microphone near a plant to capture the sound of a voice talking to it.[17] This

sound was transformed into different frequencies; as a secondary effect, it caused the image of a plant projected on a wall to extend upwards, representing a boost to the plant's growth. It was a playful invitation to take part in a more intimate encounter with a plant, and to understand how we might act to stimulate plant growth. In a sense, the project reverses the dynamic described by Gagliano, in which multimeters transduce plant vibrations into human sound: here, human sound is transformed into a range of different frequencies (between 100 and 600Hz) that have a positive effect on plant development, as recent studies have shown.[18] As in *Interactive Plant Growing* (1992), by Christa Sommerer and Laurent Mignonneau[19] – artists cited by Munguía as an important influence on her work – the human participant in *Talking Green* interacts with a real plant in a way that generates a computer-simulated image of plant growth. But while both projects increase our awareness of the sensitivity of plants and a sense of our responsibility for them, they are not equally credible in scientific terms. In Sommerer and Mignonneau's work, simulated growth took place if the human participants touched the plant or moved their hands near it, actions which in real life make little or no difference to plant growth, and in the installation merely bolster an illusory sense of human agency. *Talking Green* was more successful in revealing ways in which humans may indeed affect plant development, and in creating a more direct encounter in which real – not just simulated – plant growth could take place.[20]

However, the visible expression of that interaction – an illustration projected onto the wall – remained entirely human in its symbolism. Reflecting on the project afterwards, Munguía decided she wanted to work in a different way as, with plants, 'no se les puede hablar humano' (you can't speak human). As she started to work alongside Chávez, her aim became how to decentre human language in favour of other languages, how to shift perspectives, and, rather than simply to translate one signal to another, to ask 'qué significa en un ecosistema una señal?' (what does a signal mean within an ecosystem?).[21] The projects they have developed since represent different attempts to give a 'voice' to plants and their many interlocutors and to allow them to hack into human communication systems. Each presents an interesting set of compromises between scientific verisimilitude and artistic expression.

Rizósfera FM (Rhizosphere FM, 2016) comprised an installation and a sound intervention, both inspired by the myriad interspecies interactions that make up the rhizosphere, the soil around a plant's roots that we now know to be a site of complex connections between different plants and their environment.[22] The project was primarily centred on

a single tree, located outside the Caseros rail station in the province of Buenos Aires and very close to a branch of the Museo de Artes Visuales, run by the Universidad de Tres de Febrero. Through the creation of a hybrid network of plants and media technologies, the project reflected on and partially re-created the complex relationships that allow trees to communicate with each other via their roots and microbiomes.

Recent research has highlighted some of the complex ways in which trees, fungi and bacteria interact with each other within the rhizosphere, enabling the underground redistribution of water and minerals or acting as a mutual defence system within a forest, permitting an individual tree to raise a general alarm if it becomes diseased. These messages are carried both by chemical compounds and by electrical impulses. The vast potential for the communication of diverse messages between plants and trees, by means of the fungal underground network that connects them, leads Peter Wohlleben to describe forests as 'superorganisms with interconnections much like ant colonies'.[23] These relationships, crucial to the health of trees and other plants, are often destroyed in urban environments. The compacted soil under a pavement restricts root growth, and the harsh conditions of the urban microclimate – with heat absorbed by concrete, exhaust fumes and dry air – limit the growth of the microbes that the tree needs to connect to the wider ecosystem.[24]

Rizósfera FM responded to this act of ecological segregation by means of a poetic reconnection of the tree with other plants, placed in the exhibition space of the UNTREF's Museo de Artes Visuales. A series of DIY sensors were used to measure electrical activity in the soil near the roots of the tree outside in the street and in pot plants placed inside the museum (see Fig. 5.1; the plants were all donated by friends or neighbours living nearby). Measuring fluctuations in electrical activity in the soil rather than the roots of the tree themselves allowed Munguía and Chávez to emphasize the extent to which the tree is – or should be – part of a dynamic ecological system. These signals were amplified and translated into analogical frequencies. These were then retransmitted via local FM radio channels, allowing museum visitors to tune in using the portable radios provided and 'listen' to the rhizosphere in real time.[25] The idea was to 'hackear la comunicación humana' (hack human communication) for the expression of non-human ends, appropriating mass media systems – dominated as they are by human technologies and languages – for an interspecies performance.

Radios placed near each plant in the exhibition space also broadcast to them the 'sound' of the tree's rhizosphere outside. This is the point at which the communication constructed by *Rizósfera FM* diverges

Figure 5.1 Colectivo Electrobiota, *Rizósfera FM*, 2016. *Premio UNTREF a las Artes Electrónicas*, Museo de la Universidad Nacional de Tres de Febrero, Caseros, Buenos Aires (photograph by the artists).

from scientific plausibility, as (to the extent of our current knowledge) the sounds were not transmitted to the plants in a way that could be interpreted by them. Munguía explained that scientific verisimilitude was less important to them at this stage than being able to engage their human visitors in an encounter that could be heard and felt by them, as the central purpose was to make them more conscious of the workings of a network that is largely invisible and inaudible to them.[26] Becoming aware of the hidden connections that bind plants, fungi, bacteria and minerals in a complex ecosystem would, they hoped, 'abre una puerta para aproximarnos a lo que significa estar interconectados e interdependientes con otras especies' (open a door to understanding what it means to be interconnected and interdependent with other species).[27]

A strong interest in traditional indigenous knowledge underpins the projects and the workshops on plants that Munguía and Chávez organize. Chávez's solo project *Pacha transmisión* (Pacha Transmission, 2013) gestures towards a possible integration between the scientific and spiritual dimensions of our relationship with plants. It consisted of a site-specific installation in the patio of a house that was to be demolished, where a small tree was growing out of the patio brickwork (see Fig. 5.2).[28] Native to Argentina and Bolivia and known popularly as *palán palán* (*Nicotiana glauca*), the species has a number of medicinal benefits and is

Figure 5.2 Guadalupe Chávez, *Pacha transmisión*, 2013. FUTURISSIMA, La Sin Futuro, Buenos Aires (photograph by the artist).

used in indigenous rituals. Chávez placed sensors measuring the humidity of the soil near the tree's roots; variations in humidity were translated into a form of Morse code that was transmitted in a series of long and short bleeps and printed mechanically in real time on an advancing roll of paper. Traditional offerings also formed part of the installation.

The work projects us into a future time at which plants may be able to communicate with us via technological interfaces. The use of an antiquated technology, the telegraph – particularly with its wartime associations with cryptology – is significant here because it produces a coded script that is yet to be translated, retaining something of the mystery of a message of immense importance that requires perseverance to understand. Having talked at length with religious leaders in local indigenous communities, Chávez was interested in communicating a non-dualistic perspective on nature and technology that she finds to be inherent in their approach. Her intention was to explore the potential in art to express and create a syncretic understanding of the plant world.[29] This is very much part of a decolonial vision, one that seeks to confront Western science with other kinds of knowledge: 'saberes que se transmiten oralmente, que se transmiten desde la experiencia' (knowledge that is transmitted orally, which comes from experience). In the cosmovision of

many traditional Andean communities, plants are often spirits that help and teach humans, guiding them towards greater understanding. Chávez develops her work with plants alongside technology in an integrated way, as both are able to produce 'lenguajes descentralizados desde la visión humana' (languages that are decentred from the human perspective).[30]

Marder argues that our unwillingness 'to think through the logic of vegetal life' has led us to assume that plants are less developed than animals and humans, and that 'therefore vegetal beings are unconditionally available for unlimited use and exploitation'.[31] He proposes not only that plants should be considered as subjects, but that the model of subjectivity they represent is distinctive and at odds with Western philosophy. In contrast with other types of subjectivity, the plant has no need 'to cordon itself off from its surroundings, to negate its connection to a place, so that it can fully become itself as a consequence of this oppositional stance'.[32] It cannot be reduced to a form of agency that is either active or passive, maintaining the self instead through a constant and complex series of symbiotic exchanges with its environment. Electrobiota's work allows us to glimpse something of that 'logic of vegetal life', which emerges here as sensitivity, connectivity, community, integration and syncretism. To these characteristics of plant life, other artists – as we will see below – add those of adaptability, resilience, symbiosis, distributed agency, regeneration and transformation.

