DECOLONIZING SCIENCE IN LATIN AMERICAN ART

JOANNA PAGE

UCL PRESS

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To Geoff, who is always creative and always kind

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of Saraceno's work here are included in a chapter of *Latin American Culture and the Limits of the Human* (edited by Lucy Bollington and Paul Merchant, 2020); an abridged version of Chapter One is published in *The Anthropocene Review* (7 no. 3, December 2020) and a modified version of Chapter Three appears in *Environmental Humanities* (13 no. 1, May 2021). I am extremely grateful to the anonymous reviewers of these essays and the book manuscript who provided astute suggestions for revision.

Images of the work of Studio Tomás Saraceno have been omitted from this book as permission to reproduce them did not come through in time to meet production schedules, but readers may view them at https://studiotomassaraceno.org.

One of my purposes in this book has been to give clear accounts of the scientific ideas and processes associated with these art projects: to take seriously their engagement with these concepts and practices, beyond aesthetic choices, and to open up to non-specialist readers some of the exciting fields of knowledge these artists explore. Although I have researched these diligently, I have had little formal scientific training. I assume full responsibility for any errors, in the hope that more expert readers will forgive them as the necessary risks of transdisciplinary research. The value of such research and practice will, I hope, shine through in the innovative work of the artists featured here.

Introduction

Transdisciplinary projects that combine the aims and methods of the 'hard' sciences with those of art are increasingly being developed in communities and exhibited or performed in galleries and museums across the world. The pioneering work of SymbioticA in Australia and the Artists-in-Labs Program in Switzerland, together with organizations such as Arts Catalyst in the UK and a proliferating series of art, science and technology festivals across the world, have generated unprecedented opportunities for artists and scientists to share ideas and practices. Prestigious science and technology institutes, including MIT, NASA and CERN, have developed substantial residency programmes for artists to work alongside scientists and engineers. Engaging with fields as diverse as astronomy, geology, genetics, molecular biology, ecology and artificial intelligence, contemporary artists are redefining the boundaries between art and science while creating new forms of performance and conceptual art.

The international renown of figures such as Olafur Eliasson, Eduardo Kac and Marta de Menezes (among many others) is evidence that art–science projects are entering the mainstream. This follows some 'hesitancy' on the part of the art world to incorporate such works, which for Stephen Wilson may have stemmed from the fact that 'the literacy required to understand and appreciate such work is not widespread'.[1] Since then, as he outlines, a 'parallel world' of museums, festivals, publications, websites and other institutions and organizations has developed to exhibit and support it. Although the general public may not fully grasp the science behind such works, they are typically very appealing in their use of new technologies, creating spectacular or curious effects, and exploring modes of expression that are often sonic and kinetic as well as visual. What is certainly the case is that few scholars writing on such projects are able to bridge the disciplinary divide as convincingly as their creators do. As Wilson acknowledges, 'recognizing both the craft of, and the conceptual leap being made by, an artist

exploring computerized artificial intelligence is somewhat dependent on understanding the scientific challenges in that field as well as the nature of the artistic gesture required to move beyond the science'.[2] Demanding as this transdisciplinary work may be, it is imperative that we attempt to follow these artists in their quest to acquire the multiple literacies we need to understand and participate in the most urgent debates of our time. From the risks and possibilities of genetic modification to the nature of climate change and our response to it, many of these debates cut across divisions between science, culture, politics and ethics.

While visual art and the sciences may be enjoying a new form of rapprochement, their relationship has of course always been close. From mediaeval botanical illustrations to the stunning images created from data collected by the Hubble Space Telescope, art has played a vital role in the recording of scientific discoveries, the creation of models and the interpretation of data. This role is, of course, far from passive: modes of visualization, even the most apparently 'scientific', are never objective, creating additional meanings that may embellish, extend or even run counter to the interpretations suggested by the raw data on which they are based. Elizabeth A. Kessler, for example, has found significant resemblances between the vivid Hubble images of the cosmos and the visual language of the sublime in Romantic depictions of the American West. Such parallels point to the way in which the cosmos is re-created visually according to 'the mythos of the American frontier', casting astronomers as explorers and pioneers and reminding us of our potential to transcend what may initially seem to limit us.[3] In an age of ever-proliferating digital information, the new art form of data visualization is crucial in helping us make sense of large quantities of invisible information, but it is also far from objective in the perspectives it offers. Like photography, it may be used for scientific or artistic purposes, or both.

Art, likewise, has drawn significantly on scientific knowledge and methods over the centuries, from the development of perspective in Renaissance painting to op art and bioart. The current expansion of art–science projects and a rising interest among critics and scholars does seem, however, to suggest a growing convergence between disciplines that have often been seen as very different. Writing in the 1990s, the physicist and epistemologist Jean-Marc Lévy-Leblond found the idea of a 'universal reconciliation' between art and science to be a 'product of naive nostalgia'.[4] He considered the 'new alliances' being proclaimed to constitute rather superficial engagements, stating that '[t]he fact that artists make use of contemporary scientific theories as a reference, or claim that they illustrate them, does not mean their work throws any new

light on the theories'.[5] Indeed, he suggests that art and science should treasure their divergence, and that '[i]f the arts want to be geared to the needs of a world dominated by technoscience, they will not achieve that result by plagiarizing it or paying allegiance to it'.[6] It is demonstrably the case that much art that engages with science either fails to do so in a serious way or confines its practice to visualizing scientific theories, processes and data without subjecting them to commentary or critique. In the first case, art may merely draw on mathematical or scientific ideas as an inspiration for a work that is impressionistic and not at all scientific in register, adding nothing to our understanding of such ideas. In the second, art remains entirely subservient to science in the communication of its ideas, rarely carving out a space for critique or alternative perspectives. For Joanna Zylinska, the 'pedagogic' element of many bioart projects, which are aimed at demystifying biotechnologies and the commercial interests that underpin the biotech industry, 'can make artists adopt a somewhat servile role toward biotech and bioscience, with art becoming a mere handmaiden to science'.[7] If artists add nothing to the procedures developed by scientists, or simply present the ethical or political issues they raise as self-evident, Zylinska suggests, art–science collaborations may end up reaffirming the superior position of biotech in a disciplinary hierarchy.[8]

It is clear, however, that over the last decade, a new wave of art–science projects across the world are making credible additions to scientific knowledge while engaging the embodied, sensory qualities and the critical and reflexive capacities of art. Such projects, including the ones featured in this book, do not effectively reinforce the supremacy of science in the way that Lévy-Leblond and Zylinska describe. In some cases, they do throw 'new light' on scientific theories, by introducing new techniques of visualization or developing new materials or forms of measurement, in ways that make a verifiable contribution to scientific knowledge. Some examples of this kind of contribution are detailed in the chapters of this book. More typically, these projects extend or question the work of science through speculative explorations that connect scientific knowledge with other fields of knowledge and experience, increase our understanding of other species by promoting an aesthetic and affective engagement with new scientific findings, or deploy scientific techniques for objectives other than those of predicting, controlling or commodifying the natural world. Their aims are to create ways of approaching natural phenomena that refute mechanistic and reductionist explanations and revitalize artistic practice through new encounters with the material world.

If a rise in art–science projects is evident across many regions of the world, it remains the case that comparatively little attention has been paid to artists working beyond Europe and North America. This book explores recent art–science projects by Latin American artists, assembling a new corpus of diverse works created since 2008 that range from big-budget collaborations with NASA and MIT labs to home-grown experiments with mushrooms in an artist's kitchen. These projects draw variously on new research in evolutionary biology, zoology, plant science, genetics, geology, geophysics, atmospheric physics, astronomy, and climate and environmental science. They generally take the form of mixed-media installations, interactive technologies and performances that use scientific instruments, methods and techniques of representing data to enhance our understanding of natural-world phenomena and the sensory worlds of other species or to comment on scientific practices and discourses. Most of these works have originated within Latin America (more precisely, in Argentina, Brazil, Chile, Colombia, Ecuador and Mexico), while some have been produced by Latin American artists currently resident abroad, in Europe or North America.

A growth in art–science projects – and in research-based art in general – is being facilitated in Latin America by the excellent opportunities for transdisciplinary and creative work currently offered by a number of (usually private) universities. The great majority of the projects discussed in this book are produced by artists who also teach on university courses. This provides them with a regular income, but also allows them to draw on university research funds and to gain access to research centres and installations in the Amazon, the Atacama, Patagonia and elsewhere. Paul Rosero Contreras was able to secure permits to travel to the Galápagos through the Universidad San Francisco de Quito (Ecuador), where he gives classes, and some of his collaborative projects have been organized under the aegis of the university's interdisciplinary College of Communication and Contemporary Arts (COCOA). Claudia Müller teaches at the Pontificia Universidad Católica de Chile, where there are increasingly strong relationships between arts and science faculties, especially Engineering, and she is able to access funding for transdisciplinary projects. In Chile she can also apply for grants from a dedicated 'Art and Science' funding competition run every year by the government's Fondo Nacional para el Desarrollo Cultural y las Artes (National Fund for the Development of Culture and the Arts). Joaquín Fargas is the founding director of a laboratory for bioart established in 2008 at the Universidad Maimónides (Buenos Aires), now operating as the Laboratorio Latinoamericano de Bioarte (LatBioLab) at the

Universidad Abierta Interamericana, which provides laboratory support for his projects and an important space for collaboration between artists, biologists, and engineers in particular.

Like many transdisciplinary art–science projects, the ones explored here constitute interventions in much broader debates about the changing roles of the arts and sciences in contemporary society, as well as the relationship between them. As I will argue, the dialogue many of them establish with local or regional forms of knowledge and practice in Latin America and their situated engagement with the geopolitics of biotechnology, extractivism and climate change make important contributions to the growing corpus of art–science projects worldwide. In different ways, I will propose, these projects can be understood as participating in a decolonization of science, knowledge and nature.

Art and science in the Anthropocene

The current increase in art–science works is taking place at a moment at which the relationship between art and science has reached a critical conjuncture. This is characterized by a generalized erosion of trust in science – owing in part to its close collusion with capital – and, at the same time, by the urgent need to defend expert knowledge in the context of 'fake news' and particularly to uphold the truth of environmental science against climate change deniers. In many ways, science in Western nations retains its position of authority over the production of knowledge. As Isabelle Stengers has observed, however, its credibility as a source of objective data and analysis is increasingly undermined by 'the nature of the knowledge economy and the dependence it introduces between research choices and private interests'.[9] Many artists have sought to expose the complicit relationship between science and capital in the lucrative biotech industry, for example. And yet, in the context of a global environmental crisis, it becomes imperative to defend the truth of science against those private individuals and strategists in the employ of interested corporations who use all the resources of the internet and social media to discredit the predictions of climate scientists.

This is a crucial shift that has been noted by, among others, Bruno Latour, whose early work was associated with a social constructivist approach to science. He expresses a deep concern that while he has given priority to demonstrating a lack of scientific certainty in the construction of facts, the danger now appears to lie in an 'excessive mistrust' of such facts. As a result, 'entire Ph.D. programs are still running to make sure

that good American kids are learning the hard way that facts are made up, that there is no such thing as natural, unmediated, unbiased access to truth, that we are always prisoners of language, that we always speak from a particular standpoint, and so on, while dangerous extremists are using the very same argument of social construction to destroy hard-won evidence that could save our lives'.[10] In Latour's more recent publications we see a clear shift from pointing out the social forces at work in the construction of apparently objective facts in science to a recognition that science speaks most truthfully and accurately when it is reconnected with the world outside the laboratory. As he writes in a book published as early as 1999, 'Instead of the impossible task of freeing science from society, we now have a more manageable one: that of tying the discipline as much as possible to the rest of the collective'.[11]

Art–science projects may play a particularly effective role, as we will see, in making these kinds of (re)connection. Against the abstraction and reductionism of science, Lévy-Leblond suggests, art leads us to rediscover the 'rich denseness' and 'opacity' of the natural and human world; as he argues, it has 'become imperative today to re-establish a link between the concepts that science has elaborated and the reality from which it has isolated them'.[12] The most important challenge he identifies is not how to communicate scientific culture to the public, but how to reinsert science into culture. Art–science projects are a particularly valuable medium through which to raise awareness of questions of conservation, biodiversity and environmental change, owing to their capacity to combine rationalist approaches with those that lie beyond rationalism. The problem, as Val Plumwood defines it, is not with reason itself, but with rationalism's 'inability to see humans as ecological and embodied beings'.[13] This has created a 'dominant narrative of reason's mastery of the opposing sphere of nature and disengagement from nature's contaminating elements of emotion, attachment and embodiment'.[14] The affective, sublime, interactive and performative qualities of many of the projects discussed in this book amply demonstrate ways in which art may reach beyond the presentation of scientific data or the critique or development of new technologies to engage us in an embodied, sensory manner with the natural world.

But it is also the work of art as assemblage, often in the form of mixed-media installations, that is particularly effective in placing scientific research or new technologies alongside other matters of concern. Such assemblages often invite the viewer to understand a conflict between different worldviews (such as Western and indigenous perspectives on nature) or a contradiction between two or more objectives (such as

development and conservation). The *Sin origen/Sin semilla* exhibition curated by Arte+Ciencia (see Chapter Four) brings together opposing perspectives on the transgenic maize debate in Mexico; Rafael Lozano-Hemmer's *Atmospheric Memory* (see Chapter Two) captures multiple ways in which we inhabit the atmosphere as a physical and social medium, bringing together interactive pieces with audiovisual performances to highlight its potential for creative expression and shared experience, as well as the sobering realities of air pollution and unseen forms of digital surveillance.

In fact, while the strong preference for installation art evident in art–science projects sometimes stems from a desire to immerse the participant in a sensory experience, it is just as often designed as a way of engaging their rational, investigative skills. A number of installations, such as BIOS Ex MachinA's *Serán ceniza, mas tendrá sentido (ligeramente tóxico)* (2012), Julia Carrillo's *Frontera comprometida* (2017) and Pablo La Padula's *Zoología fantástica* (2019), reconstruct the scene of a transdisciplinary research project, placing the gallery-goer in the position of the artist/scientist and encouraging them to consider connections between disparate objects such as texts, images, maps, biological specimens and laboratory equipment. Jens Hauser argues that as the technosciences become 'powerful producers of aestheticized images', an epistemological turn emerges in art, evidenced by the fragmenting of artistic images into a series of 'material media and epistemic connections'.[15] Far from simply constituting visual representations of scientific data or ideas, many art–science installations interrogate how knowledge is constructed, as well as what role the aesthetic, affective or performative elements of art may play in that construction. Indeed, as I will argue later in this book, one of the important contributions made by many of the art–science projects I explore is precisely to bring together the cognitive and the affective, in acts that demonstrate the inseparability of questions of knowledge, empowerment, entanglement and care in a post-anthropocentric imaginary.

'Post-academic science' under neoliberalism

Many contemporary art–science projects reflect on major shifts in the construction and circulation of scientific knowledge under advanced capitalism. Since the 1970s, John Ziman claims, 'we have witnessed a radical, irreversible, worldwide transformation in the way that science is organized, managed and performed'. He characterizes this

transformation as the yielding of academic science to 'post-academic science', in the context of much closer ties between academia and industry.[16] Although 'industrial science' uses the same techniques and technologies as 'academic science', the knowledge it generates is directed towards solving specific technical problems rather than adding to our general understanding.[17] Researchers are commissioned to work towards particular goals, and the knowledge that emerges may not be made public.[18] The practices that have emerged are, as Ziman points out, 'essentially foreign' to the culture of academic science which – according to the norms of the discipline identified by Robert K. Merton in 1942 – rests on principles that include disinterestedness and the common ownership of knowledge.[19]

In many Latin American countries, scientific research has been largely dependent on state funding, and thus vulnerable to significant fluctuations for political and economic reasons. This dependence is shifting rapidly in those countries that are most actively pursuing neoliberal policies of foreign investment and market deregulation. One of the most interesting countries in which to examine the operation of post-academic science under neoliberalism is Chile, where extensive debates are taking place about the future of science in the country. Against an OECD average of 2.3 per cent, Chile invested less than 0.4 per cent of its GDP in research and development in the period 2007–13, a considerably lower proportion than some of its less developed Latin American neighbours.[20] Javiera Barandiarán observes that this low level of investment was not a result of a lack of resources, but the adoption of a neoliberal ideology that explicitly limits the role of the state.[21] Soledad Quiroz Valenzuela concurs, pointing out that those countries in Latin America that have managed to increase funding for science and technology have done so through greater state involvement.[22] Barandiarán's more recent study explores the devastating consequences for environmental governance when state agencies, rather than producing an authoritative body of scientific knowledge, outsource this role to private bodies, the state seeing itself 'as a broker between competing parties that produce their own knowledge claims'.[23] This has resulted in a widespread mistrust of the independence and objectivity not only of the advice supplied by industry-paid scientists but also of that supplied by government officials.[24] The molecular biologist Pablo Astudillo Besnier further claims that, in Chile, science has been seen in terms that are exclusively economic: pure science, or science motivated by curiosity, is considered to be 'un problema, una pérdida de tiempo, una deficiencia del modelo chileno' (a problem, a waste of time, a failure of the Chilean model).[25]

A major factor in this transition to post-academic science, in Chile and beyond, is therefore a 'greater stress on utility'.[26] David Kellogg argues that post-academic science weakens the bond between science and curiosity, while strengthening the bond between science and 'social need'.[27] Post-academic science is generally founded on market principles; Ziman observes that even public agencies such as research councils are required 'to favour projects with manifest "wealth-creating" prospects, or with practical medical, environmental or social applications'.[28] Kellogg rightly points out that this often creates a closer relationship between science and society, as scientists typically have to justify the value of their projects to a wide range of stakeholders, many of whom are not scientists themselves.[29] The pursuit of science in order to 'solve' societal problems is not often carried out in consultation with all stakeholders, however; given the weight of past errors, there is a growing awareness of the need for the co-creation of research agendas in conjunction with those people who will potentially benefit but may also be harmed.