Plant intelligence and mobility

The Núcleo de Arte e Novos Organismos (Art and New Organisms Unit, known as NANO) was founded in 2010 by Carlos (Guto) Nóbrega and Malu Fragoso as a transdisciplinary laboratory for the arts, science and technology within the Universidade Federal do Rio de Janeiro, Brazil. With a strong emphasis on hybridization and biotelematics, NANO has developed a series of interactive installations that bring organic and artificial elements together to forge hybrid systems. The overall purpose of these works is to explore the use of plants 'como agentes sensíveis para a constituição de uma experiência artística' (as sensitive agents in the composition of an artistic experience).[33] In direct opposition to more reductive or mechanist approaches to nature, they embrace 'o desconhecido, o sutil, o sensível, o metafísico presente na vida de todas as formas' (the unknown, the subtle, the sensitive, the metaphysical that is present in life in all its forms). This poetic builds in part on scientific

insights but also points repeatedly to what exceeds the means and ambitions of mainstream science.

BOT_anic (2013) is a plant–robot hybrid that features in an ongoing research project led by Nóbrega.[34] A plant is mounted on a small robot, with sensors placed to analyse the conductivity of its leaves (see Fig. 5.3). Human participants are encouraged to interact with the plant by breathing on it. The additional carbon dioxide absorbed by the leaves causes an electrophysical change; that information is sent to a microcontroller, which then activates one of two different states for the robot. When a variation in conductivity is sensed, the robot moves in the direction of the leaves affected, towards the human interactant. When the interaction stops, the robot is programmed to return the plant to its place of rest, under a light source. The hybrid nature of the work is emphasized in its construction, with the plant perched incongruously and precariously on top of its robot consort. The simple and familiar contours and colours of the domestic pot plant contrast with the complex interconnections of cables and circuit boards underneath, all fully on view.

BOT_anic stages an encounter between plants and humans that encourages us to consider how plants perceive: how they are able to sense our presence in ways that are invisible to us, which are not restricted to the five human senses. Indeed, plants are considered to have at least 20 senses, which allow them to capture information we cannot, such as changes in electromagnetic fields and different chemical gradients.[35] Nóbrega's experiments with the sensors revealed the great sensitivity of the response he wished to capture to multiple other factors, including ambient light and heat, whether the plant had been resting or not, and where on the leaf the sensors were placed.[36]

BOT_anic therefore encourages us to respond to plants as intelligent, receptive forms of life that are able to detect minimal changes in atmospheric conditions, responding and adapting as required for growth and survival. Mancuso suggests that the reason that plants have historically been dismissed as lesser life forms in the Western world is that the kinds of perception and agency they demonstrate are completely unlike those that characterize animals, including humans. When we think of plants, Mancuso asserts, we define them by their 'immobility and insentience'.[37] *BOT_anic* challenges these two preconceptions, firstly by highlighting the plant's sensitivity, and secondly by giving it wheels. This choice is crucial to the work's affective dimension, as it creates the illusion of a kind of subjectivity that we can recognize and demands that we engage with the plant as it heads towards us, rather like a curious puppy.

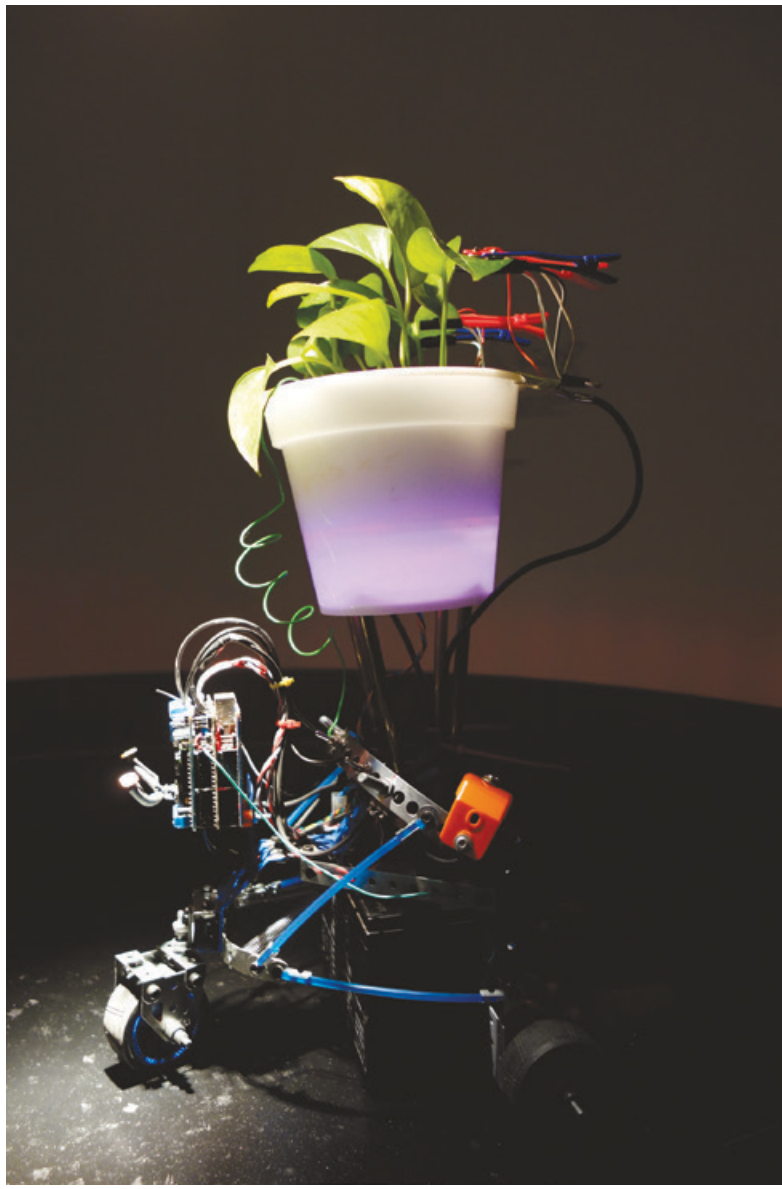

Figure 5.3 Guto Nóbrega, *BOT_anic*, 2013. *Machinarium*, Oi Futuro Ipanema, Rio de Janeiro (photograph by Steve Miller).

But the mobility the plant acquires is of course entirely unplantlike. Together with other plant behaviourists, Mancuso has emphasized that plants are not in fact immobile, a fact that we have known since the invention of time-lapse photography. Darwin himself gives substantial evidence for phototropism and other kinds of movement in plants in *The Power and Movement of Plants* (1880). However, we often continue to subscribe to the idea of their immobility, as their timeframes are so much slower than our own. Nóbrega gives his plant an entirely different kind of mobility that is clearly perceptible to us, however, being much more akin to that of an animal. This decision takes the work beyond the realm of science and into a more aesthetic, performative mode of engagement. Nóbrega sacrifices the essential *otherness* of the plant, its natural movements that are difficult for us to detect, in order to stimulate 'uma relação afetiva' (an affective relationship) between observer, machine and plant.[38]

However, the robotic element does not exist simply to facilitate and stimulate our interaction with the plant; Nóbrega also conceives that dynamic in reverse. He writes:

> Acreditamos estrategicamente no uso de plantas, assim como outros possíveis sistemas orgânicos vivos, como potenciais agregadores de uma sensibilidade conectiva aos processos tecnológicos, uma conectividade inerente aos organismos de natureza viva que parecem ter seus modelos espelhados nos sistemas artificiais que nos reorientam no mundo contemporâneo.[39]
>
> (We believe strategically in the use of plants, together with other possible living organic systems, as elements that can potentially confer a connective sensibility on technological processes, a connectivity that is inherent in living organisms, which seem to provide the models for the artificial systems that reorient us in the contemporary world.)

The role of the plant in *BOT_anic* is also therefore to express, and to facilitate, a connectivity between the human participant and technology, whose processes and forms of coupling and communication themselves often seem to mirror the kind of connectivity we see at work in the organic world. The work presents technology, not as an alien world, but as an expression of the kind of multisensorial interactivity that is already inherent in the organic world.

In his publications, Nóbrega often returns to Gilbert Simondon's conception of technological objects, not as a threat to nature, but as

potential 'mediators between nature and man'.[40] Likewise, the behaviour of living organisms may allow us to enter '[a] zona sutil entre a dureza redutiva das máquinas e a umidade complexa dos seres viventes' (the subtle zone between the reductive hardness of machines and the complex humidity of living beings).[41] Nóbrega here encourages us – like Simondon – to understand technical objects within an open system, which is what gives them their complexity, beyond the automatism of machines. *BOT_anic* points us towards a possible future in which relationships between humans, plants and machines could be even more integrated. In the future, Nóbrega suggests, plants might be able to exercise agency in their interactions with us and with technology in a range of ways that might now seem implausible.[42] He cites in this respect some of Gagliano's recent findings, which suggest the possibility that plants may be trained to respond to certain stimuli, much like Pavlov's dogs.[43]

Nóbrega has found it difficult to find scientists to collaborate with him in developing *BOT_anic* and other projects: the experiments they involve are too reminiscent of the partly pseudoscientific work of Cleve Backster on plant perception in the 1960s. *BOT_anic* makes deliberate reference to Backster's work in its use of galvanometers, although the science it draws on is now more widely accepted, unlike some of Backster's unrepeatable experiments. Nóbrega himself is interested in precisely those points of encounter between the scientific and the pseudoscientific (or in other kinds of knowledge or belief) that lend complexity to an artistic experience, evoking the tangled networks – organic, technical, cultural, spiritual – that bind us with the living and non-living worlds around us. Like Munguía and Chávez, Nóbrega refers frequently – in exhibition texts, research essays and conversation – to the power of cultural and religious beliefs regarding plants. In Brazil, plants are often strongly associated with medicine and healing, which adds, he believes, a further dimension to the relationship constructed between plant and human participant in *BOT_anic*.[44] The spiritual significance of plants does not form an explicit element of the works themselves, being largely confined to paratexts or to workshop discussions. But in other ways, the works point insistently to phenomena that mainstream science has refused to investigate as a means of carving out a space for an artistic process that is more heterogeneous, creative and poetic. This allows art to operate much more clearly in the realm of the performative than in that of the descriptive; as Nóbrega suggests, it maintains 'a potência de criar mundos improváveis e não apenas investigar redutivamente o passado, como faz muitas vezes a ciência, mas transformar o presente sem perder vínculos fecundos com

nossa memória ancestral' (the power to create improbable worlds and not only to investigate the past in a reductive way, as science often does, but to transform the present without losing fruitful connections with our ancestral memory).[45]

The priority Nóbrega accords to the artistic, performative elements of his work – over and above any more didactic content – is clear in his statement that '[t]echnology, in art practice, should be used to investigate the nature of art rather than for the sake of technology or science; it should deepen our understanding of human intuition expressed through creativity'.[46] This creativity arises from affective, sensory encounters in which both technology and living organisms may act as effective mediators for the other, forming complex systems defined by their openness. The emphasis on systems in Nóbrega's art – and that of many other artists since the 1960s – is entirely consonant with a shift in science towards studying energy and information, rather than matter in itself. On this point, Nóbrega cites Jack Burnham's observations in *Beyond Modern Sculpture: The effects on science and technology on the sculpture of this century* (1968), in which he notes a 'refocusing of aesthetic awareness […] on matter-energy-information exchanges and away from the invention of solid artifacts'.[47] Nóbrega's ongoing experimentation with telematic art, in works such as *Telebiosfera* (2013–), is part of this commitment to exploring interactions between different networks and in creating art as an open, multisensorial process that speaks to our contemporary experience in the world.

An interest in how art may construct future worlds is shared by another Brazilian artist, Ivan Henriques, currently resident in the Netherlands. Henriques combines interests in interspecies communication and environmental robotics, creating highly transdisciplinary projects that combine different systems – ecological, social and technological – in order to explore the nature of communication with other species and to promote ideas of sustainability. His projects are speculative and often utopian in their construction of new relationships between organic life and machines that enable the renewal of finite resources.

Like *BOT_anic*, Henriques's *Jurema Action Plant* (2010) is a speculative work that builds on what is currently known about plant agency and allows us to glimpse a future in which this might be expanded.[48] To develop the piece, Henriques worked with Professor Bert van Duijn, a specialist in plant electrophysiology, who had developed a technique to measure 'action potential', or the electrical signals that travel within a plant.[49] Painted in the bright yellow often used by diggers and forklift trucks and fixed up with large black rubber wheels, the *Action Plant* looks

Figure 5.4 Ivan Henriques, *Jurema Action Plant*, 2011. MA in ArtScience Graduation Exhibition, Royal Academy of Art (KABK), the Netherlands (photograph by the artist).

like an oversized radio-controlled toy (see Fig. 5.4). It carries a *Mimosa pudica* plant, connected to a custom-made circuit board. When human participants touch or bring a hand close to the plant's leaves, changes in the electromagnetic field around the plant are picked up and amplified to trigger movement on the part of the plantbot.[50]

In the machine's original design, touching the plant would make it move away from the participant, as if the machine were extending the plant's natural defence system by allowing it to move physically out of danger. In the end, Henriques decided to make the machine's movements random: sometimes it moves towards the human participant, and at other times away from them. The aim here was to avoid anthropomorphism: for him, to have the *Action Plant* move predictably towards or away from us would set up a false suggestion of emotion on the plant–machine's part. In this respect, Henriques's work differs from Nóbrega's *BOT_anic*, which more deliberately stages an affective encounter between human and plant through the machine's movement towards the participant. Neither project always functioned as programmed, however: repeated stimulation of the plant's leaves caused saturation, and it would stop responding for a while. This reminded participants that they were not dealing with a machine but a plant with more complex feedback loops,

a different relationship with time, and a capacity for fatigue and perhaps even for learning.

The *Mimosa pudica*, or 'sensitive plant', has fascinated botanists and naturalists for several centuries. More recently, it has become the subject of a controversial set of experiments on plant memory and learning carried out by Gagliano. In 2011, she found that the *Mimosa pudica*'s typical response of folding its leaves when it perceives danger could be relearned: if the plant became used to vibrations or sudden drops, it stopped folding its leaves, and could 'remember' for several days that such stimuli did not present a threat. She gives an account of this work, and her struggle to publish it, in her book *Thus Spoke the Plant*.[51] The plantbots designed by Nóbrega and Henriques – both artists have discussed Gagliano's work with her – have nothing of the rigour of a scientific experiment to investigate plant learning. However, they do show that plant reflexes are not automated responses of the kind we would expect from a simple pre-programmed machine: they are the result of a complex relationship between a plant and its environment, in which the plant is able to read and vary its responses in a way that suggests not only the operation of intelligence, but possibly memory and learning too.

Precursors to the plantbots developed by Nóbrega and Henriques were devised by Canadian and American artists Wendy DesChene and Jeff Schmuki under the collective name PlantBot Genetics. In street-based actions performed since 2009 with plants mounted on remote-controlled wheeled chassis, they draw public attention to the politics of genetically modified foods.[52] In contrast, the plantbots developed by Nóbrega and Henriques do not serve an (activist) agenda or mount a critique of biotechnologies. Their purpose is relational and affective, drawing our attention to plants as complex organisms whose modes of being and communication outstrip in sophistication the technologies we may use to approach them. They are also much more speculative in their vision of future changes in our relationship with plants: Henriques explains that the design of *Jurema Action Plant* is not only intended to increase our understanding of the way plants communicate but also to 'empower plants by enabling them to use similar technologies as humans use'.[53] These projects bring into question the paradigms that have so far dominated the development of robotics and artificial intelligence (AI); they encourage us to consider the differences between plant intelligence and machine intelligence, and how these might be coupled in new ways, for purposes beyond the human.

Bioart and 'becoming-a-medium'

In what is considered to be the earliest work of interactive cybernetic art to incorporate another species, Thomas Shannon designed a robotic structure that would move its 'limbs' when triggered by a viewer touching a plant. *Squat* (1966) is thus a precursor to both *BOT_anic* and *Jurema Action Plant*, but with a noticeable difference in emphasis. Although the connection *Squat* creates between the organic and the inorganic 'suggests that they should not be seen as opposites, but rather part of the same overarching system',[54] it is clear that the role of the plant is simply to act as an interface between the human participant and the technical object. In *BOT_anic* and *Jurema Action Plant*, the mobility granted to the plant and the unpredictability of its movements makes it less of an interface and more of an interactant. As well as becoming part of a circuit constructed by a human artist, the plant also acquires agency, even if this is sometimes of a humanlike variety.

What is significant in these works is that they simultaneously expand our conception of agency, promoting an understanding that is more complex and dynamic. While in Shannon's *Squat* the human participant caused the system to function by closing the circuit, I would suggest that the effectiveness of many of these more recent projects lies in the more ambivalent role they create for the visitor. Rather than simply being an agent who initiates the interaction, they become conscious of belonging to and participating in the wider milieu or medium in which the performance is taking place. These are not interactive works that respond instantly and automatically to a button pressed by a participant. The plants' responses are conditioned by a host of variables that are impossible to control in a gallery environment (much less in nature); the unpredictable quality of their reactions is evidence of the complex relationships they maintain with their environment and how factors such as heat, humidity, sound and atmospheric gases may affect their behaviour. Robert Mitchell argues that the 'charge' of contemporary works of vitalist bioart 'depends in part on a gallerygoer's sense of becoming-a-medium – the sense, that is, of being part of a biological milieu that has logics of transformations that exceed the gallerygoer's own goals and interests'.[55] In interacting with the plants in *Talking Green*, *BOT_anic* and *Jurema Action Plant*, the gallery visitor understands that he or she becomes part of this environment. The vibrations set in motion by the voice in *Talking Green* enhance growth, breathing on leaves in *BOT_anic* increases the concentration of carbon dioxide, and in *Jurema Action Plant* the proximity of a hand creates changes in the

electromagnetic field surrounding the plant. In contrast, in *Rizósfera FM* we become aware of the damaging effect of human activity in *blocking* the messages that bind a tree to its environment.