The question of the utility of science in Latin America is also complicated by the region's 'peripheral' status in global science. As renowned twentieth-century scientists such as Oscar Varsavsky insisted, pursuing a successful career in science has frequently meant adopting the norms and values of the most developed centres of science.[30] Pablo Kreimer affirms that even in the present day, the integration of scientific researchers from peripheral countries into international science should be regarded as an 'integración subordinada' (subordinate or dependent integration), as they are often forced to adopt lines of enquiry developed elsewhere and to subject their work to the evaluation of interlocutors located beyond the nation's borders.[31] This often leads scientists in Latin America to ignore pressing local problems in favour of collecting data that is really for the benefit of scientists in the North.[32] Alicia Massarini and Adriana Schnek explain that, for this reason, science and technology in Latin America tend to subscribe to a concept of development that relies on the continued exploitation of natural resources, securing the region's insertion into the global economy at the cost of widespread environmental damage and the neglect of urgent challenges in health, food or education.[33]

Transdisciplinary art–science projects typically share and promote some of the more positive characteristics of post-academic science while rejecting others. They are part of a move identified by Kellogg towards the multiplication and diversification of the sites of knowledge production, which now typically bring researchers based in universities and private labs together with consultants and technicians working for government

agencies or other private companies, to create forms of interdisciplinary enquiry.[34] Artists have recently gained much greater access to such networks, principally through teaching on university courses or taking up residencies in university and commercial labs; those who have gained a measure of international success are also increasingly able to establish their own studios as sites of transdisciplinary collaboration. One of the best examples of such large-scale collaborative work in this book is the Studio Tomás Saraceno, in Berlin, which brings together architects, biologists, engineers, artists, musicians and designers in a multidisciplinary space that houses the Arachnophilia Research Laboratory as well as other communities of researchers and enthusiasts.

In many important respects, though, the practices established in many art–science projects across the world run contrary to dominant trends within post-academic science. First, at a time when knowledge is increasingly becoming privatized and subject to patents, artists are stepping in to promote the value of knowledge as a commons. They are able to do so because in less commercial fields, such knowledge is in fact becoming more accessible. Although the data and tools developed by privately funded science are often jealously guarded secrets, Kellogg notes that in general scientific knowledge has become more widely disseminated and more open to public scrutiny, through online, open-access publications, which are often a condition of public funding.[35] Artists both benefit from this increased access to free data and contribute to it. Nicola Triscott observes that since the 1990s artists and curators have begun to frame their work explicitly in relation to a commons logic; she understands this turn to be entwined with 'a move in contemporary art away from a focus on the individual agency of artists (producing discrete art objects) towards art-making as an open, collective process, and a shift in thinking from political art producing political messages towards the idea of art producing a politics'.[36] The great majority of the Latin American artists discussed in this book use open-source software and technologies, such as Arduino and SuperCollider, which have been collaboratively developed and may be legally used and modified by anyone; their own modifications and results are made available in the public domain to be used in other projects, fully downloadable and free from copyright.

Such commoning practices also militate against the increasing specialization of knowledge that characterizes post-academic science. Kellogg observes that the growth in collaborative science projects permits a division of labour that means that specialists in charge of one aspect of the research may never come into contact with other researchers or technicians.[37] The need to develop specific expertise,

coupled with a fast-growing body of scientific literature, means that it is often in a researcher's interest to focus on a narrow area, in the hope of being able to make at least a modest contribution to knowledge.[38] The artists who feature in this book often work consciously against such hyperspecialization, challenging themselves to develop an understanding of their subject that crosses disciplinary boundaries, to learn and apply a wide range of techniques, to situate scientific knowledge within broader cultural, social or ethical contexts, and to present it as accessible, wherever possible, to the tenacious amateur.

Paradoxically, perhaps, artists who engage with science often attempt to defend the pursuit of knowledge for its own sake, beyond any practical or commercial utility, while simultaneously promoting the idea that science should serve the needs of a community or culture. In a context in which science has been thoroughly inserted into the 'knowledge economy', art may provide an opportunity to reinforce the cultural and scientific value of speculative research, beyond the kind of practical applications that are more easily commodifiable. In many ways, the kind of science that underpins most of the art projects explored in this book is a 'purer' quest for knowledge that stems from a curiosity about the natural world, is advanced by a series of simple experiments, and has no immediate commercial application. Many artists who are also scientists 'by day' (or have moved into art after a career in science or industry) welcome the opportunity to pursue knowledge guided by their own curiosity and creativity, rather than the need to create useful results and publish papers. On the other hand, these art–science projects are often connected with broader issues, particularly of a social, cultural or environmental nature, such as the protection of biodiversity or the promotion of indigenous knowledge and culture. Their primary aim is rarely to solve a particular problem, however, but to challenge our thinking and our practices in relation to the natural world in a way that questions the assumptions of humanism and modernity, to help us understand the impact of new technologies far beyond their intended material benefits, or to place Western scientific knowledge within a constellation of different beliefs and practices.

Art, science and public intelligence: in defence of amateurism

At the same time as calling for a greater institutional basis for science, scientists in Chile have also repeatedly pointed to the schism that

separates science from ordinary citizens and the need for programmes that would enhance public debate and allow the public to play a larger role in deciding what the priorities for a national science should be.[39] The 'Más Ciencia para Chile' (More Science for Chile) movement was founded in 2010 by Astudillo Besnier to campaign for clearer government policies to promote science and technology in the country and greater investment on the part of the state, but also to act as a bridge between academics, scientists, policymakers and citizens.[40] Similar movements are gaining visibility worldwide. The 'March for Science' organization, which identifies itself as 'the world's largest grassroots community of science advocates', has coordinated an international series of rallies on Earth Day since 2017, campaigning for publicly funded science and evidence-based public policies for the common good.[41] Public involvement in scientific research and education has grown significantly through the recent explosion in citizen science initiatives, in which members of the public volunteer to partner with professional scientists by providing data or performing certain tasks.

Rather like citizen science, art may play a crucial part in disseminating new scientific research and in increasing public awareness of, and participation in, important debates about the role of science in society. New spaces to encourage public engagement with science have been emerging in many places across the world, not least in Latin America. Many of these, such as the Centro Cultural de la Ciencia in Buenos Aires (founded in 2015), combine interactive installations and introductory courses aimed at the general public or children with a strong programme of events and exhibitions in visual arts. They join institutions with a longer history of exploring science through the creative and performing arts, such as the Espaço Ciência Viva in Rio de Janeiro (founded in 1982). Art galleries and museums across the region that specialize in multidisciplinary art, including the Laboratorio Arte Alameda (Mexico City), FLORA ars+natura (Bogotá), and the Centro de Arte y Naturaleza (Buenos Aires), also provide important spaces for the dissemination and exploration of scientific ideas, with programmes shaped by directors with a strong interest in science and technology, such as Tania Aedo. A number of individual artists participate actively in scientific outreach programmes or hold 'hands-on' workshops for members of the public to learn technical skills for creative projects.

Lévy-Leblond is critical of the huge divide he perceives between contemporary science and the sphere of politics and public debate. Although scientific research alerted us to the ozone hole, to AIDS, and

to the greenhouse effect, science's powers are very limited, he says, when it comes to addressing the causes of these dangers and presenting solutions to them.[42] Given this situation, Stengers argues that the question of 'public intelligence' becomes paramount. By understanding their role as one of producing knowledge (a task eased by keeping the public at a distance), scientists are not equipped to defend their work against their opposers; they need instead to cultivate 'connoisseurs' who will help nurture public intelligence.[43] Such 'connoisseurs' would have an interest in scientific knowledge that is not the same as that of those who produce it; in Stengers's view, they would be 'agents of resistance against a scientific knowledge that pretends it has general authority' and would produce instead what Donna Haraway calls 'situated knowledges'.[44] Elsewhere, Stengers draws a related distinction between 'experts' and 'diplomats', with the role of 'diplomats' being 'to provide a voice for those whose practice, mode of existence, world, or what is often called identity, may be threatened by a decision […] to force experts to think about the possibility that an envisaged course of action may effectively amount to an act of war'.[45]

Artists who engage with scientific methods and ideas in their practice are superbly well equipped to assume the roles of 'connoisseurs' and 'diplomats' as described by Stengers. Their work often contests science's claims to universality, revealing collusions and conflicts of interest between science, business and governments, and bringing out the social and ethical debates that new scientific research provokes. Their work emerges from the broader perspective of a 'connoisseur' who is not only able to act as a conduit of information between scientists and the public but also to hold science and big business accountable in a way that the public cannot.[46]

In many cases, art–science projects also aim to equip the public themselves with greater skills. Critical Art Ensemble, a US-based collective of media practitioners who combine art performance with activism, mounts a passionate defence of amateurism as a way of contesting 'capital's tyranny of specialization'.[47] While the amateur has been a 'scorned figure' in the management of knowledge since the Enlightenment, in which specialists and experts have dominated,[48] Critical Art Ensemble maintains that

> Amateurs have the ability to see through the dominant paradigms, are freer to recombine elements of paradigms thought long dead, and can apply everyday life experience to their deliberations. Most important, however, amateurs are not invested in institutionalized

> systems of knowledge production and policy construction, and hence do not have irresistible forces guiding the outcome of their process such as maintaining a place in the funding hierarchy, or maintaining prestige-capital.[49]

In the face of the increasing privatization and commercialization of genetic material and information, and the growing specialization of science and biotech, a bid for amateurism becomes a vital way of bridging the gap between the interests of big business and those of individual citizens. Many of the projects in this book engage in amateur practices, such as DIY biology and open-source electronics, opening up paths for others to follow them. The use of low-tech, custom-made, inexpensive or recycled components by artists such as Ana Laura Cantera, Gilberto Esparza, Colectivo Electrobiota and Interspecifics marks a contrast with the practices of huge US biotech companies or research centres based in affluent First-World universities, and also with the more costly art–science projects of monumental dimensions funded by such institutions. In contrast, some of these works are experiments that could be carried out with a home chemistry kit. Others draw on the expertise, freely given, of a wide range of collaborators, and are developed in makeshift labs, using open-source hardware and low-cost instruments, where participants may also pick up essential creative and technical skills, while learning about the biology of plants or bacteria.

Amateur engagements are a crucial element in the 'slow science' that Stengers advocates. She calls for a 'deep break' with the model of science forged in the nineteenth century, which 'promoted as a general ideal the fast, cumulative advance of disciplinary knowledge along with a correlative disregard for any question that would slow this advance down'.[50] This ideal has been shaped by science's 'exclusive, quasi-symbiotic relationship with industry' and the need to produce knowledge 'of interest to the competitive war-games of the corporate world'.[51] Instead, Stengers presses for a 'slow science' that would, like all 'slow' movements today (such as slow food or slow fashion), rediscover those relations that were cut in the name of efficiency.[52] This would allow for debate on issues that cannot be resolved within laboratories but must be negotiated with a very wide range of stakeholders. Stengers gives the example of the cultivation of genetically modified organisms in agriculture, which raises questions about cross-pollination, pesticide use, patent applications and reduced biodiversity that far exceed the concerns of biologists working in laboratories.[53] Indeed, the debate over genetically modified maize in Mexico becomes the theme of several

exhibitions curated by Arte+Ciencia, explored in Chapter Four, which bring many of these broader issues into play.

Decolonizing science and nature

In all of the above ways, and others, the art–science projects discussed in the chapters of this book reflect on the changing status of science in contemporary society and construct new relationships between science and the arts and humanities. It is my contention, however, that we can also understand these projects as participating in a move to 'decolonize' science. They do so by questioning its relationship with forms of imperial power, with the environmental depredations of global capitalism, and with a humanist philosophy that is essentially Eurocentric in its origins. They also point to the foundation of 'global' (European, then North American) science on an extreme form of rationalism that excludes other kinds of knowledge and experience. As Aníbal Quijano affirms, 'Nothing is less rational, finally, than the pretension that the specific cosmic vision of a particular ethnie should be taken as universal rationality', as this would be 'to impose a provincialism as universalism'.[54] Some of the projects discussed in this book explicitly establish critical dialogues between Western science and indigenous environmental thought in Latin America; all of them, in different ways, seek to reconnect a disembedded, abstracted scientific knowledge with the cultural, social, spiritual and ethical spheres of experience from which it has been systematically excluded in the West since the Enlightenment.

Framing my analyses in this way brings more sharply into focus the historical and contemporary relationship between science and global structures of power, which is experienced in specific ways in Latin America and other regions of the Global South. It helps us understand the exclusions on which Western science and the European project of modernity have been founded, which underpin an instrumental approach to nature as well as a continued rejection of other forms of knowledge. As Boaventura de Sousa Santos claims, 'regardless of the emergent new sciences (the sciences of complexity), the dominant epistemology continues to be heavily dependent on positivism and its belief in the neutrality of modern science, its indifference to culture, its monopoly of valid knowledge, and its alleged exceptional capacity to generate the progress of humanity'.[55]

Decolonizing science does not mean pointing out that scientific knowledge is not objective: scientists are fully aware that the act of

observing processes changes them, and that initial presumptions and hypotheses shape final results. It does mean becoming more aware of how scientific methods are rooted in social and cultural practices, and how defining proper scientific methods as those methods that have arisen within the Western tradition hides a circular logic of self-legitimation. It requires a recognition of science's involvement in histories of racism, colonialism, and the exploitation of natural resources. It also entails an acknowledgement of the (often overlooked or suppressed) roles played by non-Western people in the advance of scientific knowledge, and an understanding of the ways in which indigenous forms of knowledge might supplement, extend or indeed challenge Western theories and methodologies. Broadly, it means asking who participates in scientific research, who benefits from it, and who is impacted by it, for good or for ill.

The close relationship between Enlightenment science and colonial power was forged in early expeditions to the Americas to classify flora, fauna and minerals and to map out unknown regions, and in research into methods of mining and agriculture that ultimately aimed to turn land and peoples into sources of profit for the imperial centre. Much more recently, since the biotech revolution of the 1980s, nature has become even more thoroughly caught up in financial markets, as control extends over the creation and manipulation of living cells and tissues. In regions still shaped by the legacies of colonialism, such as Latin America, this imbrication of science with biocapitalism produces new forms of social and environmental injustice: the experimentation with transgenic crops on vast scales, the indiscriminate and insufficiently regulated use of agricultural pesticides, the privatization of land occupied by indigenous communities, the patenting of plants, and widespread practices of biopiracy. The extraction of natural resources constitutes Latin America's chief point of entry into the global market; the greatest proportion is exported, leaving behind environmental destruction, damage to health and social conflict.

In this context, to decolonize science also means to decolonize nature. While it is commonly acknowledged that European colonization often involved the plunder and destruction of the lands of the colonized, Plumwood argues that 'the concept of colonization can be applied directly to non-human nature itself'.[56] The imposition of a 'Eurocentric form of anthropocentrism' justified the control and exploitation of lands and their non-human populations by construing humans as beyond or outside nature, confining ethics to the human, and treating non-humans as inferior and available for unrestricted use.[57] Eduardo Gudynas

identifies the extractivist practices that currently play a major part in Latin American economies as extreme forms of utilitarianism that take up positions of control and domination over the environment and society. What results is an 'anthropocentric ethic' in which values are assigned only by humans and are directly linked to human needs and benefits.[58] A decolonizing approach to nature and to its instrumentalization in science therefore challenges the anthropocentrism inherent in European thought. As T. J. Demos finds, 'decolonizing nature entails transcending human-centered exceptionalism, no longer placing ourselves at the center of the universe and viewing nature as a source of endless bounty'.[59]

For Enrique Leff, the growing environmental crisis emerges as a crisis of Western culture and the rationalism of Western modernity, of a world that leads to the reification of life, the excesses of utilitarian thought, and the over-exploitation of nature.[60] Like many Latin American thinkers, Leff emphasizes that the roots of environmental damage are not to be found in ecological issues but in the dominance of Western ontological and epistemological thought, which has divided humans from non-humans and the living from the non-living, and disseminated its approaches to controlling, rationalizing and commodifying nature across the globe.[61] Western science has played a part in 'imperial designs' through its systematic disqualification of alternative knowledges, to the extent that, as de Sousa Santos claims, 'The dark side of the triumphs of science is littered with epistemicides'.[62] To decolonize science is thus to question the investment of (Western) science in a certain model of progress based on the subjection of nature. This way of thinking is rooted in the European Enlightenment and is not compatible with many other worldviews. To a series of hierarchies established by colonialism, Ramón Grosfuguel and Heriberto Cairo add both 'ecocide' (the destruction of life and the planetary ecosystem) and 'epistemicide' (the derogation and destruction of non-Western knowledge).[63] The two are intimately linked, both historically and in today's search, growing in urgency, for alternative, more sustainable ways of living. As we become increasingly aware of the ecological impact of (neo)colonialism, we are also becoming more conscious of the erasure of indigenous knowledge, and particularly those aspects of knowledge that promote more mindful and less destructive forms of coexistence in more-than-human communities.