For Mitchell, bioart produces a crucial 'oscillation' in the position of the gallery-goer, 'between an embodied sense of being-an-agent and an embodied sense of being-a-medium'. This, Mitchell finds, 'helps prolong the experience of affect'.[56] Just as crucially, in these works it also helps us perceive our place within a shared ecology, in which each species becomes the milieu of others, and habitats are formed and destroyed through minute changes to the countless interactions that compose them. We are thus drawn into an understanding of how we are implicated, bodily, in the performances that we are witnessing. Plants, usually relegated to forming part of a landscape or a milieu for human action, are here co-agents in a milieu that is continually being constructed as a result of multiple relations between different species, other forms of matter and geophysical forces.

The deliberately low-tech and clunky design of these works marks a strong visual contrast between the living plants and the surrounding machinery that emphasizes the role of technology in mediating this encounter. This aesthetic is typical of biohacking and maker-movement techniques, which often make use of low-cost, everyday devices and expose their workings rather than hiding them inside patented cases and emulating the smart, glossy appearance of many contemporary machines. Indeed, an important function of bioart more generally, Daniel López del Rincón suggests, is to open up the 'black boxes' of biotechnology.[57] This is certainly a key motivation here: Henriques describes the use of visible circuitry as a 'political choice' that stems from a desire to 'demystify hidden technology'.[58] In these works, however, the emphasis is placed squarely on the extraordinary power of plants, rather than the sophisticated technology of humans. Many works of bionic art are governed, López del Rincón finds, by the ideas of 'substitution' and 'improvement' (of the biological by the technological, in both cases). Technology demonstrates the possibility of rendering biology obsolete and of overcoming the limits of nature.[59] These works, in contrast, seek a more balanced relationship between the two. Their interactive and performative elements, together with their speculative designs, encourage us to imagine a different and much more collaborative relationship that might develop in the future between technology and the organic world.

These projects introduce human viewers and participants to some of the most startling discoveries that have been made in plant studies in particular, knowledge which – Gagliano asserts – 'allows us

to appreciate plants as sovereign subjects of their own lives rather than usable objects of ours'.[60] Even more compellingly, however, the 'logic' of plant and fungal life that is harnessed in these projects points in itself to new models for coexistence in a common world. While many scientists and philosophers have recently argued that the evidence of plant intelligence, purposiveness and responsiveness should lead us to regard them as autonomous subjects, Marder has taken an opposing approach. He describes vegetal life as an example of 'heteronomy', as plants 'are not sovereignly self-determined and do not assert themselves over and against their environment'.[61] This provides us with an unusual model for subjectivity, he argues, in which the subject does not need to separate itself from its surroundings or transcend its place in order to become itself. 'If vegetal being is to be at all, it must remain an integral part of the milieu wherein it grows': plants contribute a 'non-essentialized mode of "living-with …"' and of thinking that is 'fluid, receptive, dispersed, non-oppositional, non-representational, immanent, and material-practical'.[62] This kind of living-with offers a vision of a collective, collaborative coexistence that would be characterized by much greater integration and synergy than is currently the case in relationships between humans and non-humans, or between humans themselves, for that matter.

II. The language of cetaceans

In *The Spell of the Sensuous*, the philosopher, ecologist and magician David Abram regrets the absence in contemporary Western culture of the 'profound attentiveness to other species and to the Earth' that he finds in rural indigenous societies. Our senses have become dulled to non-human nature, he laments, whose sounds are drowned out by incessant motors and whose existence is carefully managed through domestication and mechanized farming.[63] Ariel Guzik expresses a similar loss when he writes:

> ¿Cómo se comunican los lobos, los halcones o las ballenas azules? ¿Cuál es el lenguaje de los insectos y las plantas? Nuestros ancestros lo sabían. Coexistían con ellos. Ahora, inmersos en nuestro autismo antropocéntrico, lo hemos olvidado.[64]
>
> (How do wolves, falcons or blue whales communicate? What is the language of insects and plants? Our ancestors knew. They coexisted with them. Now, immersed in our anthropocentric autism, we have forgotten it.)

For many years, Guzik has designed and built fantastical machines to enable encounters with whales and dolphins in their natural environment. With a strong presence in ancient mythology and in seafaring tales of the modern age, these animals have in more recent times become the subjects of surprising scientific revelations concerning their intelligence and advanced communication skills. In designing his ocean-faring capsules, Guzik draws on a knowledge of the science of acoustics. The impressive technical precision of his devices is coupled, however, with an aesthetic that evokes the fantastical and the mythological; he is keen to preserve mysteries rather than to decipher them, and his primary interest is to create an affective encounter rather than to generate empirical data for analysis. His work demonstrates ways in which art may mediate between the spiritual and the scientific in a re-enchantment of the natural world.

While Guzik's aim has been to communicate with cetaceans by entering their own sensory world of acoustic perception, he has also created a cetacean language in the form of a script composed of ideograms. The written language may be considered a performative element in his work, as cetaceans do not of course naturally communicate in this way. Although dolphins have been trained to read a series of simple symbols in scientific experiments, Guzik's intention here is to create an imaginary context for his work, one that provokes reflection on the non-human origins of human language, pointing the way to a deeper understanding of communication that is thoroughly embedded in an embodied experience of the time and space of our natural environments.

Nereida (2007) is a submersible capsule made from a long tube of fused quartz crystal, suspended in a bronze frame (see Fig. 5.5). Its long, taut strings resonate when the crystal tube detects vibrations, creating ethereal, serene, bell-like notes that sound a little like a glass armonica.[65] Toothed whales and dolphins have poor vision, relying on echolocation to navigate and hunt prey. They 'see' by emitting biosonar clicks and interpreting the echoes that return from sound waves bouncing off objects in the water. All marine mammals use sound to communicate with each other, often in rhythmic sequences at different frequencies that may be used to identify individuals or to coordinate hunting.[66] *Nereida* composes, as Guzik puts it, 'un lenguaje material' (a material language) that echoes the sounds these marine mammals emit in order to communicate or to map out their surroundings.[67] It is a poetic response to their unique form of vision and expression. The capsule has been tested several times in the Mar de Cortés (Gulf of California), with hydrophones used on some expeditions to record the sounds made by passing dolphins and whales,

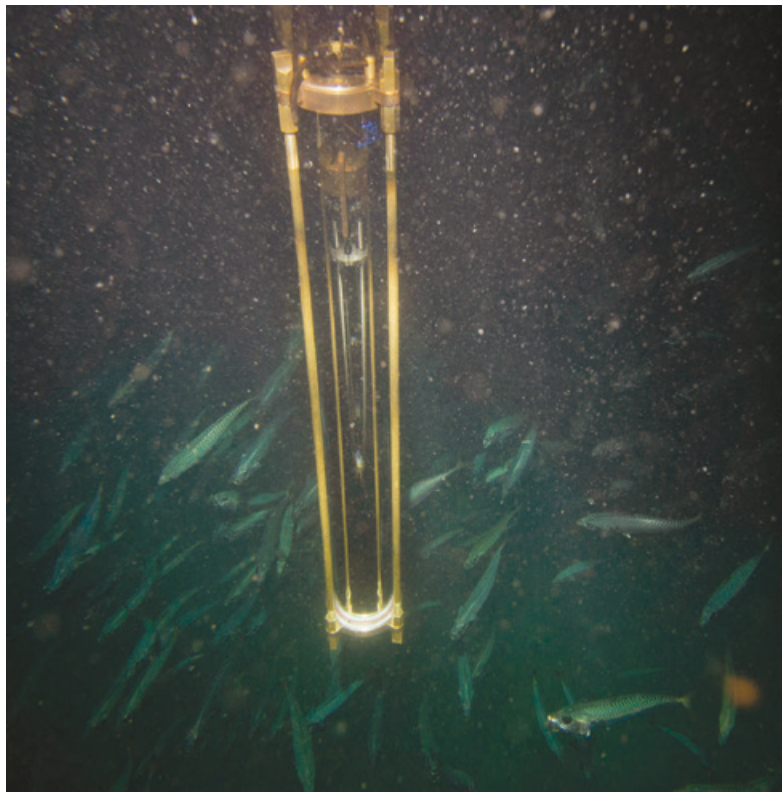

Figure 5.5 Ariel Guzik, *Nereida*, 2007. Site-specific installation/performance, Gulf of California, Mexico (photograph by Raúl González).

which receive their echo in the vibrating strings. *Nereida* was named after the sea nymphs in Greek mythology who helped sailors through storms; his own work, Guzik explains, 'propone reinstalar el encantamiento en el mar' (proposes to restore enchantment to the sea).[68]

Holoturian (2015) develops this vision further, with a capsule that is able to descend deep into the sea. Its retro style and iron casing bring to mind early designs for submarines and submersibles (see Fig. 5.6). Inside, as well as a resonating instrument, it carries a living plant, intended as an 'offering', which remains in a safe habitat (warm, light, dry) while it travels to another world (cold, dark and watery).[69] During these encounters with cetaceans, Guzik remains on a boat nearby, preferring not to enter their habitat directly. His approach contrasts sharply with the more invasive techniques that have been used by some marine biologists, trainers or zookeepers: he intends to pursue forms of

Figure 5.6 Ariel Guzik, *Holoturian*, 2015. Site-specific installation/performance, Gulf of California, Mexico (photograph by Raúl González).

communication with whales and dolphins 'without limiting their freedom and without any intentions of intrusion, training, or domination'.[70] For his third project, however (still in development at the time of writing), he will build a ship that allows him to take a more direct and embodied role in acts of communication, while still respecting the autonomy of his interlocutors. With one capsule above water connected to another below the surface, the craft will drift without a motor through the sea. The resonating instrument will send out sonic waves as usual, but this time it will be linked to his heartbeat or his voice. He would be able to live out there for a while, he thinks.

In exhibitions of Guzik's work, the capsules are accompanied by captivating line drawings of designs from his notebooks and examples of cetacean calligraphy, the writing system he has imagined (see Fig. 5.7). Although there is some resemblance between these symbols and the rounded loops and hooks of Arabic script, it becomes apparent that they are not organized according to the conventions of human writing systems, even ones that are based on ideograms rather than an alphabet. Guzik explains that only some of the symbols are figurative, bearing a relationship with the visible world. Others are signals and frequencies, unfolding over time, or the interference of two harmonic waves. Still others may change their forms according to the intensity, density and oscillation speed of elements such as electricity, magnetism or sound waves, or the dynamics of atmospheric conditions that modulate the wind, tides, clouds, the wind or the sun.[71] In effect, cetacean calligraphy responds to the particular modes of perception of toothed whales and dolphins, in which the world is given through sound waves; these are affected by water temperature and pressure, or the presence of wind-generated bubbles at the sea surface. The writing is not therefore based on visual representations but on the spectrums through which the material world unfolds to cetacean senses.[72]

Guzik's cetacean calligraphy maps the possibility of a written language that is much more embedded in sensory experience and the material environment than our own has become. For Abram, as writing became more arbitrary – by becoming alphabetic, for example – language began to 'separate itself from the animate flux of the world'.[73] Human writing evolved from the traces and scratches with which animals marked their surrounding landscape; early pictorial systems were made up of signatures of the more-than-human world.[74] In oral cultures today, Abram still finds an emphasis on 'the sensorial affinity between humans

Figure 5.7 Ariel Guzik, *El enunciado de Nereida* (Nereida's Discourse), 2019 (photograph provided by the artist).

and the environing earth'[75] that has lessened in societies that have adopted alphabetic writing systems. In these, a direct contact with the non-human world has been lost, allowing us to imagine that language provides evidence of human exceptionalism. Guzik's cetacean calligraphy reminds us that language is rooted in reciprocal, sensory exchanges with nature. As Abram suggests, 'Communicative meaning is always, in its depths, affective; it is rooted in the sensual dimension of experience, born of the body's native capacity to resonate with other bodies and with the landscape as a whole.'[76]

For Guzik, cetacean calligraphy emerges from visions and becomes a form of invocation.[77] For us, too, the script may evoke the sacred quality of ancient runes and the magical power of esoteric symbols. The sacred and the fantastical are not opposed in Guzik's work to the revelations of science. The re-enchantment of the natural world will not involve a rejection of modern science and technology, because disenchantment was not produced by these. Max Weber famously attributed the disenchantment of the world to the rise of science, rationalism and secularism in Western societies. While in traditional societies the world 'remains a great enchanted garden',[78] he wrote, scientific progress has ensured that 'one can, in principle, master all things by calculation', leaving 'no mysterious incalculable forces' that lie beyond our technical means.[79] Many scholars have since disputed Weber's claims, arguing that there has been no decline in belief in magic and mysticism, and that ideas and practices relating to technology are infused with spiritual or religious understanding.[80] What also seems clear is that it is not science that has produced the 'disenchantment' of the world, but the growing incapacity

to perceive the sensuous, animate world around us that Abram laments. Indeed, science provides an important means of becoming alive again to the possibilities of non-human agencies, becoming in our time a powerful generator of wonder and the marvellous.

In the context of the increasing threat of extinction faced by many species of cetaceans and the widespread depredation of natural habitats, we cannot afford to assign a vision of the world as a 'great enchanted garden' to the quaint and colourful beliefs of non-modern societies; it may prove to be a vital key to adopting less invasive and destructive practices. Jane Bennett defines enchantment as 'a feeling of being connected in an affirmative way to existence'.[81] Among 'sites of enchantment' today she mentions 'the discovery of sophisticated modes of communication among nonhumans'.[82] Most importantly, enchantment yields a sense of deep connection with a lively world.[83] This entanglement with the non-human, Bennett argues, is 'the contingent source of receptivity and generosity toward other bodies'; as such, enchantment is 'a mood with ethical potential'.[84] This is the kind of enchantment that Guzik's work creates: one that is affectively connected with the world, as revealed in part by our growing scientific understanding of non-human communication, but that adopts none of the invasive or dominating practices that have often yielded such knowledge. To be enchanted is to feel the attraction of curiosity towards beings whose forms of consciousness are, Guzik acknowledges, 'marcadamente diferentes' (markedly different) from our own.[85] As it does in Guzik's work, this response may inspire respectful forms of conversation and collaboration and an openness to rethinking how we communicate with other species and our environment.

III. Microbe music

The Interspecifics collective, based in Mexico City, develops projects to explore the bioelectrical activity of bacteria, plants and slime moulds. Its members build custom-made, DIY machines to record this activity and use open-source software to turn it into images and sounds. Their projects create an interface for the 'performatividad expresiva' (expressive performativity) of microorganisms, allowing their complexity and diversity to be expressed in a language that can be understood both by machines and by humans.[86] The electrical currents and fields produced in living cells and tissues form a communication and signalling system that is essential to maintaining the organism's health. The decision to convert these electrical currents into sound creates 'a transducer bridge beyond

language' that connects human listeners in an embodied way with the agency of other organisms.[87]

In 2015, Interspecifics members Leslie García and Paloma López took part in 'PhyChip', a project funded by the European Commission.[88] The project brought biologists, material scientists and computer scientists together to build innovative computing devices operated by the slime mould *Physarum polycephalum*. Slime mould has become the focus of a growing number of research projects that investigate complexity and emergence in the behaviour of apparently simple organisms. As a single-celled amoeba lacking any neural circuitry, *Physarum* is nevertheless able to solve complex mathematical problems, such as finding the shortest route between food sources, through its dynamic branching network system. It is widely believed that biomorphic computer devices, combining chips with living organisms such as slime mould or bacteria, may lead to a revolution in the electronics and computer industry.

Invited to join the PhyChip project as resident artists, García and López were based in the Media Environments Department at the Bauhaus University, Weimar (Germany), where their role was to undertake what was categorized as 'artistic research'. They developed the *Phytracker*, a computer vision tool that generated sound and image compositions based on the behaviour of *Physarum*. Far from being a whimsical work of art that simply converted the remarkable activity of slime mould into an exotic aesthetic form, the sonification techniques they developed made a measurable contribution to the scientific project. The new tools they designed allowed scientists to view *Physarum*'s activity from multiple perspectives at the same time. They had been measuring electrical activity with electrodes, but García and López's techniques allowed them to view it from above and to compare information from this visual tracking with data from bioelectrical measurements.[89] The *Phytracker* is thus an excellent example of the role that art may play, not only in communicating scientific results more effectively to a wider audience, but in developing tools that are useful to scientific research projects and encourage a more multidimensional approach within them.