To decolonize science is therefore to understand that the universal, abstract knowledge Western science has produced – which has yielded uncountable insights – is only one kind of knowledge among many others that may bring benefits to individuals and communities. It is

to ask what kinds of knowledge and practice have been systematically excluded from its disciplines, and to start to reconnect spheres of experience that have been sundered in science's quest for abstraction. In this task of reconnection, indigenous knowledge is proving to be a powerful model. Where Western science aims to produce universal knowledge through processes of reduction and abstraction, indigenous knowledge tends to be place-based, holistic and relational. Instead of division and classification, indigenous worldviews emphasize interconnectedness and mutability. Scientific innovation will undoubtedly play a role in solving some of the world's most intractable problems, but there is an increasing awareness that such challenges will only be met through approaches that are thoroughly transdisciplinary and transcultural. In other words, a rise in scientific literacy should be accompanied by a similar growth in intercultural literacy.

One of the richest contributions of Latin American environmentalism has been its focus on the relationship between culture and nature, as Leff affirms. In contrast with the commitment to 'green' development and technological fixes to environmental problems that characterize responses in the North, in Latin America the vision of sustainability that has been gaining strength is 'founded on the relationship held by traditional, indigenous, and rural societies with their environment'.[64] Although the many indigenous cultures of the Americas are diverse in their beliefs and practices, they hold a number of principles in common. The Aymara researcher and political activist Fernando Huanacuni Mamani explains that these include a fundamental understanding of life as community in which everything is interconnected and interdependent and in which 'vivir bien' (living well; in the original Aymara and Quechua terms, to live in plenitude) means to live in balance and harmony with everything that is.[65] Importantly, to live well is to know how to live together: 'No se puede vivir bien si los demás viven mal, o si se daña la Madre Naturaleza. Vivir bien significa comprender que el deterioro de una especie es el deterioro del conjunto' (One cannot live well if others are not living well, or if Mother Nature is harmed. Living well means understanding that damage to one species is damage to the whole).[66] On the precepts of *buen vivir* are built economies that are based on self-sufficiency and redistribution, and a respect for nature as a living subject rather than as a commodity or a resource for human consumption.[67] The Andean concept of Pachamama differs markedly from the Western idea of nature, as it does not distinguish nature from culture: humans are *in* nature, not separate from it. Nature cannot therefore be objectified and commodified as inert matter in the way that it has been in Western modernity.

In the context of a global ecological emergency, the ontologies and epistemologies of indigenous thought, which establish relations of continuity between the biophysical, human and spiritual worlds, are increasingly being seen as viable alternatives.[68] However, Santiago Castro-Gómez finds that recent recognitions of the value of indigenous knowledge are 'pragmatic rather than epistemical', leaving the foundations of knowledge essentially unquestioned:

> Although the wisdom of indigenous communities or black communities can now be seen as 'useful' for the conservation of the environment, the categorical distinction between 'traditional knowledge' and 'science', elaborated in the Enlightenment of the eighteenth century, is still in force. The former continues to be seen as anecdotal knowledge, not quantitative and lacking methodology, while the [latter] continues, in spite of the transdisciplinary efforts of the last decades, to be taken as the only epistemically valid knowledge.[69]

At the same time, an uncritical embrace of indigenous knowledge as the solution to all modernity's ills is also deeply problematic. Depicting indigenous people as guardians of a natural wisdom that Westerners have lost brings us dangerously close to a Romantic exoticization of the 'noble savage'. In his study of local and global science, Paul Sillitoe exhorts us to move beyond polarized representations, stating, 'In anthropology we have learnt to tread the middle road between thinking that all traditional tribal ways are inherently sustainable and environmentally sound […], and the reverse that all peasants are ignorant and demand development, or worse civilisation'.[70]

What is more, constructions of indigenous knowledge as essentially 'other' to Western science ignore a long history of hybridization between those knowledge systems that in Latin America dates from the earliest colonial times and is still very much in evidence today. The strategic deployment of positive images of indigeneity by indigenous actors today call on Western conceptions of difference in asserting non-Western identities; these tactics 'are, almost by definition, markers of hybridised knowledge systems'.[71] A relevant example here would be the concept of *buen vivir* itself, which has been shaped through a process of dialogue with critical currents within Western thought, including feminist and environmentalist movements, and aims to influence global debates beyond the Andean region.[72] Michael R. Dove and others point out that indigenous values have been prized in recent years precisely for

their apparent 'anti-modern' character, and that the rise of interest in indigeneity is therefore 'both a product of, and a marker of, modernity'.[73]

The efforts of many of the art–science projects here to hybridize systems of knowledge both recognizes the prior interconnections that have already shaped them, and avoids the pitfalls of idealizing indigenous (or other forms of) knowledge in an essentialist or acritical manner. In this way, they are able to reflect in a nuanced way on the region's complex and often paradoxical relationships with modernity. Latin America has long been the source of important critiques of Western modernity and scientific rationalism, whether these are inspired by indigenous thought or the historical experience of the (neo)colonial exploitation of nature and the erasure of alternative epistemologies. In recent years, these critiques have emerged with particular force in the decolonial theories of Latin American(ist)s such as Enrique Dussel, Walter Mignolo, Arturo Escobar and Mary Louise Pratt, among many others. Importantly, however, Leff reminds us that this decolonization of knowledge 'no es tan sólo una empresa filosófica y teórica' (is not only a philosophical and theoretical exercise); it is rooted in social practices and in the emergence of new political actors, and forms part of a wider process of emancipation.[74] It is perhaps Latin American thinkers who are doing the most to connect environmentalism with the aims of social and cultural pluralism: to think environmental knowledge in the context of 'una política de la diversidad y de la diferencia' (a politics of diversity and of difference).[75] These ideas are explored further in several chapters of this book.

Not all of the artworks studied here engage explicitly with indigenous knowledge and beliefs, but they all align themselves with the broader decolonial aims of deconstructing the role of science in the colonization of nature, and (re)situating science within a wider web of epistemologies and ontologies. In this way, they respond to de Sousa Santos's call to replace 'science as a monopolistic knowledge' with 'science as part of an ecology of knowledges'.[76] They often set science alongside other forms of knowledge and practice, whether indigenous or otherwise, which may not be empirically measured; their inclusion challenges science's exclusive claim to authority as an explanatory narrative. They refuse the binary distinctions between culture and nature, human and non-human, that are used to uphold claims of human exceptionalism; they develop scientific techniques that demonstrate instead the intelligence and creativity of other species and invite us to take part in more collaborative relationships with them. Plumwood defines 'two historic tasks that arise from the rationalist hyper-separation of human identity from nature'

in Western culture. These tasks, 'of (re)situating humans in ecological terms and non-humans in ethical terms', would serve as apt descriptions of the challenges that the artists in this book set themselves.[77]

These projects are therefore congruent with many of the aims and tactics of critical posthumanism and new materialism, as articulated by Rosi Braidotti, Karen Barad and others. Both movements are committed to thinking through questions of agency and the vitality of matter in the context of advanced capitalism and its 'opportunistic commodification of all that lives'.[78] For Braidotti, 'Zoe, the non-human, vital force of life, is the transversal entity that allows us to think across previously segregated species, categories and domains'. She describes '[z]oe-centred egalitarianism' as 'the core of a posthuman thought that might inspire, work with or subtend informational and scientific practices and resist the trans-species commodification of life by advanced capitalism'.[79] It is in this spirit that many of the art–science projects discussed here make the vibrant life of matter present to the senses, staging the myriad connections and coevolutions that make nonsense of arbitrary divisions between human and non-human species, and between species and their milieus.

From the local to the planetary: constructing a common world

In their construction of such milieus, many of these projects mediate in interesting and distinctive ways between the local and the planetary. As they travel to exhibitions across the world, they often engage with the species and habitats of local ecosystems: for an exhibition in Lithuania, for example, Kuai Shen chose to work with species of ants that were native to the local area (see Chapter Seven), while Gilberto Esparza adapts his *Plantas autofotosintéticas* project by using polluted water collected from the city in which a particular museum is located (see Chapter Six). While embedding themselves in the local, many projects nevertheless construct perspectives that are planetary in their scope. Ursula Heise is one of a number of scholars who have recently argued for the importance of 'a sense of planet' in raising ecological awareness, finding that questions of environmental ethics may be very effectively framed through a 'nonlocal' approach to knowledge as well as a place-based one.[80] Many of the projects studied in this book have rendered visible and audible the unimaginably powerful geophysical forces that have shaped life on Earth, expanding our horizons to embrace planetary perspectives.

A planetary perspective runs the risk of enabling a totalizing conception of the world as a single unity. This was the vision that underpinned the universalism of Enlightenment science and thought, in which European centres projected their own understanding of nature (and their imperialist will to dominate and appropriate it) onto the rest of the world. It also lies behind uncritical versions of cosmopolitanism and globalism, which erase political and cultural difference. While exploring concepts and experiences of the planetary, the works explored in this book challenge any notion of the planet as a stable, timeless or bounded entity and readily acknowledge that its production in art, science and philosophy is inescapably cultural. They do this in several ways. First, they extend the horizons of the planetary, situating Earth within the immeasurably vast, dynamic forces that structure the universe and within a cosmic time that eludes human grasp. Second, the planet they imagine is not a single unit or a totality but a dynamic, relational system in which multiple worlds come into coexistence; in short, they explore the planet as pluriverse. And third, they locate planetary knowledge at a crossroads between science, politics and culture, drawing on religious or spiritual enframings in order to historicize or extend our understanding of how the planetary is produced within political or cultural spheres. They approach the planet as the new horizon for collective human action while remaining fully aware of its geopolitical inequalities and cultural differences.

A similar sensibility marks these artists' construction of a common world, which emerges as another important theme in this book. Their projects do not envision a kind of utopian future coexistence devoid of conflict and contradiction; rather, they focus on the vulnerabilities that result from cohabitation and the kinds of accommodations we may need to make in order to promote the interests of different communities and other species. This is the focus of Stengers's notion of 'cosmopolitics'. For Stengers, 'cosmopolitics' is explicitly not Kant's 'cosmopolitanism', which would include all citizens of the world within a single community, and the formation of a global federation as a necessary condition for 'perpetual peace'.[81] Her 'cosmopolitical proposal' does not reduce the divergence between multiple worlds, but aims 'precisely to slow down the construction of this common world, to create a space for hesitation regarding what it means to say "good"'.[82] It is a demand that decisions are taken 'in the presence of' those who may become the 'victims' of those decisions.[83] This would involve a questioning of science's subordination of other knowledges, practices and forms of being through its claims to universality.

The scope and organization of this book

Like many of the art–science projects explored within it, this book attempts to bring together the insights and methodologies of different disciplines and intellectual traditions. To this end, as well as drawing on concepts and frameworks from the natural sciences and the creative and performing arts, I explore relevant paradigms that have been developed within human and cultural geography, anthropology, sociology, philosophy and cultural studies. I highlight the work of Latin American(ist) environmental and decolonial thinkers, such as Leonardo Boff, Marisol de la Cadena, Arturo Escobar, Eduardo Gudynas, Enrique Leff and Maristella Svampa, alongside theorists who may be more familiar to European and North American readers, such as Jane Bennett, Nigel Clark, Bruno Latour, Timothy Morton, Val Plumwood, María Puig de la Bellacasa, Isabelle Stengers and Anna Tsing.

This breadth is essential if I am to approach one of the main theoretical purposes of this book, which is to consider points of convergence (and friction) between environmentalism, posthumanism and decolonial thought from a Latin American perspective. Some of these have already been traced by thinkers such as Escobar, whose concept of the 'pluriverse' embraces both human and non-human world-makings, within relational ontologies that do not rest on a division between nature and culture. Many indigenous thinkers from Latin America emphasize the extent to which *buen vivir* is not simply an environmental concept but a political and social one. As the intellectual and indigenous leader Floresmilo Simbaña explains, 'el Sumak Kawsay no es un concepto que se puede entender por sí mismo, necesariamente está unido al de Plurinacionalidad y éstos se encuentran directamente ligados a lo comunitario, que es la base constitutiva de ambos' (Sumak Kawsay (good living) is not a concept that can be understood in itself; it is necessarily coupled with that of Plurinationalism and these are directly tied to the communitarian, which is the constitutive basis of both).[84] If attempts to associate nature and human society too closely have often fuelled racism, slavery and misogyny as well as nostalgic primitivism, this book will set out ways in which 'arguments from nature' are being reappropriated in these art–science projects for more liberatory ends: to challenge anthropocentrism, to question the philosophical, social and economic foundations of modernity, and to promote forms of biocentric thought and practice that have emerged from indigenous cultures in the South.

Chapter One, 'A planetary art beyond the human', examines the increasing number of Latin American art–science projects that explore the possibility of representing geological and cosmic time, giving visible, audible or tangible expression to the powerful forces that shape the planet's systems, which often lie beyond the limits of human perception. I explore projects by five artists – Ariel Guzik (Mexico), Michelle-Marie Letelier (Chile–Germany), Rafael Lozano-Hemmer (Canada–Mexico), Claudia Müller (Chile) and Paul Rosero Contreras (Ecuador) – who draw on the science of turbulent dynamics, which governs phenomena such as solar flares, gravity, electromagnetic and seismic waves, winds, tides, tsunamis and volcanic eruptions. While it has become vital to recognize the extent to which humans have become 'geological agents' in their impact on the planet, these projects stage encounters with elements and forces that defy human influence. They remind us of the fundamental asymmetry that governs our relationship with a volatile planet, which is often lost in the accounts of the entanglement of humans and non-humans that have come to prevail in the humanities and social sciences. Engaging critically and affectively with the *in*human thus becomes an important way of thinking beyond anthropocentrism in these works.

The installations discussed in Chapter Two, 'The atmosphere as a planetary commons', present the atmosphere simultaneously as a natural resource and as a shared space of social existence. Several recent projects by Rafael Lozano-Hemmer reveal the unseen turbulences of the air, which absorbs not only our breath and our words, but also increasing carbon emissions. The participatory elements of his works draw attention to the atmosphere as a common medium that connects us all through the act of respiration. The experience of a shared vulnerability that emerges in his work encourages us to revisit Judith Butler's notion of precariousness, developed largely within the context of political violence, and to extend her insights to form the basis of an environmental ethics. The lighter-than-air structures designed by Tomás Saraceno (Argentina–Germany), often powered by solar energy and the wind, allow us to imagine a new nomadic mode of life in floating cities that would transcend national boundaries, while making us more aware of our dependence on the elemental forces that govern the universe. Works by both artists invite us to reflect on the nature of a commons, or commoning, as a practice that is embodied, existential, ecological, political and economic.

Chapter Three, 'Art and environmental change: beyond apocalypse', explores projects by Joaquín Fargas (Argentina) and Paul Rosero Contreras (Ecuador) that imagine environmental futures in ways that challenge some of the premises of apocalyptic narratives of

the Anthropocene. In contrasting these projects, I ask how they endorse or subvert the linear, teleological temporality of apocalypticism and the anthropocentrism that often motivates the representation of climate change as reversible (we save the planet) or, indeed, as irreversible (we destroy the planet). Drawing on the work of Andreas Weber and several Latin American scholars, including Eduardo Gudynas and Raquel Gutiérrez Aguilar, I suggest ways in which biosemiotic and biocentric perspectives may make a valuable contribution to the 'feminist counterapocalypse' proposed by Joanna Zylinska.

The art–science projects brought together in Chapter Four, 'Science in an ecology of knowledges', develop a critique of Western science by resituating it in relation to the indigenous knowledge it has systematically excluded. It opens with an exploration of the connections between the terrestrial and the celestial forged in artworks and performances by the artist duo Lina Mazenett and David Quiroga (Colombia), who approach geology and astronomy through the lens of Amerindian cosmologies. Their projects question the exclusions on which modern rationalism is founded and resituate science within a broader 'ecology of knowledges' (Boaventura de Sousa Santos). In the second part of this chapter, 'Transgenic maize: between the *milpa* and the monoculture', I explore two exhibitions curated by the Arte+Ciencia collective (Mexico). Their work stimulates public debate around the risk to native maize varieties presented by the genetically modified (GM) crops that American agro-biotech companies are intent on growing in the country, by contrasting monocrop farming with the ecological benefits of the indigenous tradition of polyculture. They develop a critique of the privatization of knowledge and of life itself, connecting advances in science and biotechnology with broader questions of biological diversity and cultural plurality.

The projects discussed in Chapter Five, 'Interspecies communication and performance', create means of encounter and interaction between humans and other organisms, including plants, animals, bacteria and slime mould. These works draw on the remarkable findings of biologists and plant scientists concerning the capacity of non-human species for cognition, communication and memory, encouraging us to rethink how we interact with other species within a shared ecology. The first part of the chapter, 'Plantbots and the logic of vegetal life', discusses works by Colectivo Electrobiota (Argentina), Guto Nóbrega (Brazil) and Ivan Henriques (Brazil–Netherlands) that emphasize the subjectivity, sensitivity and agency of plants, and the wealth of interconnections they maintain with other species and their environment. The following part, 'The language of cetaceans', centres on the extraordinary machines that

Ariel Guzik (Mexico) has designed and built to facilitate an encounter with whales and dolphins in their natural environment. As well as drawing attention to the singular intelligence of these mammals, his work reminds us that all language is rooted in reciprocal, sensory exchanges with our environment. The final section, 'Microbe music', explores how the Interspecifics collective (Mexico) uses sound to explore the bioelectrical activity of bacteria, plants and slime moulds, to demonstrate the performativity of living matter, and to stage collaborative forms of performance between different species.