Back in Mexico, García and López, with the other members of Interspecifics, have continued to develop a series of live performances based on the bioelectrical activity of different microorganisms. *Non-Human Rhythms* (2016) translates into sound the activity of bacterial fuel cells and of *Physarum polycephalum*.[90] In the latter case, as for the PhyChip project, a dual approach was taken to the sonification process. The first focused on the bioelectrical activity of the organism, as measured analogically, while the second used optical pattern recognition

software to register its movements. These sources of data were combined to control the selection of different musical features such as pitch, texture and rhythm.

In *Micro-Ritmos* (*Micro-Rhythms*, 2016), a related project, small variations in voltage in microbial fuel cells are amplified and used to generate light patterns; changes in the light are tracked by Raspberry Pi cameras using Open Computer Vision (open-source computer vision and machine learning software).[91] A pattern recognition algorithm (written in Python, an open-source programming language) then detects repeating sequences in the light display and converts them into a real-time graphic score for an eight-speaker audio system, with the help of SuperCollider (an open-source platform for audio synthesis and algorithmic composition). Although a number of different technologies are therefore overlaid here, Interspecifics draws attention to the fact that they are rooted in the exchanges that are initiated in, and by, the very organisms being observed. As they suggest, the 'interspecies system' that is created 'evokes the origins of coded languages' in the electrical signalling within and between cells in living organisms.[92] The sudden flashes of light in the dark performance space and the unpredictable bursts of sound that interrupt a low oscillating frequency make for a dramatic viewing and listening experience that allows us to glimpse something of the dynamic activity of the microbes, which would normally be undetectable.[93]

Speculative Communications (2017) builds on and extends the machine learning elements of previous projects. The living organisms featured here are bacteria belonging to the *Paenibacillus* species, many of which are able to develop complex colonies on semi-solid surfaces, demonstrating the cooperative behaviour of individual cells that allows for the development of sophisticated kinds of self-organization. Collectively, *Paenibacillus* bacteria are able to store information and even learn from past experience in ways that provide evidence of advanced communication, social behaviour and intelligence. They cooperate to present a flexible response in the face of environmental hazards, behaving much like a multicellular organism or even a social community.[94]

For this project, *Paenibacillus* bacteria are nurtured in an environment controlled by an Arduino and a Raspberry Pi. Other Raspberry Pis are attached to a series of microscope lenses and used to track the morphology and motion of the microorganisms, with the help of Open Computer Vision. A machine learning algorithm analyses visual samples and is able to identify patterns in changes occurring over time. This information is then received by an AI algorithm, which generates an audiovisual composition by selecting from a range of tools

to translate the data into gestures in image and sound. Designed by Emmanuel Anguiano, another Interspecifics member, the AI module learns and coevolves with the microorganisms. As it does, it produces a generative piece that continually changes and never repeats itself. The live performance therefore allows an audience to witness how the system evolves over time. The system is not therefore simply one of sonification – the use of sound to convey information – but an instance of interspecies co-creativity that brings together human programmers, intelligent technology and microbes. The machine learning element of the system organizes the sounds into a composition with a structure, giving shape and intelligibility to the multiple individual decisions made by individual cells and demonstrating how self-organization results in coherent strategies.

The term 'generative music', first used by Brian Eno in 1995, has since defined any constantly changing music created by a system. Contrary both to the predictability of recorded music (always the same, in each listening experience) and to the artist-centred unpredictability of live music, generative music creates an ever-changing composition that appears to attribute creativity to machines themselves. In reality, of course, it is not that human input is absent, but that it is confined to the provision of the first set of data and the setting of initial parameters. What is interesting about *Speculative Communications*, in contrast, is that the creativity is shared in a hybrid system between the machines and the ongoing activity of the microorganisms. It is thus a coevolutionary process, in which the machine's learning process responds to the decision-making logics of microorganisms over time.

In a 45-minute live performance of *Speculative Communications* staged in 2018, the visuals displayed on a split screen behind García and López switched between different sources: actual images of *Paenibacillus* in movement, the Computer Vision version, and real-time numbers generated by the AI algorithm (see Fig. 5.8).[95] The role of Felipe Rebolledo, another member of Interspecifics, was to create spectacular three-dimensional visuals that were also shown as part of the performance, giving volume to the flowing bacterial movements in a virtual landscape of shifting peaks and mutating psychedelic colours (see Fig. 5.9). For the performance in Mexico City at the MUTEK Festival, where they were given a Saturday night slot on the main stage, they decided to change the original electroacoustic sound for a techno ambience.[96] While the images conjure up an alien world invisible to normal human perception, the repetitive rhythms and futuristic synthesized sounds lie within a

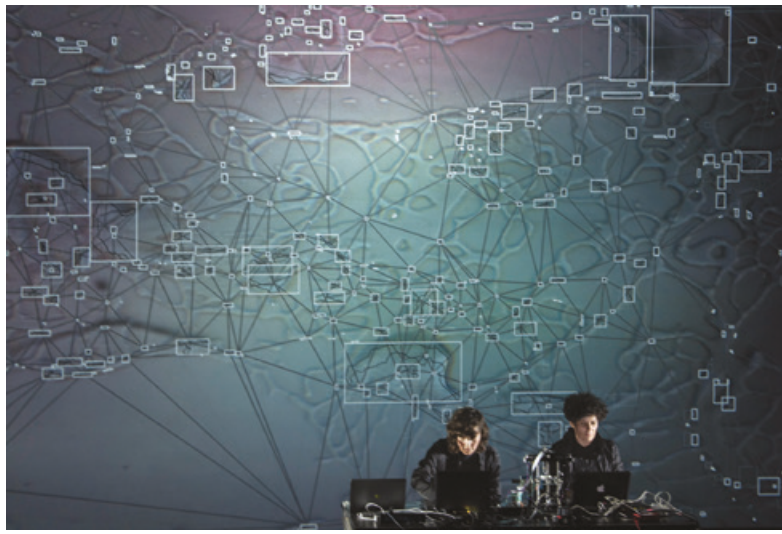

Figure 5.8 Interspecifics, *Speculative Communications*, 2018. Live performance, MUTEK Festival, Mexico City (photograph by Ella Rinaldo for MUTEK Montreal 2018).

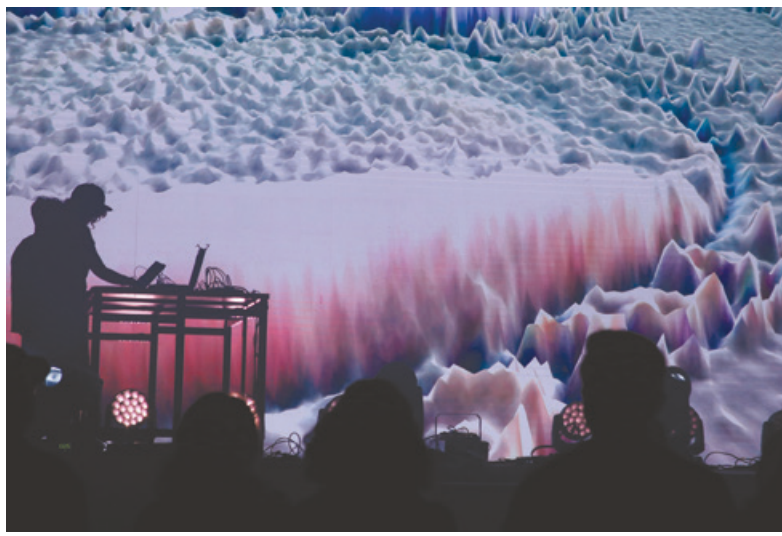

Figure 5.9 Interspecifics, *Speculative Communications*, 2018. Live performance, MUTEK Festival, Mexico City (photograph by Ollin Miranda for Interspecifics MUTEK_MX 2018).

recognizable techno idiom, establishing a relationship between human and bacterial cultures through sound.

Eventually, the Interspecifics members hope to be able to refine the system so that their presence on stage is not needed, giving greater emphasis to the creativity of the non-human elements of the system.[97] The overriding aim of their projects is to focus our attention on 'la performatividad de la agencia material' (the performativity of material agency). As García explains, they want to show that 'todo está danzando' (everything is dancing) – vibrating, oscillating, fluctuating – and that all life is linked via the electrical and electromagnetic phenomena arising from the continual transfer of energy between cells, organisms and their environments.[98] While opening up to us the dynamic world of non-human intelligence, these projects also re-anchor digital computing in the material substrates that it has never transcended, despite its rhetoric of immateriality. Demonstrating the extent to which these substrates are active and self-transforming recasts computing as a continual negotiation between human and non-human agencies, rather than a simplistic hierarchical relationship between programmer and programmed, thus moving from a model of control to one of collaboration.