Chapter Six, 'Revising systems art: biological time and the ethics of care', considers how art–science works of the twenty-first century in Latin America revisit and revise systems art of the 1960s and 1970s. Their greater interest in biological time and the coevolution of life forms and technology, as well as the ethics of care, updates systems art for a more post-anthropocentric era. The first section of the chapter brings together projects by Gilberto Esparza (Mexico), Ivan Henriques (Brazil–Netherlands), and Ana Laura Cantera (Argentina) that develop technologies to promote the renewal of ecosystems. I propose the term 'slow robotics' to characterize their emphasis on sustainability and the coevolution between technology and living organisms, replacing the drive for speed and the wasteful consumption of energy that mark the robotics industry. In the second part, I explore curation as care in works by Fargas, Marina Zerbarini (Argentina) and Lina Espinosa (Colombia), drawing on the work of Leonardo Boff and María Puig de la Bellacasa to discuss the ethics of care that emerges from the interdependence and reciprocity that bind us within more-than-human ecosystems.

The final chapter, 'Sensory worlds and the pluriverse', discusses works by Saraceno and Kuai Shen (Ecuador–Germany) that explore the sensory worlds of spiders and ants respectively, focusing on themes of multispecies cohabitation and co-creation. Saraceno's spiderwebs help us think, not only about connectedness, but also about the coevolution of different species and their milieus. Kuai Shen explores a mutualism that is both biological and sociocultural, creating analogies between ant behaviour and the communitarian organization of traditional societies in the Andes. Through my analysis of the works of both artists, I trace connections between Jakob von Uexküll's sensory worlds in biology, the concept of embodied cognition developed by Francisco Varela, and the concept of the pluriverse as theorized by Escobar and other decolonial thinkers.

While this introduction has focused principally on how these art–science projects intervene in the sphere of science and public

communication, the conclusion explores to a greater degree how they may be understood within the field of artistic practice and research. I move from a discussion of the specific understanding of knowledge that these projects create – which expands cognition to include the embodied, sensory, creative and ethical dimensions of our entanglement with the 'objects' of our knowledge – to suggest a series of ways in which they revise modes of participation and dematerialization in art as part of their commitment to exploring the 'radical relationality' (Escobar) that subtends decolonial approaches to politics, nature and science.[85]

A important note on the corpus, on 'art–science', and on 'nature'

In creating a corpus for this study, I have given priority to those art projects that not only represent scientific ideas or processes but make direct use of techniques and methods borrowed from science. A useful distinction in this regard is drawn by Daniel López del Rincón, who contrasts two major strands in bioart: the 'tendencia biotemática' and the 'tendencia biomedial'. The first takes biotechnology as a subject, while the second uses it as an artistic medium.[86] Not all the projects in this book fall into the bioart category; others draw on techniques from geology, physics, chemistry or astronomy. However, in a similar way to biomedial art, they use scientific instruments or experimental methods or demonstrate scientific principles at work in forces and matter.

I have selected art projects that experiment with technologies only if they do so to reflect on scientific knowledge or practice, or to directly advance our understanding of, and engagement with, the natural world beyond the human. This purposely leaves out a much broader range of potential works that explore new media technologies, robotics, neuroaesthetics and digital art, to the extent that these are more focused on exploring questions of a sociological or psychological kind, such as the extension of human powers through new prostheses, the risks and possibilities of artificial intelligence, or the impact on individuals and societies of new forms of technological mediation. As Lévy-Leblond reminds us, too, 'The fact that a form of artistic creation, whatever its merit or value, borrows tools from contemporary high technology (e.g. infography, electronic palette) or concepts from contemporary science (e.g. chaos theory, fractals) does not necessarily establish de facto a rich and deep relationship with science and technology'.[87] I have chosen

instead those art projects that deploy technology to increase our scientific understanding of the more-than-human world.

All the artists gathered here were born in Latin America and most continue to be resident there. Some of them currently live in Europe or North America, but maintain links with their home countries, returning there for exhibitions or performances (Saraceno), working with species that originate in the region and conducting research in specific habitats there (Kuai Shen) or engaging with topics that are clearly connected with current issues of environmental and political importance in the region (Letelier, Lozano-Hemmer). As is so often the case in the contemporary art world, the two artists with the highest international profile (Saraceno and Lozano-Hemmer) pursue transnational careers; my intention is not to read their work (or that of any other artist here) as 'Latin American' in a reductive or essentialist manner, but to explore what aspects of their work are highlighted when we bring them into dialogue with other artists from the region. My interest in constructing a Latin American corpus is twofold. It is in part a strategic decision, in order to address a significant gap in existing scholarship on art–science projects. But it also stems from the political imperative to understand the relationship between science and coloniality in one of the most biodiverse regions of the world, which is also suffering some of its worst environmental disasters and depredations, variously caused by intensive open-cast mining, large-scale deforestation or monocrop agriculture. Studying these works from a Latin American perspective also brings into view points of contact between decolonial thought and environmentalism, which are approached in a variety of ways in the chapters of this book.

Using the term 'art–science' to describe this corpus is a debatable choice. For a number of artists, this category is associated with a certain kind of blockbuster exhibition in which it is really science that brings the novelty, and the immediacy of artistic spectacle prevails over the creation of a more meaningful poetics. Nóbrega, for example, contends that what he does is not 'art–science' or even 'art–technology', but simply art; segregating art in this way is unhelpful, as it deters curators and critics who are not interested in science or technology and prevents those who are from approaching works in terms of their poetics instead of their engagement with science.[88] In deploying the category 'art–science' here, my intention is to reappropriate this term for artistic works and critical practices in which art and science are held in a genuine and productive tension, allowing new poetics and perspectives to emerge. This does not take place in a uniform way; while I contend that there is a value in bringing them together as a corpus, my discussions of the projects in this

book do not erase the very different relations they conceive between art and science, as well as the diverse ways in which they circulate within and beyond the world of art.

A final note: the term 'nature' is often rejected by writers who wish to avoid the suggestion of a world that is somehow beyond culture or the human and sidestep the idealistic or primitivist overtones the word has acquired, particularly in Romanticism. The alternatives are often equally misleading, however: 'environment' also implies a separation between humans and their surroundings, and relegates the non-human world to the background, while 'biology' or 'biosphere' excludes elements that we consider to be non-living. Where I cannot be more specific in references to 'the plant world', 'landscape', 'the planet' or 'the geosphere', I have often resorted to 'nature' as a convenient catch-all term, while attempting to make clear that, unless I am referring to Enlightenment views that I am subjecting to critique, my own use of the word is not to be understood as something humans can transcend or that is opposed to culture.

Notes

1. Wilson, *Art + Science Now*, 9.
2. Wilson, *Art + Science Now*, 9.
3. Kessler, *Picturing the Cosmos*, 11, 17, 231.
4. Lévy-Leblond, 'Brief encounters', 211.
5. Lévy-Leblond, 'Brief encounters', 211–12.
6. Lévy-Leblond, 'Brief encounters', 212.
7. Zylinska, *Bioethics in the Age of New Media*, 151.
8. Zylinska, *Bioethics*, 151–60.
9. Stengers, *Another Science Is Possible*, 15.
10. Latour, 'Why has critique run out of steam?', 227.
11. Latour, *Pandora's Hope*, 114.
12. Lévy-Leblond, 'Brief encounters', 214, 215.
13. Plumwood, *Environmental Culture*, 19.
14. Plumwood, *Environmental Culture*, 5.
15. Hauser, 'Biomediality and art', 218.
16. Ziman, *Real Science*, 67, 172.
17. Ziman, *Real Science*, 78.
18. Ziman, *Real Science*, 78–9.
19. Ziman, *Real Science*, 79; see 'The normative structure of science' in Merton, *The Sociology of Science*.
20. Quiroz Valenzuela, *Ciencia*, 48.
21. Barandiarán, *Science and Environment in Chile*, 191.
22. Quiroz Valenzuela, *Ciencia*, 48.
23. Barandiarán, *Science and Environment in Chile*, ix, 6.
24. Barandiarán, *Science and Environment in Chile*, 194.
25. Astudillo, *Manifiesto por la ciencia*, 98–9. All translations are mine unless otherwise stated.
26. Ziman, *Real Science*, 72.
27. Kellogg, 'Toward a post-academic science policy', 18–20.
28. Ziman, *Real Science*, 173.
29. Kellogg, 'Toward a post-academic science policy', 17–18.
30. Varsavsky, *Ciencia, política y cientificismo*, 45.

31. Kreimer, *Ciencia y periferia*, 69, 201, 215.
32. Varsavsky, *Ciencia, política y cientificismo*, 46.
33. Massarini and Schnek, *Ciencia entre todxs*, 76.
34. Kellogg, 'Toward a post-academic science policy', 14, 18.
35. Kellogg, 'Toward a post-academic science policy', 15.
36. Triscott, 'Curating contemporary art in the framework of the planetary commons', 386.
37. Kellogg, 'Toward a post-academic science policy', 18.
38. Ziman, *Real Science*, 41.
39. Quiroz Valenzuela, *Ciencia*, 23–5.
40. See http://www.fundacionmasciencia.cl. Accessed 20 October 2020.
41. See https://marchforscience.org. Accessed 20 October 2020.
42. Lévy-Leblond, *La Pierre de touche*, 55.
43. Stengers, *Another Science Is Possible*, 20–1, 7–9.
44. Stengers, *Another Science Is Possible*, 9; see also Haraway, 'Situated knowledges'.
45. Stengers, *Another Science Is Possible*, 153.
46. Stengers, *Another Science Is Possible*, 8–9.
47. Critical Art Ensemble, *Digital Resistance*, 6.
48. Critical Art Ensemble, *Digital Resistance*, 112.
49. Critical Art Ensemble, *Digital Resistance*, 8–9.
50. Stengers, *Another Science Is Possible*, 98.
51. Stengers, *Another Science Is Possible*, 99, 107.
52. Stengers, *Another Science Is Possible*, 104.
53. Stengers, *Another Science Is Possible*, 3.
54. Quijano, 'Coloniality and modernity/rationality', 31.
55. De Sousa Santos, *Epistemologies of the South*, 193.
56. Plumwood, 'Decolonizing relationships with nature', 52.
57. Plumwood, 'Decolonizing relationships with nature', 53.
58. Gudynas, *Extractivismos*, 433–4.
59. Demos, *Decolonizing Nature*, 19.
60. Leff, *Racionalidad ambiental*, ix–x.
61. Leff, *Discursos sustentables*, 197.
62. Dalea and Robertson, 'Interview with Boaventura de Sousa Santos', 158.
63. Cairo and Grosfoguel, 'Descolonizar los sueños de la Razón para dejar de producir monstruos', 13.
64. Leff, 'Latin American environmental thinking', 443.
65. Huanacuni Mamani, *Buen Vivir/Vivir Bien*, 32–3, 49.
66. Huanacuni Mamani, *Buen Vivir/Vivir Bien*, 49.
67. Huanacuni Mamani, *Buen Vivir/Vivir Bien*, 9, 52–4.
68. Escobar, *Sentipensar con la tierra*, 117.
69. Castro-Gómez, 'The missing chapter of Empire', 295.
70. Sillitoe, 'Local science vs. global science: An overview', 17.
71. Dove et al., 'Globalisation and the construction of Western and non-Western knowledge', 141.
72. Escobar, *Designs for the Pluriverse*, 148.
73. Dove et al., 'Globalisation and the construction of Western and non-Western knowledge', 131.
74. Leff, *Racionalidad ambiental*, xii.
75. Leff, *Discursos sustentables*, 196–7.
76. De Sousa Santos, 'Beyond abyssal thinking', 69.
77. Plumwood, *Environmental Culture*, 8–9.
78. Braidotti, 'A theoretical framework for the critical posthumanities', 35.
79. Braidotti, 'A theoretical framework for the critical posthumanities', 42.
80. Heise, *Sense of Place and Sense of Planet*, 55–6.
81. See Kant, *Perpetual Peace: A philosophical essay*.
82. Stengers, 'The cosmopolitical proposal', 995.
83. Stengers, 'The cosmopolitical proposal', 997.
84. Simbaña, 'El *sumak kawsay* como proyecto político'.
85. Escobar, *Pluriversal Politics*, xiii.
86. López del Rincón, *Bioarte*, loc. 133.
87. Lévy-Leblond, 'Brief encounters', 212.
88. Correspondence with the author, 4 June 2020.

1
A planetary art beyond the human

In the mid-1990s, Michel Serres was already registering the devastating impact of 'dense tectonic plates of humanity' on a hitherto 'mute world'.[1] Our excesses, he writes, have awoken the 'mute, passive, obscure things' around us that had 'obediently slumbered', but will now respond to us with violence.[2] In such discourse we recognize the now common tropes of thresholds and tipping points, often deployed by climate scientists and echoed by scholars who assert that humans are now truly 'geological agents' in their impact on the planet.[3] Getting to grips with the consequences of human activity for the Earth's systems is unarguably an essential step in forging policies to mitigate the damage. But in the political urgency that shapes many debates about climate change, there is a risk, as Dipesh Chakrabarty points out, that 'humans emerge as the subject of the drama of the Anthropocene' while geological time fades from view.[4] An emphasis on human agency may simply lead us full circle, back to the anthropocentric conception of a docile Earth made up of inert matter, only stirred by our own excesses, and waiting to be saved or destroyed by its human inhabitants.

A growing number of transdisciplinary art–science projects across the world are taking up the challenge of representing geological and cosmic time, and of rendering visible, audible and tangible the powerful but often invisible forces that shape the planet's systems and even its orbit through space, such as gravity, atmospheric turbulence, and electromagnetic and seismic waves. Many do so in ways that do not emphasize the geological agency of humans so much as the enormous power and dynamism of systems that are wholly beyond human control. This brings an important corrective to narratives of the Anthropocene in which humans are often granted too much power in a 'mute world'. In part I of this chapter, I will argue that art may play a more powerful role in engendering a genuinely planetary perspective when it pays attention

to those forces we cannot compel. Gesturing towards the *limits* of human agency with regard to the Earth may ultimately be a more effective way of challenging anthropocentrism, and of helping us to locate human history more properly within planetary time. My corpus is drawn from recent Latin American art–science projects that frame the turbulent dynamics of the Earth's systems – in solar flares, earthquakes, winds, tides, tsunamis and volcanic eruptions – that are impervious to human action. These projects challenge the notions of ecological balance and harmony that persist today in narratives of conservation and climate change, pointing instead to the inherent violence and chaotic phenomena that have always shaped the planet's geosphere.

The projects in this chapter turn to – and often literally tune into – the planet and to the forces that influence its geophysics. They take part in a new emphasis on the planetary that is becoming increasingly evident in art and in other creative and intellectual fields.[5] For Mitchell Tomashow, if '[g]lobal environmental change is simultaneously ubiquitous and invisible', an ecological perception that is based on 'a sense of place' and what we can 'see, hear, smell, taste, and touch' gives us the most effective point of entry to interpreting the biosphere.[6] Ursula Heise argues instead that 'what is crucial for ecological awareness and environmental ethics is arguably not so much a sense of place as a sense of planet', which can be stimulated through 'nonlocal types of knowledge' as well as place-based ones.[7] The works discussed below do not take on the challenge of making planetary forces visible to us by immersing us in the ecologies of our own backyards; neither do they perform site-specific interventions in matter. They focus instead on making visible or audible forces that transcend a particular location and may lie beyond human perception, often devising performances that leave no material trace behind. These are some of the ways in which they revise the practices of earth art to produce what might more appropriately be termed a 'planetary art', as I will suggest below.

The works presented here invoke natural forces of enormous power without lapsing into species-bound narratives of human agency or vulnerability. The solar flare simulations created by Rafael Lozano-Hemmer explore the dynamics of the most powerful explosions in the solar system, which can have a dramatic impact on Earth, 93 million miles away. Works by Claudia Müller focus on the interplanetary forces that produce tides and trace the impact of the Pacific-wide tsunami triggered by the 1960 earthquake in Valdivia, Chile, the most powerful ever recorded. Michelle-Marie Letelier highlights the influence of global wind and tide patterns in the development of extractivist industries in South America and in trade routes to and from the continent. Her work

demonstrates particularly well that a turn to the planetary may in fact reveal, rather than erase, differences in geography, culture or politics. A machine designed and built by Ariel Guzik captures electromagnetic waves to produce an exquisite and unpredictable music. Paul Rosero Contreras captures the tremors that animate the Earth's crust in the Andes and the cracking of glacial ice in Antarctica, creating works that expose us to the vast – but often invisible – forces that bring tectonic plates or ice shelves to collide, separate or melt. Using techniques of rescaling, the creation of formal analogies that suggest self-similar structures across massively different scales, and the transduction of one energy state to another, these works produce shifts in perspective and spatial relations that unroot us from any specific place. This does not mean that they are abstracted from materiality. Several of the works use sound, partly for its immersive and affective qualities, but also because it connects us physically with a planet on which all matter, organic or inorganic, vibrates. They emphasize in this way the intricate resonances and reciprocities that bind all matter into a dynamic, evolving system.

I. Inhuman agency

The works by Lozano-Hemmer, Müller and Letelier presented in this part of the chapter respond to Timothy Morton's proposal that 'Art in the Age of Asymmetry must thus be a tuning to the object', as the cycles of the Earth 'demand a geophilosophy that doesn't think simply in terms of human events and human significance'.[8] They allow us to explore a tension between, on the one hand, the intimate entanglement of human and planetary histories and, on the other, what Morton refers to as the 'withdrawnness' of the unseen forces and objects that shape the Earth's systems. I read these projects as important gestures towards the asymmetry that governs encounters between humans and the inhuman agencies that shape the conditions of life on our planet. I use 'inhuman' rather than 'non-human' here to refer to those forces and dimensions in which human presence and influence are entirely absent. The imbalance of power between the human and the inhuman, Nigel Clark argues, is often lost in the accounts of entanglement that have recently prevailed in many branches of the humanities and social sciences. While Clark acknowledges the seminal importance of Bruno Latour's sustained study of the complex assemblages of humans and non-humans that make up human society, for example, he reminds us that 'all is not equal in the world of mixing and mobilizing things'.[9] Although remaining fully aware

of the many ways in which humanity has become 'a preeminent force in planetary nature', often to the severe detriment of the environment, Clark also chooses to focus on what earth sciences reveal about the dynamics of the physical world *beyond* our capacity to intervene, emphasizing in this way 'our susceptibility to the earth's eventfulness'.[10] An understanding of this vulnerability, which is unevenly experienced across the world, helps to guard us against the universalizing tendencies of species-thinking and is essential, as I argue below, to an ethical, decolonial approach to the geopolitics of environmental change.

The limits of human agency

Rafael Lozano-Hemmer (Mexico–Canada) studied chemistry before working as an artist, developing projects that cross the boundaries between architecture, performance and electronic art. Many of his participatory works take place in public spaces such as plazas, parks or the night sky above a city. They redeploy technologies of surveillance – robotic searchlights, biometric data tracking, and geolocation techniques – for aesthetic, relational or democratic ends that subvert the uses for which they were originally developed. The monumental scale of his urban projects is often repeated in his gallery works, including *Blue Sun* (2018) and *Solar Equation* (2010), examples of a number of quasi-architectural solar models that Lozano-Hemmer has designed to simulate the turbulent flares and sunspots that can be observed on the surface of the sun.[11] In these works, Lozano-Hemmer drew consciously on the kinetic art of Jesús Rafael Soto (Venezuela) and Julio Le Parc (Argentina), whose own giant spheres invite participation, appearing to shift subtly in the light as the viewer moves around the work.[12]

In comparison with *Blue Sun* and *Solar Equation*, the smaller scale of *Flatsun* (2011) gives greater prominence to the interactive element programmed into these works.[13] I will suggest that this interactivity allows the work to convey some of the contradictions that mark Anthropocene thought on human agency. With a diameter of 140 centimetres, *Flatsun* is exactly a billion times smaller than the real sun. The disc-shaped screen is mounted in a dark gallery, with its centre at torso height (see Fig. 1.1). It uses complex algorithms to simulate the solar flares that erupt from the turbulent gases and tangled magnetic field lines at the sun's surface.[14] A pinhole camera registers the presence of gallery visitors, producing greater turbulence when it detects more movement, or slowing down and eventually fading to black if no one is there.

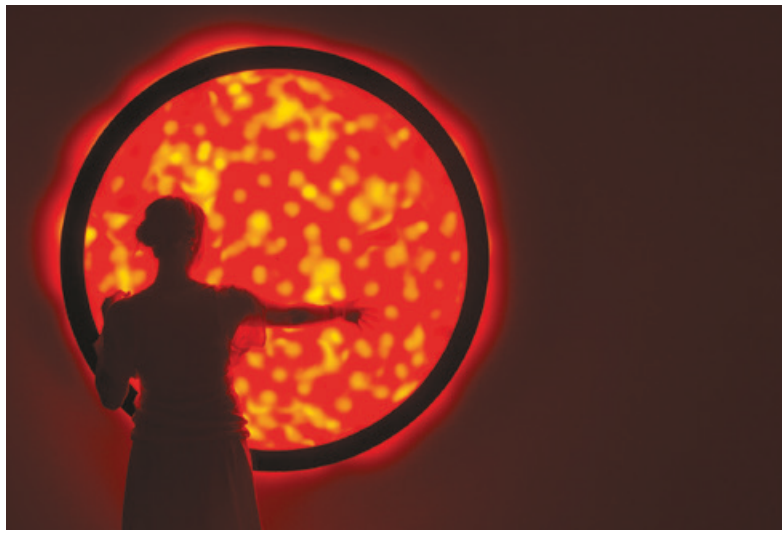

Figure 1.1 Rafael Lozano-Hemmer, *Flatsun*, 2011. *Trackers*, La Gaîté Lyrique, Paris (photograph by Antimodular Research).

Flatsun was inspired by the images that have emerged from the Solar and Heliospheric Observatory (SOHO) and the Solar Dynamics Observatory (SDO), which have been operating since 1996 and 2010 respectively. Real-time and archived videos capturing solar flares and sunspots are available to view from both observatory websites.[15] Lozano-Hemmer describes the conversion of hydrogen into helium and the creation of the elements that make up the universe as 'the image of our time'. He explains:

> es una imagen de Blake, es una imagen turbulenta, es una imagen que sí nos pide una cierta humildad y que nos lleva a adquirir una conciencia de la violencia del universo, sobre todo cuando contemplamos la escala con la que esas explosiones suceden.[16]
>
> (it is an image from Blake, a turbulent image, an image that does demand a certain humility from us and that makes us aware of the violence of the universe, especially when we contemplate the scale on which these explosions are taking place.)

However, the act of scaling down the sun to a comfortable size, hanging it on the wall of a gallery and making it interactive speaks not of our humility but of our presumption in imagining that a giant star might

respond to our actions. Standing in front of the screen, we are reminded of our cosmic insignificance, but also encouraged to imagine a power that we do not possess: there is currently no action humans can take that can impact the sun, while we on Earth are certainly vulnerable to the action of solar flares, which can knock out power grids and satellites.

Although the small scale of the disc affords us an apparently objective viewpoint, its interactive element works against this: every one of our actions produces a reaction, meshing us together in a single system with the object of our observation. This sense of intimate connectivity pervades our contemporary understanding of our species' relationship with the Earth and its climate. As we become increasingly aware both of the sensitivity of the Earth to our actions, we may conclude with Latour that 'the Earth is no longer "objective", in the sense that it can no longer be kept at a distance, considered from the point of view of Sirius and as though it has been emptied of all its humans'.[17] Our planet and its atmosphere are no longer simply a backdrop to human activity, simply the environment in which humans have evolved; there are no subjects and objects, but acts of co-production in which '*[a]gencies* are redistributed'.[18]

Flatsun also becomes a hyperbolic performance of our increasing power as a species to affect the geophysical dynamics of our own planet, and even to intensify or counteract the sun's effects on weather in space.[19] Since the discrediting of geocentric models of the universe, science has persuaded us of the diminished importance of humans on a planet that is not at the centre of the universe; in contrast, we are now being asked to acknowledge the inordinate power of human action over the ecosystems of an entire planet. Thinking about the vast cumulative effects of humans as a species on the Earth's systems may be an important step in understanding the scale of the crisis we are in. But that same vision can return to us an inflated sense of human power and importance in relation to our environment, and it still tacitly relies on an ontological separation between humans and nature that is central to Enlightenment thinking. At the same time, the turbulent dynamics of the solar flares simulated in *Flatsun* remind us of our insignificance and powerlessness, reminding us of cosmic dramas that are being played out on scales beyond our imagination and which lie well beyond the reach of human agency. Lozano-Hemmer's work thus captures the unstable, continually oscillating notions of human agency that characterize the Anthropocene, in which the evaluation of our own power as individuals or as a species swings from hubris and narcissism to impotence and back again.

Tides, tsunamis and other hyperobjects

If in *Flatsun* we are asked to imagine the dizzying prospect of being able to provoke the sun's explosions, in the work of the Chilean artist Claudia Müller the stars and planets remain stubbornly beyond the reach of human influence. Her installations allow us to apprehend the agency of 'hyperobjects' that are normally too vast for us to perceive and exceed our conceptual grasp. Morton uses the term 'hyperobjects' to refer to 'things that are massively distributed in time and space relative to humans', such as black holes, the solar system or radioactive materials.[20] We can never see hyperobjects directly or in full, but we can infer their presence and the force they exert from graphs, instruments, sunburn, radiation sickness or tsunamis.[21] They are both present to us and 'profoundly withdrawn', beyond human reach.[22] In other words, they are only detectable through their imprint on other objects; as Morton puts it, 'hyperobjects disclose interobjectivity'.[23] Müller's projects focus on the action of interplanetary forces such as gravity and electromagnetism on the Earth's systems, and particularly on the hydrosphere. These are forces that radically shape the foundations of life on Earth but which we can barely measure with instruments, let alone see directly with our eyes, emanating from realms beyond the reach of human agency.

A number of Müller's videos and installations demonstrate the dynamics of water flow and how it is affected by the gravitational pull of the sun and the moon as well as by the topography of a river basin. They become a study of time and space, as mediated through the flow of water: of how the elliptical orbit of the planets creates the cyclical rise and fall of tides on Earth, how the volume of water and the gradient of the slope modify the flow of a stream, how gravity interacts with water and air pressure to form a vortex, or how the measured fall of water from one container to another has been used by humans to calculate time. Capturing the effects of gravity on water flow in scaled-down models allows us to grasp the workings of powerful elements and forces that are often invisible to the human eye; conversely, it also helps us to situate the familiar and the everyday within a cosmic interplay of matter and energy. In *Constelante* (Constellating, 2011), for example, a whirlpool is created in a small bucket of liquid with the help of a water pump.[24] As it rotates at the base of the tub, a vortex develops as a result of the interaction between centrifugal force and gravity, leaving a hole at the centre. The image of the vortex is projected by an overhead camera onto a nearby wall, producing the illusion of depth on the wall's surface, as if we were staring into a wormhole.[25] Ground coffee is mixed into the water

contained in the tub, making it darker and denser, slowing down the rate of rotation and allowing it to capture the light, accentuating its circular motion. The motor, to which a timer is attached, works intermittently, so that the whirlpool forms, unforms and re-forms in a continual cycle. The title of the exhibit suggests a cosmic dimension to these cycles, and indeed the projected whirlpool brings to mind the swirling star trails of spiral galaxies.

The spinning of both whirlpools and spiral galaxies takes place because of the action of gravity, a fundamental force that keeps planets in orbit but also profoundly shapes our everyday experience on Earth. Just as in *Constelante* we may behold the structure of galaxies in a bucket, Müller's works are often intended to create contemplative images from natural phenomena and glimpses of the cosmic sublime in the elements that surround us every day. The kind of visuality *Constelante* affords us is not the monarch-of-all-I-survey perspective of interstellar adventure, but one that finds, as Christian Moraru puts it in his study of the aesthetics of planetarity, 'the macro's murmur in the vernacular of the micro, in the tiny, the local, and the humble'.[26] Müller explains that the work was inspired by a glimpse of a whirlpool in a dirty puddle on the street: in even the most common of everyday experiences we can detect the forces that compose the universe.[27] We gain a sense of how intricately the planet is formed and re-formed, continually and at all scales, by forces that exceed our grasp.

In *Semi Diurno* (*Semidiurnal*, 2013), the central space is dominated by three columns, reaching from the floor to the ceiling of the gallery.[28] In each column, slender steel rods support the vertical arrangement of eight water containers. Seven of the bottles are upended, with water passing from one container to the next in a controlled flow through nozzles. From the final container, resting on the ground, the water is pumped up to the top, to begin its journey downwards again. The columns act as clepsydras, one of the oldest known instruments for measuring time, and commonly used in many of the world's regions before the invention of the pendulum clock in the seventeenth century. The flow of water from one container to another is regulated, and the level of water in one of the containers may be compared with marked lines that represent time passed. Narrow nozzles are used to create a more predictable laminar flow from the natural turbulence of water, making it possible to measure time with reasonable accuracy.[29]

This central work is surrounded, however, by other pieces that emphasize forces and flows that may be harnessed by human technology but cannot be tamed by it (see Fig. 1.2). The installation as a whole

Figure 1.2 Claudia Müller, *Semi Diurno*, 2013. Galería Die Ecke, Santiago, Chile (photograph by Patricia Novoa).

focuses on the non-local interactions of objects that are too immense for us to perceive or imagine, which are both spatially separated and intimately connected, producing a convergence of very different scales. 'Semi-diurnal', the term from which the exhibition takes its title, is the name given to a tidal cycle in which two high and two low tides occur every day, of around the same height. The exhibition featured a video that demonstrates the natural rhythms of tides, which are caused by the gravitational pull of the moon and the sun as the earth rotates. Composed of shots taken around sea level by an underwater camera, the video demonstrates the rise and fall of the tides; around its semi-circular form a series of graphics have been added during the editing process to show the changing phases of the moon over a month.[30] A series of accompanying watercolour illustrations, in varying shades of vivid blue, also take tides as their theme. But here the predictable, everyday rhythms of high and low tides, and the direction of the world's ocean currents, give way to the extraordinary and extreme event of a tsunami. One of the illustrations traces the trajectory of the large merchant ship *Santiago*, tossed around Corral Bay in the turbulent waves of the tsunami that followed the 1960 Valdivia earthquake in Chile, among the most powerful ever recorded; others show the travel time of tsunamis across the Pacific Ocean at one-hour intervals (see Fig. 1.3).

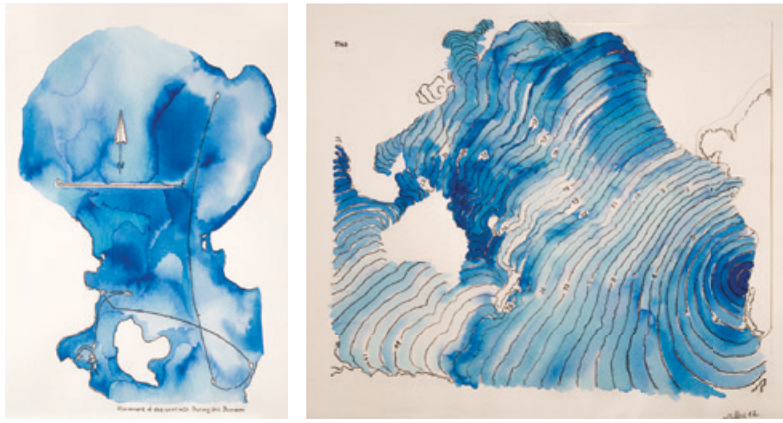

Figure 1.3 Claudia Müller, *Medidas mareales III* and *IV*, *Semi Diurno*, 2013. Galería Die Ecke, Santiago, Chile (photographs by Patricia Novoa).

Müller's work encourages us to understand the extent to which the Earth's elements are forged, held in place or put into motion by forces of immense power that operate across enormous distances, such as gravity and electromagnetism. It thus demonstrates the extent to which our experience of time and space is dependent on forces that originate well beyond the limits of the Earth's atmosphere. Morton suggests that 'such gigantic scales are involved – or rather such knotty relationships between gigantic and intimate scales – that hyperobjects cannot be thought as occupying a series of now-points "in" time or space'.[31] For this reason he calls them 'nonlocal': they produce a 'false immediacy' (such as raindrops falling on our heads) that is really the effect of an enormous system of interconnections that we cannot see and can barely measure (such as global warming).[32] This contradictory experience of embodied immersion in apparently local phenomena produced by the complex interaction of galactic forces is effectively conveyed in the video. The camera plunges us repeatedly below the water level of the sea as the tide rises in accordance with the pull of gravity, creating a sense of the intimacy and immediacy of being engulfed by the swelling sea that is contradicted by the great distance separating us from the cosmic forces at play in its currents and tides.

In her study of earth art, Amanda Boetzkes finds that many contemporary artists (she cites James Turrell, Chris Drury and Olafur Eliasson) are turning to 'the aesthetic dimension of elementals', such as air, light and water.[33] In this way, Boetzkes suggests, artists may 'resist the perceptual intention to conceive of the earth environment as

a set of things or as a closed system'.[34] These elements are themselves subject to forces and phenomena, like gravity, that are entirely removed from human control. Müller's studies on water expand our sense of the planetary far beyond the bounded and the tangible. They exemplify the shift from earth art to planetary art I propose here, which involves a shuttling between the local and the (inter)planetary, and between tangible matter and invisible forces, displacing the human as agent.

Trade winds and toxic metals

A fundamental asymmetry in encounters between humans and geophysics is also evident in the work of Michelle-Marie Letelier. Many of her projects focus on the chemical properties of minerals such as copper, coal and nitrates, while exploring their roles within histories of extraction and global trade. Letelier has dedicated several years to researching the export from Chile to Europe of sodium nitrate, a chemical compound used to make both fertilizers and explosives (thus serving life and death). Sodium nitrate, also known as Chilean saltpetre or 'white gold', became Chile's main export towards the end of the nineteenth century, once the nation had secured a virtual monopoly over the trade, having annexed those areas of Peru and Bolivia that were rich in saltpetre deposits during the War of the Pacific (1879–84). The Chilean supply of saltpetre to the Allies for ammunition during the First World War was a significant factor in their victory, and historians have suggested that it was only Germany's discovery of a method to produce a synthetic form of nitrate that allowed it to continue fighting as long as it did.[35] The rise of synthetic nitrates and the collapse of nitrate prices at the close of the war brought the Chilean saltpetre boom to an end.