The artist and theorist Dmitry Bulatov maintains that while 'traditional technologies' are founded on a distinction between 'the thing being developed and the developer, the structure being built and the builder, the operational system and the operator, the material and the tool', works of technobiological art make evident that 'natural processes are unaware of this basic duality'. In life, cells build and shape themselves, direct themselves, and regulate their own activities.[99] This concept of performativity accords strongly with the ontology of 'agential realism' developed by Karen Barad, for whom '[m]atter is neither fixed nor given nor the mere end result of different processes. Matter is produced and productive, generated and generative.'[100] The work of Interspecifics enmeshes technology with natural communication systems in a way that expands both our understanding of living organisms and the hierarchical, instrumental ways in which they have so often been inscribed into technological processes and discourses.

Process ontology in biology, and bioart as a nomadic science

In many ways, contemporary bioart responds to the apparent dematerialization of electronic art and digital culture by reasserting the presence of matter. Often turning to sound and touch as well as sight,

it creates the opportunity for more embodied, intimate encounters with that matter. The projects discussed in this chapter broaden our awareness of diverse forms of intelligence, cognition and performativity beyond the human. They use technology to stage encounters with living organisms such as bacteria and plants that have played a crucial role in the evolution of the biosphere we know, but whose particular modes of communication are normally imperceptible to us.

In this manner, they distance themselves from a gene-centred bioart that is transfixed by the possibilities offered by new gene transfer techniques. Rather than manipulating the DNA of an individual organism, the artworks I have discussed here are more interested in articulating the opportunities and challenges that result from living in community with other organisms. More broadly, they are at odds with the dominant paradigm of molecular biology, not only because of its 'love affair with genes',[101] but also because of its preference for mechanistic accounts that assume that entities pre-exist the processes in which they participate. Through their emphasis on dynamic flows and changing states, within organisms and between organisms and their environment, they lend support instead to the 'process ontology' approach that has so far been adopted only by a minority of biologists and philosophers of biology.[102] This approach does not start from 'things' as the building blocks of life but from the 'processes' that allow organisms to emerge as such within densely interconnected ecological communities. It recognizes that 'organisms, despite their apparent fixity and solidity, are not material things but fluid processes; they are metabolic streams of matter and energy that exhibit dynamic stabilities relative to particular timescales'.[103] This understanding is mirrored in the artworks explored here, whose focus is not on manipulating substances to create a new individual (like Kac's Edunia or Alba) but on revealing the processes through which organisms create, maintain and transform themselves.

For Gilles Deleuze and Félix Guattari, an attention to flux and to processes of becoming define a 'minor' or 'nomadic' science, which is opposed to a more formalized 'state' or 'royal' science, engaged in a search for laws and constants.[104] For minor science, in contrast, 'it is not exactly a question of extracting constants from variables but of placing the variables themselves in a state of continuous variation'.[105] Equations exist, but they 'effect individuations through events, not through the "object" as a compound of matter and form'.[106] Deleuze and Guattari also use the terms 'reproducing' and 'following' to distinguish between these two kinds of scientific procedure. 'Reproducing' looks for ways to eliminate variables in order to arrive at a constant, and 'implies the permanence

of a fixed point of *view* that is external to what is reproduced: watching the flow from the bank'.[107] 'Following', on the other hand, searches for the singularities and 'engages in a continuous variation of variables, instead of extracting constants from them'.[108] In short, it follows 'the flow of matter'.[109]

It will be clear that the art projects discussed in this chapter very much follow 'the flow of matter' in this way, in their emphasis on the changing energy states of organisms and the exchanges that take place between them and their environment. Their turn to sound and to performance accentuates this focus on flows of energy as processes that extend across time, allowing us to grasp more fully the dynamism of living matter. Such techniques immerse us in the same flux, rather than securing for us a detached position of observation. In other ways, as well, these projects could be considered 'minor' practices in relation to mainstream science (and art). In the aesthetics of these works there is a consistent avoidance of the spectacular, the sensational and the high-tech that can sometimes align bioart too closely with the biotechnologies from which it purports to take critical distance. The works by Colectivo Electrobiota, Nóbrega and Henriques discussed here favour instead a do-it-yourself aesthetic of visible circuit boards and simple programming, fitted for the kinds of everyday perception and communication they promote with species that are everywhere around us. The analogue, retro quality of Guzik's *Holoturian*, evoking the ocean-going expeditions of Jules Verne's fiction, also deliberately avoids the more futuristic imaginaries usually generated by contemporary biotechnology as well as many works of bioart. The exception here might be the bacteria and slime mould performances orchestrated by Interspecifics, which do make use of stunning computer graphics; the software in question is open source, however, and the devices used are inexpensive and can be mastered by non-experts with relative ease. Both the hacker, do-it-yourself aesthetic and the enigmatic idiom of Guzik's work may be understood as 'minor' practices in the sense intended by Deleuze and Guattari. They take biotechnical knowledge and practices out of the institutional spaces of scientific laboratories and into new spaces that are domestic (artists' own kitchens), semi-public (workshops, schools, galleries, local communities), or natural (forests, rivers, seas). In doing so, they organize encounters with other species that remain thoroughly embedded in the complexity of the environments with which they – and we – are constantly interacting.

Notes

1. Foster, 'Postmodernism', xv.
2. See http://www.marianosardon.com.ar/cultivos/cultivos_text.htm for further description of the project. Accessed 9 November 2020.
3. See http://www.emilianocausa.com.ar/emiliano/textos/Sensible_interactividad_vida_artificial_y_musica_en_tiempo_real.pdf. Accessed 26 October 2020.
4. See https://www.martinbonadeo.com.ar/albums/72157681516877936. Accessed 26 October 2020.
5. Gessert, *Green Light*, 139.
6. De Barros, 'Lo impensado del arte en un mundo en mutación científica', 111.
7. Yeregui, 'Prácticas co-creativas', 3–4.
8. Latour, *Politics of Nature*, 138.
9. Latour, *Politics of Nature*, 137.
10. La Mettrie, *La Mettrie: Machine man and other writings*, 83, 84.
11. See Hall, 'Plant autonomy and human-plant ethics'.
12. Hall, 'Plant autonomy and human-plant ethics', 179.
13. Gagliano, *Thus Spoke the Plant*, 138.
14. Stark, 'Deleuze and critical plant studies', 181–2.
15. Marder, *Plant-Thinking*, 3.
16. Conversation with the author, 22 April 2019.
17. The work was shown as part of the fourth edition of *FASE – Encuentro de arte, ciencia y tecnología: Post ecología: Hacia una naturaleza y una cultura sustentable*, held at the Centro Cultural Recoleta, Buenos Aires, Argentina, between 11 and 14 October 2012. See http://www.gabrielamunguia.com/portfolio/tallking-green [sic]. Accessed 26 October 2020.
18. See, for example, Hassanien et al., 'Advances in effects of sound waves on plants'; Mancuso explains that low frequencies (of the range Munguía deployed) promote seed germination, plant growth and root lengthening. Mancuso and Viola, *Brilliant Green*, 75–6.
19. See http://www.interface.ufg.ac.at/christa-laurent/WORKS/FRAMES/FrameSet.html. Accessed 26 October 2020.
20. *Talking Green* also differs from another project inspired by the potential benefits to plants of human–plant communication, developed by Latvian artists Rasa Šmite and Raitis Šmits. In *Talk to Me* (2011–), messages from human participants are played back to plants in the gallery space. As Šmite and Šmits explain, the work responds to interests that are 'less biological than social' and is entirely symbolic. See http://smitesmits.com/TalkToMeInteractiveLV.html. Accessed 26 October 2020.
21. Conversation with the author, 22 April 2019.
22. The work was shown as part of the *Premio UNTREF a las Artes Electrónicas* exhibition held at the Museo de la Universidad Nacional de Tres de Febrero, Caseros, Buenos Aires, between 31 March and 13 May 2016. See https://colectivoelectrobiota.wordpress.com/proyectos/rizosfera-fm. Accessed 26 October 2020.
23. Wohlleben, *The Hidden Life of Trees*, 3.
24. Wohlleben, *The Hidden Life of Trees*, 174–6.
25. The process of recording the frequencies and transmitting them over radio is documented in the following video: https://www.youtube.com/watch?v=0HBXCHmhPa0. The opening sequence pays particular attention to the tree's urban environment. Accessed 26 October 2020.
26. Conversation between Gabriela Munguía and the author, 22 April 2019.
27. See https://colectivoelectrobiota.wordpress.com/proyectos/rizosfera-fm. Accessed 26 October 2020.
28. See https://guadalupechavezpardo.wordpress.com/2014/10/29/pacha. Accessed 26 October 2020. *Pacha transmisión* was shown as part of the *FUTURISSIMA* exhibition held at La Sin Futuro, Buenos Aires, on 7 December 2013.
29. Conversation with the author, 17 May 2019.
30. Conversation with the author, 17 May 2019.
31. Marder, *Plant-Thinking*, 2, 3.
32. Marder, *Plant-Thinking*, 69.
33. See https://www.gutonobrega.art/botanic. They include the earlier works *Ephemera* (2008), *Equilibrium* (2008) and *Breathing* (2009). Accessed 26 October 2020.

34. Nóbrega's experimentation with plants dates from 2005, as part of his doctoral research, but *BOT_anic* was not shown publicly until 2013, as part of the *Machinarium* exhibition at Oi Futuro Ipanema, Rio de Janeiro, between 13 July and 8 September that year. A video recording of *BOT_anic* in action may be viewed at https://vimeo.com/236335826. Accessed 26 October 2020.
35. Mancuso and Viola, *Brilliant Green*, 4.
36. Conversation with the author, 2 May 2019.
37. Mancuso and Viola, *Brilliant Green*, 255.
38. See https://www.gutonobrega.art/botanic.
39. Nóbrega, '*Bot_anic.* Acoplamentos estruturais entre plantas, homens e máquinas', 146.
40. Simondon, *On the Mode of Existence of Technical Objects*, 15; cit. Nóbrega, '*Bot_anic.* Acoplamentos estruturais entre plantas, homens e máquinas', 152.
41. Nóbrega, '*Bot_anic.* Acoplamentos estruturais entre plantas, homens e máquinas', 146.
42. Conversation with the author, 2 May 2019.
43. Gagliano's experiments with training pea seedlings are published in her book *Thus Spoke the Plant* (2018), also cited elsewhere in this chapter. Her work on plant intelligence (and particularly her holistic approach) has met with considerable scepticism over the years on the part of 'mainstream' scientists.
44. Conversation with the author, 2 May 2019.
45. Correspondence with the author, 16 June 2020.
46. Nóbrega, 'Art and technology', 81.
47. Burnham, *Beyond Modern Sculpture*, 369; cit. Nóbrega, 'Art and technology', 114–15. Guto Nóbrega's work is strongly influenced by Jack Burnham and particularly by the cybernetic and telematic art of Roy Ascott, who supervised Nóbrega's PhD thesis.
48. *Jurema Action Plant* was first developed as part of the summer residency programme at V2_ Institute for the Unstable Media in Rotterdam in 2010.
49. The Hortus Botanicus in Leiden assisted with specific knowledge about the *Mimosa pudica* and helped him grow the plants he needed. In giving permission for images of his works to be reproduced in this book, Henriques wished to record his gratitude to his family, his friends and 'the fantastic team, including the scientists and engineers that have been involved with the developments of such projects'.
50. A recording of interactions with the *Jurema Action Plant* may be viewed at https://vimeo.com/24265573. Accessed 26 October 2020.
51. It was eventually published in 2014. See Gagliano et al., 'Experience teaches plants to learn faster and forget slower in environments where it matters'; see also Gagliano, *Thus Spoke the Plant*, Chapter N.
52. One of the machines is called Monsantra, a deliberate reference to Monsanto, and the plant is germinated from GM seeds the company supplies. See https://www.monsantra.com/monsantra. Accessed 26 October 2020.
53. See https://ivanhenriques.com/works/jurema-action-plant. Accessed 26 October 2020.
54. Shanken, *Art and Electronic Media*, 143.
55. Mitchell, *Bioart and the Vitality of Media*, 70.
56. Mitchell, *Bioart and the Vitality of Media*, 71.
57. López del Rincón, *Bioarte*, loc. 6487–98.
58. Correspondence with the author, 21 June 2020.
59. López del Rincón, *Bioarte*, loc. 5124–7.
60. Gagliano, *Thus Spoke the Plant*, 107.
61. Marder, *Plant-Thinking*, 68.
62. Marder, *Plant-Thinking*, 69, 53, 152.
63. Abram, *The Spell of the Sensuous*, 27, 28.
64. Guzik, 'Caligrafía cetácea', 108.
65. A video of the launch of *Nereida*, with samples of the music created on the soundtrack, may be viewed at https://vimeo.com/31861841. Accessed 27 October 2020.
66. See Sayigh, 'Cetacean acoustic communication'.
67. Guzik, 'Caligrafía cetácea', 113.
68. Guzik, 'Caligrafía cetácea', 113.
69. Conversation with the author, 21 August 2019.
70. Triscott, *Ariel Guzik – Holoturian*, n.p.
71. Guzik, 'Caligrafía cetácea', 112.

72. Conversation with the author, 21 August 2019.
73. Abram, *The Spell of the Sensuous*, 107.
74. Abram, *The Spell of the Sensuous*, 95–7.
75. Abram, *The Spell of the Sensuous*, 71.
76. Abram, *The Spell of the Sensuous*, 74–5.
77. Guzik, 'Caligrafía cetácea', 112.
78. Weber, *The Sociology of Religion*, 270.
79. Weber, *Essays in sociology*, 139.
80. See, for example, Landy and Saler, *The Re-Enchantment of the World*; Josephson-Storm, *The Myth of Disenchantment*; Noble, *The Religion of Technology*; Szerszynski, *Nature, Technology and the Sacred*.
81. Bennett, *The Enchantment of Modern Life*, 156.
82. Bennett, *The Enchantment of Modern Life*, 4.
83. Bennett, *The Enchantment of Modern Life*, 131.
84. Bennett, *The Enchantment of Modern Life*, 158, 131.
85. Guzik, 'Caligrafía cetácea', 112.
86. See http://interspecifics.cc/comunicacionesespeculativas/proyecto. Accessed 27 October 2020.
87. See http://interspecifics.cc/work/statement/. Accessed 27 October 2020.
88. Led by Professor Andrew Adamatzky, PhyChip was a three-year project that began in March 2013 with funding from the European Commission's Seventh Framework Programme (FP7) within CORDIS and the FET Proactive scheme. See the project website at http://www.phychip.eu. Accessed 27 October 2020.
89. Conversation with the author, 13 August 2019.
90. The project was developed in collaboration with Theresa Schubert from Bauhaus University, Weimar, and the PhyChip team. A live performance was given on 4 February 2016 as part of the *Inoculum – Connecting the Other* event organized by the Bauhaus University, and held at CLB Berlin.
91. The project was developed in collaboration with Juan David López Hincapié and Adrián Rodriguez García from the Centro de Investigación y Desarrollo Tecnológico en Electroquímica (CIDETEQ), Mexico. It was commissioned by and first performed at the Museum of Modern Art in Medellín, Colombia, on 28 September 2016.
92. See http://interspecifics.cc/work/micro-ritmos-2016. Accessed 27 October 2020.
93. A video of the performance held in September 2016 at the Museo de Arte Moderno in Medellín, Colombia, is available to view at https://vimeo.com/190665110. Accessed 27 October 2020.
94. See Ben-Jacob, 'Social behavior of bacteria'.
95. This live performance was held on 3 May 2018 at the CALA Alliance, Phoenix, Arizona, US.
96. Conversation with the author, 13 August 2019. The live act was part of an extended series of performances by digital and sound artists held at Fábrica, Mexico City, on 24 November 2018. An extract from the performance may be viewed at https://vimeo.com/320857134. Accessed 27 October 2020.
97. Conversation with the author, 13 August 2019.
98. Conversation with the author, 13 August 2019.
99. Bulatov, 'A new state of the living', loc. 2838.
100. Barad, *Meeting the Universe Halfway*, loc. 2741–2.
101. Jaeger, 'Foreword', xi.
102. Meincke, 'Autopoiesis, biological autonomy and the process view of life', 3.
103. Dupré and Nicholson , 'A manifesto for a processual philosophy of biology', 17.
104. Deleuze and Guattari, *Nomadology*, 16.
105. Deleuze and Guattari, *Nomadology*, 28.
106. Deleuze and Guattari, *Nomadology*, 28.
107. Deleuze and Guattari, *Nomadology*, 31; emphasis in original.
108. Deleuze and Guattari, *Nomadology*, 31.
109. Deleuze and Guattari, *Nomadology*, 33.