The centrepiece of her exhibition *Caliche Winds*, Letelier's *Offshoring Pathways* (2014) consisted of a large plexiglass (acrylic) tray containing a sodium nitrate solution, into which positively and negatively charged copper wires had been placed.[36] The wires traced the nitrate shipping routes taken by the *Peking*, one of the largest sailing ships ever built, which made 34 voyages to and from northern Chile around the treacherous Cape Horn from 1911 until the opening of the Panama Canal in 1914. As the solution evaporated over the course of 10 days, the sodium nitrate precipitated out, forming transparent crystals that allowed the dark colour of the tray beneath to show through. This created the appearance of a land mass roughly the shape of the South American continent. At the same time, copper ions dissolved into the solution along the negatively charged copper wire, colouring the ocean a vivid

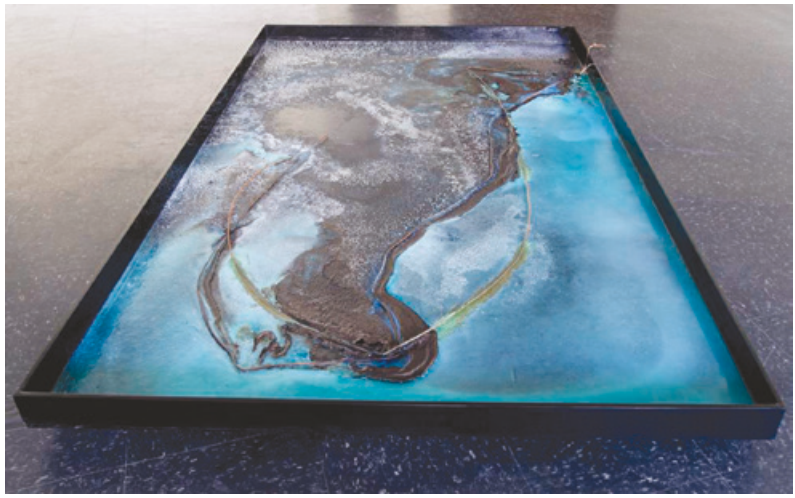

Figure 1.4 Michelle-Marie Letelier, *Offshoring Pathways*, 2014. *Caliche Winds*, El Museo de Los Sures, New York (photograph by Mariana Garay, marianagaray.com).

blue-green (see Fig. 1.4).[37] The presence of copper in the installation was also historically significant, as copper took over as Chile's main export after the decline of the saltpetre trade. Electrolysis, which was needed to create the reaction in *Offshoring Pathways*, is also used to purify copper from the ores extracted through mining.

Among the accompanying sketches and photographs was a drawing entitled *Winds, Routes and Turbines*, a reinterpretation of Matthew Fontaine Maury's 1857 'Winds and routes' chart.[38] Maury's map was produced to accompany his monumental *The Physical Geography of the Sea* (1855), the first comprehensive study of oceanography to be published. Letelier 'updates' Maury's chart, adding contemporary shipping routes (for example, via the Panama and Suez canals) and fictional offshore wind farms. She leaves the continents plain white and removes most of the labels, in order to focus the viewer's eye on the dense patterning of ocean currents and winds that facilitated European expansion (see Fig. 1.5). For the Buenos Aires exhibition in 2017, energy for the *Offshoring Pathways* installation was supplied in the form of a small wind turbine, again symbolizing the importance of wind in the development of global trade routes.[39] Wind was also a decisive factor in the original formation of Chile's nitrate deposits. Although their precise origin is still a matter of debate – they may have been generated by algae and bacteria in desert basins, blown across the desert in sea spray, or even ejected into

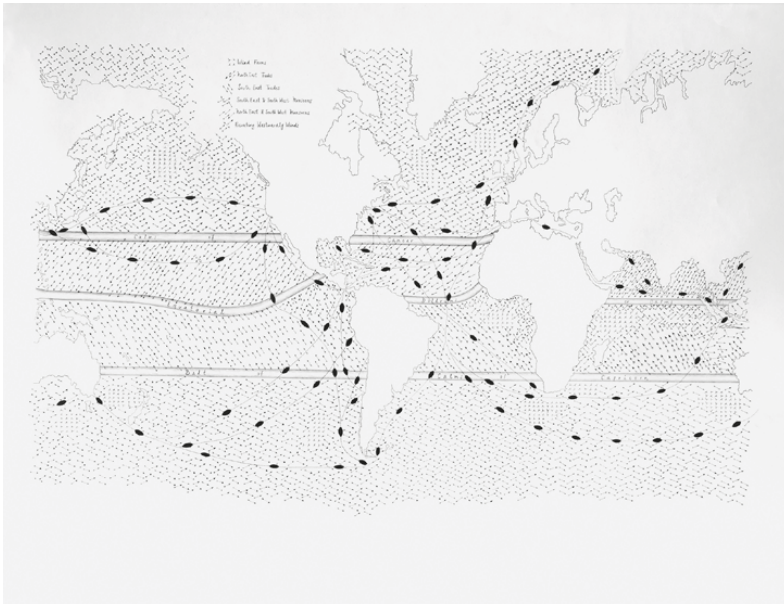

Figure 1.5 Michelle-Marie Letelier, *Winds, Routes and Turbines*, 2014. *Caliche Winds*, El Museo de Los Sures, New York (photograph by Mariana Garay, marianagaray.com).

the atmosphere as a result of volcanic activity – wind evidently played a critical role in transporting them across the desert.[40]

In her study of meteorological art, Janine Randerson finds that artists have often used scientific visualization processes in their works with the purpose of creating 'new ways to envision, revisit, or resist the power relations of meteorological mapping'.[41] Maury's work, like that of many oceanographers over time, principally served military and commercial ends. Letelier's reworking of the map performs a different function. To incorporate this iconic map within *Caliche Winds* is to encourage reflection on the conditions that have enabled the large-scale extraction, transport and trade of raw materials from South America over several centuries. What is highly significant here is that Letelier does not primarily point to the socioeconomic or geopolitical causes of empire or extractivism. Ultimately, *Caliche Winds* seems to suggest, Europeans were able to expand into South America and to develop lucrative trade routes because of the direction of the prevailing winds and tides.

Does this mean that modern world history has followed a course that is predestined in the chemical composition of minerals or the currents that shape oceanic flows? To dispense entirely with human

agency here would be nonsensical. But if the social, economic and environmental injustice of extractivism in Chile (and many other countries in Latin America) finds its causes in European expansionism and the history of global capitalism, it is also rooted in planetary geophysics, and specifically in the uneven distribution of minerals and in the particular patterns of winds and tides. We are reminded by Letelier's works that the 'geo-' of 'geopolitics' does not refer simply to the cultural or political location from which we speak, but also to the geological make-up of its landscapes and its position within the atmospheric and oceanic systems of the planet. We glimpse the truth that no quest for social justice, however fervent, will make a level playing field of this planet, whose prevailing winds carry contamination from one continent to another, and whose tectonic volatility is disproportionately felt in its poorest regions.

Letelier's work embeds human agency within a much broader and deeper set of planetary forces in a way that echoes Manuel De Landa's non-linear history of the world. In place of 'a chronicle of "man" and "his" historical achievements', De Landa offers a meditation on 'the history of matter-energy in its different forms and of the multiple coexistences and interactions of these forms'. This single 'matter-energy' expresses itself in different ways in 'rocks and winds, germs and words'.[42] De Landa rewrites the history of the colonization of the Americas as one in which microbes and wind circuits play a determining role. As is well known, the introduction to America of certain diseases – to which inhabitants of the densely packed urban centres of Europe had built up immunity over centuries – wiped out millions of indigenous people to an extent that would have been impossible otherwise, despite the 'cultural advantages' of the Spanish, whose firearms were in fact insufficient and inaccurate.[43] Similarly, De Landa emphasizes the 'gigantic "double conveyor belt" formed by the trade winds and the westerlies' that took Europeans to the New World and back again.[44] This 'geological' approach places human history in close relationship with the trajectories taken by other forms of matter and energy, demonstrating that '[c]ulture is not a completely separate sphere of reality, but instead mixes and blends with flows of organic (and even mineral) materials'.[45] Letelier's work reminds us in a similar way that human history and the dynamics of global exchange are profoundly entwined in the material history of nitrates and other minerals as they drift, dissolve, crystallize and settle across the planet, even before being mined and shipped by humans; these many transformations and movements have had an enduring impact on the rise and fall of cultures and empires.

Significantly, *Offshoring Pathways* excludes any visualization of human experience. By working at a microscopic level (the formation of crystals) to represent much bigger forces (the shaping of a continent's landscape via mining sites and trade routes), the individuals who worked in the mines or on the boats are effectively lost to sight, as are the millions whose lives were (and are) affected by the various inequalities produced by political expansion into, and the economic exploitation of, South America. This absence is also conspicuous in an earlier project, in which Letelier documented the abandonment of the mining camp at Chuquicamata, the world's largest open-cast copper mine, located in the middle of the Atacama Desert in the north of Chile, and the place to which she moved at the age of eight.[46] Letelier returned as an adult to photograph and film the deserted camp, from which thousands of inhabitants had to move, as the site was declared unsafe in 2002 because of the high levels of toxins unleashed by mining operations. Among other contaminants, arsenic is often present in high quantities in copper deposits in Chile; if untreated, it is released through mining processes into the air and water around the mine. The Chuquicamata camp has become yet another of the ghost towns scattered across the Atacama, testament to past mining booms in Chile. Much of the site has now been covered with tons of waste material from the nearby mine.[47]

Writing about Latin America, a region that has been profoundly and literally shaped by mining and other forms of extractivism, Mario Blaser and Marisol de la Cadena maintain that

> extractivism is how the Anthropocene makes itself present in this part of the world: what can be more eloquent of human geological force than the removal of mountains in a time-efficient search for minerals, the damming of large bodies of water to reroute rivers for hydroelectric commercial purposes, the transformation of rain forests into palm oil plantations or cattle grasslands and of deserts into land for industrialized agriculture?[48]

Devoid of human inhabitants, Letelier's works register the vast scale of human displacement that has resulted from mining in Latin America, which has created – as Blaser and de la Cadena attest – 'expendable populations in massive proportions' that are uprooted to meet the demands of 'necropolitical alliances between the state and corporations'.[49] Extractivism, as Blaser and de la Cadena argue, continues the colonial practice of 'terra nullius', creating space for the expansion of one world 'by rendering empty the places it occupies and making absent the worlds

that make those places'.[50] The apt title of an exhibition of Letelier's mining camp photographs, 'ERASE', could refer both to the Spanish 'érase una vez …' ('once upon a time …') or the English 'erase', meaning 'to remove the traces of'.

A recent emphasis on the undeniably enormous impact of our activity on the planet's landscapes can lead us to forget the far more powerful effects on us of its own colossal explosions and upheavings, carried out on a very different timescale. It is the absence of humans in Letelier's works – and in the abandoned camp itself – that speaks volumes about the asymmetry of human and non-human agency in such encounters. While it is human intervention in the geological landscape that has released pollutants to the point of uninhabitability, these heavy metals were already present in the earth, locked into layers of sediment as a result of volcanic activity over millions of years. They point to the planet's past, an unimaginably deep time whose earth-churnings and convulsions have far outstripped all our mining efforts in magnitude; they also point forward to the prospect of a planetary future without us. From the perspective of geological time, the distribution of agency and power looks very different. If empires have been built on the extraction and commodification of geological material, that matter – far from passive or inert – may yet prove a decisive agent in the history of human existence on the planet. For the present, its effects are most keenly felt where the largest and least regulated extraction operations are concentrated, often in Latin America and elsewhere in the Global South.

Inhuman agency and ethics

The works by Lozano-Hemmer, Müller and Letelier discussed above remind us of the extent to which human society is, as Nigel Clark puts it, 'intrinsically, inescapably, ensnarled in a mass of forces and objects that greatly pre-exist our emergence and have no need of our continued existence'.[51] Müller in particular moves away from representing geological events as human-induced, as exceptional, or even as natural disasters, as all of these would insert the Earth into human dramas being played out within human temporalities. Letelier likewise traces the flows, crystallizations and sedimentations that have profoundly shaped human society, and continue to do so. As De Landa argues, 'To view human history as unfolding immersed in this cauldron of nonorganic life is one way to eliminate notions of progress or unilineal development' and therefore to find ways of understanding planetary history in ways that are less mired in humanist narratives.[52] In their mappings, mediations

and materializations of seismic forces and tidal waves, these artworks confront us with the crashing indifference of geophysics to the fates of humanity, and the troubling truth that environmental justice is our idea, not the planet's. We did not start with an Earth in perfect equilibrium that we then proceeded to mess up, but one that was already governed by unequal and unpredictable forces. This understanding suggests that the quest for climate justice is practically impossible, while remaining, of course, ethically imperative.

Clark suggests that the recent attention given by the social sciences to complex, hybridized and technologically mediated 'nature-cultures' may usefully draw our attention to 'the co-constitutive relations of the social and the physical'. This may lead us to over-emphasize, however, those realms of life in which human elements play a significant role, and 'discourage thinking in terms of natural systems in which the human imprint is negligible or non-existent'.[53] Confronting the limits on our 'capacity to construct, enact, perform, compose, assemble, or otherwise renegotiate the realities in which our lives pass' means rethinking ethics in the context of a volatile Earth.[54] Clark advocates 'a receptiveness to the needs of others' that does not primarily look for social, political or economic wrongs to put right, tracing the many and undeniable ways in which the privileged are guilty of, or complicit in, the suffering of the underprivileged. Instead, it would arise from an understanding of our shared vulnerability to the planetary elements that is an ineradicable part of the human condition.[55] In other words, our response to suffering should be founded on an understanding of what we cannot change, as well as what we can.

Addressing geography's emphasis on the human political drama that shapes geopolitics, Elizabeth Grosz argues: 'What we understand as the history of politics – the regulations, actions and movements of individuals and collectives relative to other individuals and collectives – is possible only because geopower has already elaborated an encounter between forms of life and forms of the earth.'[56] She reminds us, like Letelier, that 'geopower, the relations between the earth and its life forms, runs underneath and through power relations, immanent in them, as their conditions of existence'.[57] While theories of the Anthropocene tend to focus on the inscriptions that humans leave on the Earth's surface, this notion of geopower also calls us to attend to the impact of the Earth's dynamics on human bodies and societies. Grosz's theory of art, as I will suggest below, provides a powerful way of understanding how art is composed of (and brings into being) this reciprocal becoming that binds all life to planetary matter and energies.

II. Seismic encounters and the acoustic sublime

Reflecting on artworks that produce sonifications of seismic data and other natural phenomena – including *Air Pressure Fluctuations* (2000) by the artist and scientist Felix Hess and *The Place Where You Go to Listen* (2004) by the composer John Luther Adams – Timothy Clark identifies a 'putative avant garde' that seeks to reframe real phenomena as 'a kind of installation art'. Its value, he suggests, lies in its quest 'to shake human cultural frames and scales of perception, revealing our own implication in material dynamics we cannot command and the illusoriness of any would-be sovereign overview'.[58] The works by Ariel Guzik, Paul Rosero Contreras and Rafael Lozano-Hemmer explored below reorganize our perception in this way, opening our senses to the forces and vibrations that surround us and resonate with our own bodies, but that normally remain undetectable by us. Their use of sound and other waves brings us into intimate connection with the universe, as the capacity to vibrate and to resonate is shared by all matter, living and non-living.

The enframing of chaos

To enter Ariel Guzik's studio, located in a neighbourhood in the south of Mexico City, is to be instantly enthralled by a cornucopia of mesmerizing mechanical inventions. In the centre of the main room rises the monumental *Cordiox*, whose gentle, pure tones infuse the space with an ethereal beauty. *Cordiox* captures the subtle variations in electromagnetic waves criss-crossing the atmosphere and translates them into a harmonious spectrum of serene, crystalline notes.[59] It produces a kind of acoustic sublime in which we feel ourselves to be submerged in the expanses of the atmosphere, made present to us through the sounding of invisible waves that traverse the air.

Guzik founded the Laboratorio de Investigación en Resonancia y Expresión de la Naturaleza (Laboratory for Research into Resonance and Expression of Nature) in 1990. His work brings together diverse interests in music, biology, ecology, physics and traditional medicine. He collaborates with specialists to develop unique resonating instruments that capture atmospheric signals, the song of whales, or subtle physiological expressions in plants. Many of these instruments take decades to perfect. *Cordiox* is a far cry from the avant-garde of electronic sound art, relying largely on analogue rather than digital technology and requiring no amplifiers or speakers. At the core of *Cordiox* is a hollow

cylinder of fused quartz, custom-made by a specialist German company and, at almost two metres in height, the largest of its kind in the world (see Fig. 1.6). Quartz has natural resonating and piezoelectric properties; it accumulates electric charges if mechanical stress is applied to it, in the form of pressure or heat. Alongside the quartz tube run three sets of four-metre steel strings, around 180 in total, held extremely taut within the steel frame and coupled with the quartz tube via a wooden bridge. The strings are set in motion by signals sent from a receiver, which captures electromagnetic waves and separates them into bands linked with specific groups of strings, to produce certain sounds.

Cordiox is designed to evoke the spirit of nineteenth-century instruments created to explore the nature of light, space, gravity, electricity, magnetism and other forces. These machines emerged from questions that were 'previas a las aspiraciones subsecuentes de explotación industrial' (prior to the subsequent dreams of industrial exploitation).[60] In them, Guzik finds a breath-taking beauty that is rooted not so much in their own aesthetics as in their ability to allow natural phenomena to 'sing' through them, giving a voice to nature.[61] Although *Cordiox* is based on intricate equations and years of experimentation, it does not *explain* its enchanting music: the intention is to 'asomarse a ciertos fenómenos aún dotados de misterio, sin despojarlos de esa virtud' (approach certain phenomena that are still endowed with mystery, without stripping them of that virtue).[62]

Guzik's work, along with that of the other artists introduced in this chapter, inspires an ontology of art that has little to do with representation. In rendering cosmic forces sonorous, it exemplifies the understanding of art presented by Gilles Deleuze and Elizabeth Grosz as the production of intensities and affects through the framing of chaos. Drawing on both Deleuze and Charles Darwin (in the company of other philosophers and biologists), Grosz proposes that 'the arts produce and generate intensity, that which directly impacts the nervous system and intensifies sensation', and that art 'enables matter to become expressive' rather than functioning as a system of images and signs.[63] For Deleuze, art becomes in this way 'not a matter of reproducing or inventing forms, but of capturing forces' in a way that expands our normal perception.[64] These forces are those of time, or elemental forces such as pressure, gravity or attraction. In Deleuze's definition, 'The task of painting is defined as the attempt to render visible forces that are not themselves visible. Likewise, music attempts to render sonorous forces that are not themselves sonorous.'[65] Art is an enframing of chaos in order to produce a sensory composition.[66]

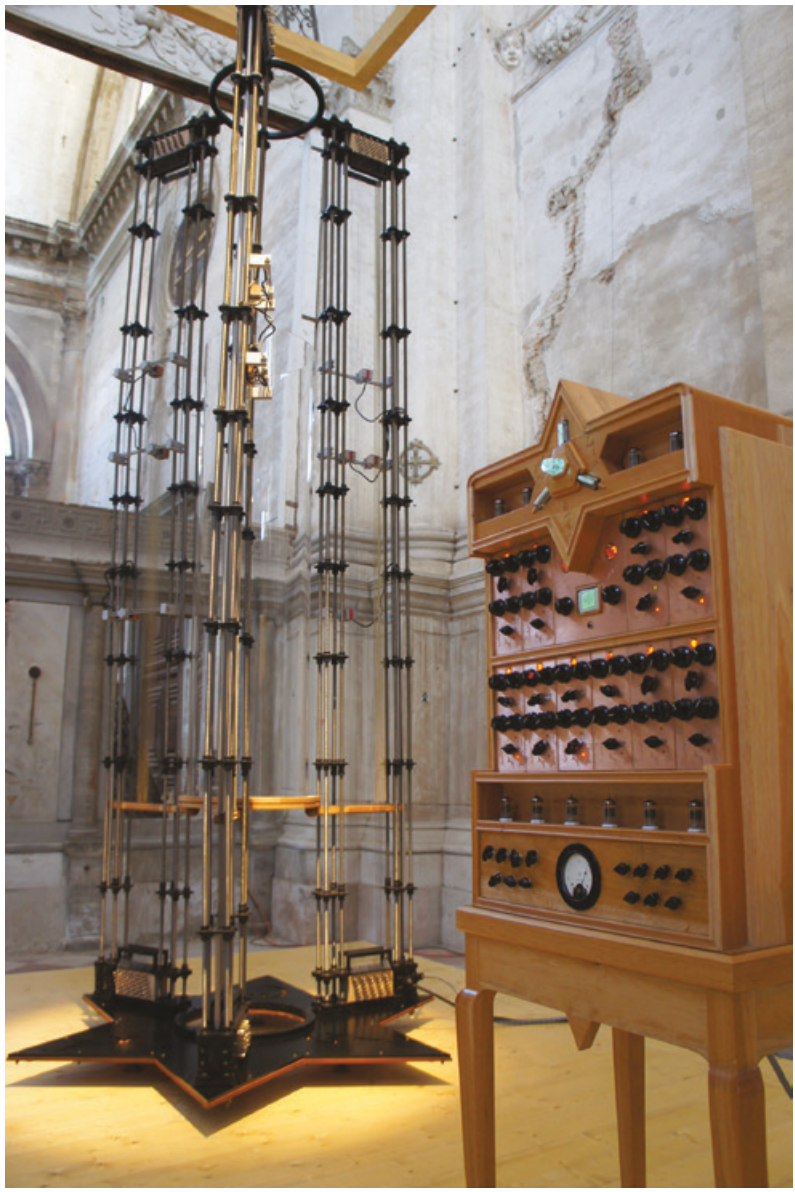

Figure 1.6 Ariel Guzik, *Cordiox*, 2013. Mexican Pavilion, 55th Venice Biennale, former church of San Lorenzo (photograph by Catalina Juárez).

The interplay between order and chaos, two orders that are always coupled in the production of art,[67] can clearly be seen in Guzik's *Cordiox*. Like an Aeolian harp, *Cordiox* draws attention to the agency of nature, as mediated through a device of human fabrication that channels and orders noise. Guzik explains that it is 'una especie de máquina de reversa de la entropía' (a sort of reverse-entropy machine) that uses a tuner to order chaotic signals into fixed frequencies that correspond to different notes.[68] The waves initially captured vary, of course, meaning that the sounds being produced by *Cordiox* are always different. If the language of 'capturing', 'enframing' and 'enabling' used by both Deleuze and Grosz to describe the operation of art can sometimes suggest a rather secondary role, in which art merely receives and organizes natural phenomena, Guzik emphasizes the fact that *Cordiox* not only makes such forces perceptible but also creates a structure through which other 'fenómenos no previstos' (unpredicted phenomena) may be created. This takes place as the strings resonate with the quartz tube, producing further resonances in an ongoing conversation that is also affected by the surrounding architectural space and that envelops human listeners in an affective experience. These are the kind of becomings engendered by art, which are, as Grosz affirms, 'not imaginative becomings – the elaboration of images and narratives in which a subject might recognize itself, not self-representations, narratives, confessions, testimonies of what is and has been – but material becomings' in which the 'cosmological imponderables', the imperceptible forces that shape the Earth, 'touch and become enveloped in life'.[69]

Artworks produced through the capture of sound and other atmospheric waves are perhaps uniquely able to convey the enframings of chaos and the material becomings that characterize the relationship that all art develops with the non-human world, in Grosz's theory. These dynamics are also very evident in the work of Paul Rosero Contreras (Ecuador). For *Audiopoiesis* (2013), he recorded the natural frequencies of surfaces in the Antarctic – icebergs, glaciers, frozen lakes – by means of contact hydrophones. The frequency spectrums were modified to make the sounds audible to human ears and then interwoven into an electronic composition.[70] The rhythmic taps and synthesized shudders of the soundscape produce an other-worldly effect. While the result is not dissonant, it takes us beyond the limits of our cultural experience; in this way, Rosero explains, his use of sound here (and in other works) is intended as a process of 'dehumanization'.[71] In a sense, his recordings are also a way of grasping the enmeshing of human and geological time, as the 'sonidos secretos' (secret sounds) of polar surfaces are 'bancos

de preservación de la historia humana' (banks that preserve human history).[72] We know that polar ice contains evidence of human-assisted climate change in the form of trapped gas bubbles, and that the sounds of Antarctica therefore contain coded references to the human impact on global temperatures, ice thickness and melting rates. This human history is not deciphered for us in Rosero's soundscapes, however, remaining opaque and resistant to interpretation.

In this respect, *Audiopoiesis* contrasts with a precursor in Antarctic soundscape art created by the US-based environmental artist Andrea Polli. *Sonic Antarctica* (2009) is a 70-minute album that combines fragments of interviews with meteorologists and climate scientists with field recordings and sonifications of science data. As Randerson explains, the project was designed to expand our sensory experience of the Antarctic and to make complex data more meaningful; in this way, 'Polli proposes that the intimacy of sound connects the human to the nonhuman in a collective experience of hearing.'[73] The recurrent presence of the expert human voice, however, reveals a didactic impulse behind the project: a desire to explain the meaning of what is being heard. In contrast, the sonification of data in Rosero's project is designed to bring us into a more direct sensory relationship with geological forces, but also to displace us as humans from a position of knowledge. Like Guzik's *Cordiox*, while making such forces perceptible it also preserves something of mystery in natural phenomena.

The limits of human knowledge are similarly suggested in Lozano-Hemmer's *Seismoscopes* series (2009–), in which seismic vibrations are recorded and translated via a plotter to produce a pre-programmed drawing of a sceptical philosopher.[74] The philosopher traced by the first seismoscope is Francisco Sanches, who wrote *Quod nihil scitur* (*That Nothing is Known*) in 1576 to argue that the limitations of man's senses only allowed him to perceive appearances, not to understand the real substance of things. Although *Cordiox*, *Audiopoiesis* and the *Seismoscopes* gather data that is of interest to scientists and use instruments developed for the scientific analysis of natural phenomena, they do so in ways that allow us to understand important differences between art and science. Guzik observes that when science studies the dynamics of turbulence, thermal noise and other atmospheric phenomena, it does so to examine statistical probabilities, rather than to trace the particularities and individual trajectories of their diminutive components.[75] Grosz characterizes the difference between art and science in a similar way, stating, 'Where science seeks the regularities, predictabilities and consistencies – the patterns – of this chaos, art seeks its force, its impact.'[76]

If science attempts to extract from chaos 'a mode of comfort and order, a form of predictability, in the world', art focuses on its 'expressive qualities', and its capacity to generate sensations.[77] Art, science and philosophy all engage with the chaos of the natural world, but for different purposes, in order 'to compose, calculate, or conceptualize'.[78] Grosz suggests therefore that we understand the relations between art and science as 'a kind of incommensurable summoning up of the same forces and contingencies through different, possibly untranslatable, goals and techniques'.[79]

What art and science do share, Grosz maintains, is an interest in 'the vibratory structure of the universe, the emanating vibratory force of chaos itself'.[80] While science turns this vibration into information, seeking 'a pattern and, eventually, measurement, ratio, or formula', art makes it sensory.[81] The phenomenon of resonance in physics blurs distinctions between subject and object, or object and milieu, describing a system of reciprocal stimulation. *Cordiox*, *Audiopoiesis* and the *Seismoscopes* bind us intimately and affectively to the planet and the cosmos through resonance, giving us a sense of the complexity and immensity of the elemental forces that compose and organize our environment and that continually touch and traverse our bodies.

Seismic encounters and the volatility of the Earth

This notion of reciprocity is developed further in other works by Rosero, produced in situ at the summits of active volcanoes in Ecuador and other countries. *Stornato* was created in October 2015 on the summit glacier of the active Cotopaxi volcano in Ecuador, during a period of high seismic activity and daily emissions.[82] Rosero dragged a cart containing a 3D printer up the volcano and used contact hydrophones placed on the ice to record the glacier's vibrations. The signal was then processed with the help of custom software and printed using polylactic acid (a biodegradable thermoplastic polymer), finished with sulphur powder. The resulting sculpture was a spiral of spikes of varying heights (see Fig. 1.7).[83] Its delicate, ethereal beauty belies the immensely destructive power of the forces it registers, which resist any human attempt to predict or control them.

The knowledge of plate tectonics that emerged in earth sciences in the late 1960s radically reformed our understanding of the planet, turning apparently exceptional events such as earthquakes and volcanic eruptions into the ordinary consequences of the continual movement of the Earth's crust. *Stornato* has nothing of the utility of a seismograph, used to monitor and predict seismic activity in order to alert humans to

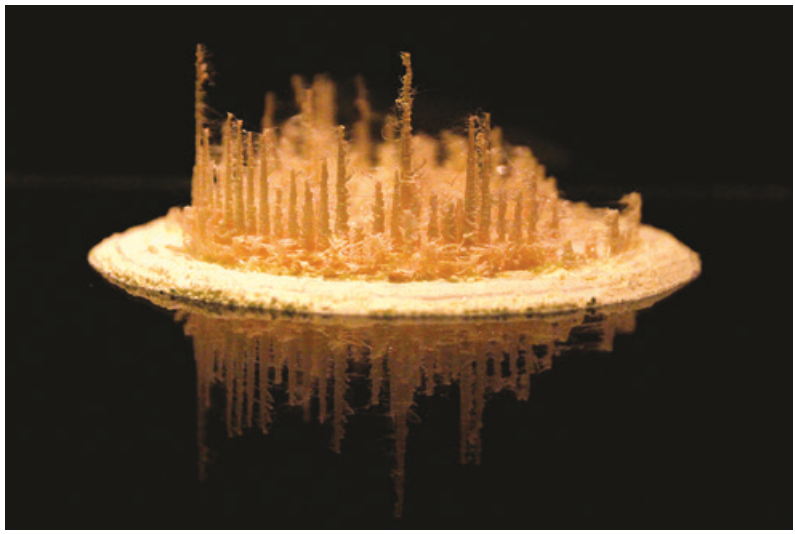

Figure 1.7 Paul Rosero Contreras, *Stornato Version I*, 2015. *Premio Nacional Nuevo Mariano Aguilera*, Centro de Arte Contemporáneo de Quito (photograph © Paul Rosero Contreras/Dos Islas Studio).

the risk of danger. Its intent is not to understand in order to minimize harm to humans, but to give material expression to the restless creative and destructive energies of the Earth. In its conversions of acoustic energy to electrical and then to mechanical and thermal energy, *Stornato* references the manifold and continual transformations in nature that convert one form of energy – thermal, chemical, kinetic, acoustic – to another, and which are responsible for the complex chains of non-linear causality that bring greater instability to climate cycles and other phenomena.

The action of carting the printer up to the glacier and creating the piece – no mean feat given the weight of the printer, the high altitude and the low temperature – was recorded as a performance in a video that is usually exhibited alongside the sculpture, a still from which is shown in Fig. 1.8. The video's title, *The Opening* (2015), gains meaning from Rosero's exhibition text, in which he cites Maurice Merleau-Ponty's concept of touch, bringing together the sensing being and the sensible in an intertwining made possible by the fact that 'the world is made of the very stuff of the body'.[84] Rosero cites Judith Butler's summary of Merleau-Ponty's thought on this subject:

Figure 1.8 Paul Rosero Contreras, *The Opening*, still from video, 2015.

> To be touched is, of course, to undergo something that comes from the outside, so I am, quite fundamentally, occasioned by that which is outside of me, which I undergo, and this undergoing designates a certain passivity, but not one that is understood as the opposite of 'activity'. To undergo this touch means that there must be a certain openness to the outside that postpones the plausibility of any claim to self-identity.[85]

In his essay 'Eye and mind', Merleau-Ponty contrasts painting with modern science in its apprehension of the world. 'Science', he claims, 'manipulates things and gives up living in them', while art draws upon the 'fabric of brute meaning' that science prefers to ignore.[86] 'It is by lending his body to the world that the artist changes the world into paintings', as the artist is immersed in the world through the embodied nature of his perception, bringing body and world together in a common 'flesh'.[87]

A sense of this intertwining and reciprocal composition is reinforced by the camerawork for the video, which emphasizes horizontality over hierarchy. Low- and high-angle shots, which might have suggested the looming might of the volcano or the impressive feat of the human climber, are avoided in favour of ones that show movement across the frame on a horizontal plane. Picture-postcard shots of the volcano's cone are also conspicuously absent, leaving images of increasingly barren rocks and screes as the artist ascends,

accompanied by the howling wind. Nature is not depicted here as a force to be conquered, however, and there is no hint of the punishing physiological effects of altitude that had to be overcome, which might have produced a narrative of human heroism.

The work itself, *Stornato* – meaning diverted or transferred, in Italian – uses a range of media technologies to capture, convert and transmit data obtained from natural sources. Jussi Parikka suggests:

> Our relations with the earth are mediated through technologies and techniques of visualization, sonification, calculation, mapping, prediction, simulation, and so forth: it is through and in media that we grasp earth as an object for cognitive, practical, and affective relations.[88]

In Rosero's work, however, the earth as given to us through such techniques is not only something we grasp, but also that which grasps us. A number of elements in *Stornato*'s form speak of a reciprocal 'touch' between humans and the environment, in which each adapts itself to the demands of the other, and receives the form of the other as it impresses its own, in such a way that the categories of 'active' and 'passive' do not apply.

The work performs a meshing together of artistic, technological and geological processes that demonstrates the locus of art at the site of a material intertwining between the body and the world. The technique Rosero used to print the model is known as fused filament fabrication (FFF). A plastic coil is passed through a heating chamber that turns it into molten material, which is then deposited in layers. The process is strikingly similar to the heating of magma in chambers beneath the Earth's crust, which is ejected in molten form and solidifies to form strata. Sulphur, used as a medium in the construction of *Stornato*, is also referenced in the casing for the 3D printer in *The Opening*, which is given the appearance of a cart piled high with yellow rocks, indicating the practice of sulphur mining at volcano sites. These materials have not simply been enlisted for human purposes: to obtain minerals and to work with them to fashion objects we have to adjust ourselves to their own demands, in encounters that shape us both. Sulphur mining is a form of extraction that involves severe damage to human health as a result of toxic fumes, and climbing active volcanoes brings obvious risks. Rosero's works do not simply engage in biomimicry or geomimicry – one could, of course, understand all art and technology as drawn from the forms and

rhythms of nature – but epitomize the way in which art is produced from an encounter between the human body and its material environment in which both are shaped. In another project on vibrations developed in Antarctica, for example, Rosero documented his body's physiological response to the environment, including pupil adaptation to extreme brightness.[89]

The language of reciprocity, reflexivity and mutualism in Merleau-Ponty's account of the 'chiasm' or the 'touch' between body and world suggests a symmetry that is far from the truth, however. In understanding the 'stuff' of our bodies and that of other things to be intertwined and continually co-constituting we should not assume that this encounter is one between equal powers. A number of Rosero's volcano works, including videos and 3D sculptures generated from seismic activity, were brought together in *The Andean Pavilion*, shown as part of BIENALSUR in 2017.[90] Rosero describes the installation as 'the reenactment of a momentary encounter between a volcano, a human, and a machine', and an exploration of the human–environment dynamics that undergo constant change in settings that are 'heavily defined by natural phenomena'.[91] The works were explicitly conceived as a response to discourses of climate change that assert the geological agency of humans, which lead Rosero to conclude that 'el mismo concepto del Antropoceno es bastante antropocéntrico' (the very concept of the Anthropocene is quite anthropocentric).[92] His work offers a counter-emphasis on the devastating and untameable inhuman force of volcanoes.[93] It is perhaps not a coincidence that discourses heralding the new geological agency of humans have emerged from the urban Global North, where natural disasters are comparatively rare.[94] It is harder to imagine them gaining the same purchase in a country as vulnerable to earthquakes and volcanic eruptions as Ecuador. It remains the case that the effects of a nuclear bomb, the epitome of humanity's destructive power, are still dwarfed by the force of a volcanic explosion.

Nigel Clark affirms that 'the reason why global climate is susceptible to being changed by human "forcings" is because it is inherently unstable'.[95] However great the scale of human intervention in the planet's systems, an important asymmetry remains: 'the impression that deep-seated forces of the earth can leave on social worlds is out of all proportion to the power of social actors to legislate over the lithosphere'.[96] Rosero points not to the exceptional and tragic human consequences of an earthquake but to the continual seismic shudders that demonstrate the inherent volatility of the earth, beyond any register of catastrophism.

Beyond landscape and earth art

The Western tradition of landscape art, which places an objectified nature under the gaze of a human subject, is challenged in several ways in the works studied in this chapter. Their continual shifts in scale and perspective require us to perform mental leaps that take us from the molecular to the astronomical in a way that troubles the static, linear viewpoint of landscape painting. By rejecting naturalistic modes of representation, many of these works avoid re-creating an illusion of mastery over nature. The staging of chemical reactions (Letelier), transductions from one energy state to another (Rosero, Guzik), and the interplay of planetary and cosmic forces (Müller, Lozano-Hemmer) emphasize the performativity of matter rather than the creativity of the human artist; far from being relegated to being a background to human activity, the non-human world comes to the fore in all its vibrant power and creative force. In all cases, the 'landscapes' created in the works are not the subjective renderings of an individual artist but the result of the interaction of geophysical forces and chemical reactions that are too complex for us to model with accuracy.

We can see in the work of all of these artists an important distancing from the kind of environmental art that aims to produce a direct experience of nature for human viewers. There is no attempt here to provide a transparent, unmediated access to nature, in the way that Morton finds to be characteristic of ecomimesis.[97] If the techniques of hypermediation used do demonstrate our ability to record and remix traces of natural phenomena, they also register how removed we are, perceptually, from the sources of their power, and how little control we may exercise over these. Rob Nixon suggests that, given the relative invisibility of the 'slow violence' of environmental catastrophe, its portrayal in images and narratives becomes a formidable task.[98] He reserves an important role for 'writer-activists' – surely artists too – in bearing witness to threats that 'remain imperceptible to the senses, either because they are geographically remote, too vast or too minute in scale, or are played out across a time span that exceeds the instance of observation or even the physiological life of the human observer'.[99] The timeframe of *Offshoring Pathways*, for example, whose reactions take place at a rate that eludes our immediate senses, points very effectively to the 'slow violence' of environmental change that Nixon describes. It registers a temporality that exceeds our grasp and, at the same time, draws attention to the potential role of art in expanding our perception of planetary time.

These artworks create a particularly unsettling version of the sublime as developed in landscape painting, among other artistic forms and movements. In the face of the failure of the imagination to grasp the vast expanses of space and time, and the power of the forces that govern these, the Kantian sublime returns us to a more comforting satisfaction in the capacity of human reason to encompass what had originally disoriented us and in our technological mastery over nature. Pulling us into the thrill of an (inter)planetary sublime, these works generate more unease than comfort: their acts of technological mediation and transduction may demonstrate how we are able to frame and even sometimes to harness physical forces for aesthetic, economic or other ends, but they remind us that we remain signally unable to predict where and when they will manifest themselves, and thus we remain vulnerable to their effects. Although we experience the mind-expanding, quickening sensation of the sublime, we are not allowed to forget that any sense of mastery is – as in *Flatsun*, *Semi Diurno* or *Stornato* – merely an illusion.

In an essay on art in the Anthropocene, Susan Ballard and Liz Linden searched for an artwork that might 'embody the social and cultural impacts of the Anthropocene', in providing 'evidence of humans acting with geological force on the planetary system'.[100] They opted for Robert Smithson's *Spiral Jetty* (1970) which, as they acknowledge, has become an obligatory reference for art historians discussing earth art, especially within the context of the Anthropocene.[101] Smithson's material intervention into the land fuses artistic practice with geological process in a way that seems to exemplify the increasing capacity of humans to act directly on the geosphere and the biosphere. It expresses a 'sense of self *as part of* the planetary Earth System'[102] that is crucial to negotiating a path through the Anthropocene to a future era in which human activity will be less destructive. While the artworks I have explored in this chapter also remind us, powerfully and affectively, of the extent to which we are intricately enmeshed in the Earth's systems, they cultivate a sense of the planet *beyond* the human that allows us to understand its dynamics more fully, and to resituate human agency more properly within geohistories of matter and energy.

Although these projects bear some conceptual affinities with the earth art (or land art) movement in the 1960s and 1970s, they make no interventions into landscapes and produce no site-specific works, other than short performances that leave no lasting material impression on sites. Indeed, the intention is often precisely to avoid an invasive act. Instead, they organize and document mobile, live, fleeting encounters with the fluxes of elemental phenomena and the trembling of the earth.

For the most part, they are not representations of (or interventions in) matter but transductions of energy. They do not enact a return to the Earth as the ground of unmoveable certainties, as an escape from modernity, or as a Romantic reaffirmation of inner spirituality. In her reading of artworks by Olafur Eliasson, Boetzkes suggests that 'the goal is […] not to recover nature in a disenchanted modern environment but rather to show how technology might be redirected toward the destabilization of habitual ways of perceiving natural events and can be the basis of a sensitive interaction with the earth'.[103] The technologies of transduction used by the artists discussed here similarly destabilize and defamiliarize the planet, disclosing the ceaseless flows and mutations that characterize an apparently inert matter. Although these works in many ways embed art in nature in order to show the entanglement of human and non-human histories, they also demonstrate the powerful *dis*embedding effects of art – its rescalings, its mixing up of milieus, and its folding in of space and time – that help us think beyond the limits of human perception. Their preference for transduction, which (as Adrian Mackenzie points out) 'aids in tracking processes that come into being at the intersection of diverse realities', helps us understand how art is produced in the coupling of heterogeneous forces and orders.[104]

The art and science of the inhuman

Ballard and Linden suggest that Smithson's work and its critical reception in the art world contributed to a disciplinary shift that takes us 'from art understood within the white walls of the gallery to art in direct conversation with the planet'. Ironically, however, as they note, this did not take place 'in collaboration with disciplines outside the domain of art itself'.[105] The projects I have discussed here are much more genuinely transdisciplinary in the way they bring together the aesthetic and the scientific. As we have seen, they deploy a range of scientific recording, imaging and modelling techniques in order to register the effects of (inter)planetary forces and to make them present to us. Many of them also clearly aim to increase our understanding of the natural world, an objective shared with most scientific experiments and forms of data visualization and interpretation. Where, then, does the specificity of the aesthetic reside here?

In his discussion of contemporary works of bioart and ecoart from Latin America, Jens Andermann uses the term 'becoming-unspecific' to describe the way these artworks stage the dissolution of the artistic into scientific practice or into forms of life itself.[106] In this process, he

does not find a rejection of the aesthetic experience itself, but of 'una forma determinada de entenderla como aquello que nos distingue y nos constituye en humanos y sujetos: como aquello que nos especifica' (a particular way of understanding [aesthetics] as that which differentiates us and constitutes us as humans and subjects: as that which specifies us).[107] The works I have discussed belong neither to bioart (they do not incorporate living material) nor really to ecoart (they are not primarily motivated by ecological or environmental concerns). As I have suggested, they inscribe themselves instead within a contemporary variant on earth art, which we might call planetary art, to mark its stronger connection with the geological and the cosmic sublime and the (inter)planetary forces that shape the Earth's systems. But they participate nevertheless in the same redefinition of the aesthetic that Andermann observes, which displaces us as humans from a privileged position as subjects and re-creates us as co-agents of the aesthetic, not just with other living forms, but with the fundamental physical forces and chemical interactions that have given form to everything on Earth and in the universe.

The specificity of the aesthetic remains evident here in the deliberate distance taken from the more instrumental aims of science and technology with respect to the natural world. Rosero's expressive renderings of seismic energy disclose to us the continual vibrations that shake the Earth and shape its landscapes but would be entirely useless in the science of earthquake prediction. Likewise, the analogies and mappings created by Letelier and Müller are often impressionistic rather than scientifically accurate but are designed to suggest a broader conceptual truth concerning the interconnections between human histories and geological time, or between the local and the galactic. We could understand these works as decolonial in their representation of nature as a set of forces that cannot be measured, contained or exploited by human technology. They call into question the (Eurocentric) 'planetary consciousness' that arose, as Mary Louise Pratt argues, from imperial mapmaking and circumnavigation projects,[108] by promoting sensory relationships with planetary forces that are not based on the systematization of nature for the purposes of colonization and commercial exploitation. The scale of the forces they register return to us a sense, not of our domination of nature, but of the immensity and power of that which lies beyond our influence. What is more, they replace the 'rationalizing, extractive, dissociative understanding' of universalist European science[109] with an experiential knowledge that is rooted in affect and social relations as much as in data and analysis, and that interrogates the complex relationships between geophysics and geopolitics.

Nigel Clark suggests that science is 'one of the most important ways' we have of understanding not only how our activities interweave with those of the world around us, but also 'what the world does in our absence'.[110] The arts and humanities often articulate the importance of their role in 'humanizing' science, re-embedding it within the social, cultural, political or ethical contexts from which it has been abstracted in the production of generalizable knowledge. I would argue that a rather different relationship between the disciplines is being forged in these projects, in which science paves the way for art to engage critically and affectively with the *in*human. The sensory, affective experiences these artworks stage with elements and forces of the Earth that lie beyond human influence and human time may play a crucial role in enabling the construction of a planetary imaginary and in helping us navigate towards a less anthropocentric era. What is more, their engagement with the inhuman allows us to read them as exemplars of the ontology of art developed by Grosz, in which the common ground for music and all other forms of art are the 'invisible, inaudible forces' of chaos in the universe, which cannot otherwise be experienced as they are 'fundamentally inhuman'.[111]

Notes

1. Serres, *The Natural Contract*, 16, 3.
2. Serres, *The Natural Contract*, 48, 39.
3. Oreskes, 'The scientific consensus on climate change', 93.
4. Chakrabarty, 'Anthropocene time', 25.
5. Elias and Moraru, 'Introduction'; Moraru, 'Decompressing culture'.
6. Thomashow, *Bringing the Biosphere Home*, 36, 77, 5.
7. Heise, *Sense of Place and Sense of Planet*, 55, 56.
8. Morton, *Hyperobjects*, loc. 3062, 217.
9. Clark, *Inhuman Nature*, xvi.
10. Clark, *Inhuman Nature*, xiii, xiv.
11. *Blue Sun* formed part of the *Decision Forest* exhibition held at the Amorepacific Museum of Art in Seoul, between 3 May and 26 August 2018. *Solar Equation* was tethered over Federation Square during the 2010 Light in Winter Festival in Melbourne, Australia.
12. Soto's *Sphère Concorde* (1996) and *Sphère Bleue de Paris* (2000) are obvious precursors, as is Le Parc's *Sphère Rouge* (2001–13). Together with Carlos Cruz Diez, these are the artists whose influence Lozano-Hemmer cites most frequently, although a web video documenting the Québec exhibition of *Solar Equation* in 2019 places it in a long line of spherical sculptures by international artists that stretches back for decades and centuries, including Buckminster Fuller, Otto Piene, and Anish Kapoor. See https://vimeo.com/294842561. Accessed 21 October 2020.
13. *Flatsun* was first shown as part of the solo exhibition *Trackers* at La Gaîté Lyrique, Paris, from 30 September to 13 November 2011.
14. Sixty thousand red and yellow LEDs are controlled by algorithms such as Navier-Stokes equations, which play an important role in computational fluid dynamics, and Perlin Noise, which is used in computer graphics to represent the complexity of natural phenomena.

15. See https://sohowww.nascom.nasa.gov and https://sdo.gsfc.nasa.gov. Accessed 20 October 2020.
16. Álvarez Romero, *Pseudomatismos/Pseudomatisms*, 39.
17. Latour, *Facing Gaia*, 62.
18. Latour, *Down to Earth*, 76; emphasis in original.
19. Gombosi et al., 'Anthropogenic space weather'.
20. Morton, *Hyperobjects*, loc. 106.
21. Morton, *Hyperobjects*, loc. 1263, 2682.
22. Morton, *Hyperobjects*, loc. 3023–4.
23. Morton, *Hyperobjects*, loc. 1454.
24. *Constelante* was exhibited as part of the group show *Entrestiempos*, held at the Galería Macchina, Santiago, Chile, in 2011. Images of the work may be viewed at https://claudiamuller.net/portfolio_page/constellant. Accessed 21 October 2020.
25. A video of the whirlpool and its projection may be viewed at https://vimeo.com/184923318. Accessed 21 October 2020.
26. Moraru, 'Decompressing culture', 213.
27. Conversation with the author, 10 September 2019.
28. *Semi Diurno* was exhibited at the Galería Die Ecke in Santiago, Chile, between 31 May and 6 July 2013.
29. This is achieved by using a nozzle with a small diameter, which reduces the rate of flow. However, the accuracy of clepsydra clocks is also affected by changes in temperature, which alter the viscosity of water.
30. The graphics show the phases of the moon in the month of February 2012. The video may be viewed at https://vimeo.com/87709396. Accessed 21 October 2020.
31. Morton, *Hyperobjects*, loc. 887–9.
32. Morton, *Hyperobjects*, loc. 910–14.
33. Boetzkes, *The Ethics of Earth Art*, 15, loc. 352.
34. Boetzkes, *The Ethics of Earth Art*, 102, loc. 1699.
35. Hardach, *The First World War, 1914–1918*, 59–60.
36. Letelier developed her work on saltpetre crystals with the assistance of Michele Galletti, an Italian electrical engineer, while undertaking a residency as part of the International Studio and Curatorial Program (ISCP) in New York, 2014. *Offshoring Pathways* was first shown as part of the *Caliche Winds* exhibition at El Museo de Los Sures, New York, between 15 and 27 July 2014.
37. A video showing the progressive changes may be viewed at http://michellemarieletelier.net/work/offshoring-pathways/ or https://vimeo.com/180240268. Accessed 21 October 2020.
38. This may be viewed at https://davidrumsey.georeferencer.com/maps/362910390734/view. Accessed 21 October 2020.
39. It was shown as part of a group exhibition entitled *Pensamiento Salvaje*, held at the Casa Nacional del Bicentenario in Buenos Aires, Argentina, between 15 September 2017 and 28 January 2018, in the context of the 2017 BIENALSUR.
40. Ericksen, 'The Chilean nitrate deposits', 372–3.
41. Randerson, *Weather as Medium*, 45.
42. De Landa, *A Thousand Years of Nonlinear History*, 21–2.
43. De Landa, *A Thousand Years of Nonlinear History*, 132–3.
44. De Landa, *A Thousand Years of Nonlinear History*, 53.
45. De Landa, *A Thousand Years of Nonlinear History*, 111.
46. 'ERASE' was exhibited in 2004 in the CODELCO Corporate Building, Calama, Chile, in BECH Gallery, Santiago, Chile and Galleria Perlini Arte, Padua, Italy.
47. Operations at Chuquicamata are currently undergoing a transition to underground block cave mining, expected to be completed by 2022, in an attempt to extend the life of the mine for another 40 years.
48. Blaser and de la Cadena, 'Introduction', 2.
49. Blaser and de la Cadena, 'Introduction', 2.
50. Blaser and de la Cadena, 'Introduction', 3.
51. Clark, *Inhuman Nature*, 105.
52. De Landa, *A Thousand Years of Nonlinear History*, 265.

53. Clark, *Inhuman Nature*, 15.
54. Clark, *Inhuman Nature*, 30.
55. Clark, *Inhuman Nature*, 66–7.
56. Yusoff et al., '*Geo*power', 975.
57. Yusoff et al., '*Geo*power', 975.
58. Clark, *Ecocriticism on the Edge*, 187, 188.
59. *Cordiox* was first exhibited in the former church of San Lorenzo (the Mexican pavilion) at the 55th Venice Biennale, between 1 June and 24 November 2013. A video of the instrument in operation may be viewed at https://www.youtube.com/watch?v=wdw0Xm0TmIc. Accessed 22 October 2020.
60. Guzik, *Cordiox*, 4.
61. Guzik, *Cordiox*, 4–5.
62. Guzik, *Cordiox*, 5.
63. Grosz, *Chaos, Territory, Art*, 3, 4.
64. Deleuze, *Francis Bacon: The logic of sensation*, 56.
65. Deleuze, *Francis Bacon: The logic of sensation*, 56.
66. Deleuze and Guattari, *What Is Philosophy?*, 206.
67. Grosz, *Chaos, Territory, Art*, 9–10.
68. Conversation with the author, 2 October 2019.
69. Grosz, *Chaos, Territory, Art*, 23.
70. A remix of the recording can be heard here: https://soundcloud.com/microcircuitos/paul-rosero-audiopoiesislive-remix, with a selection of individual location recordings available here: http://paulrosero.com/index.php/portfolio/audiopoiesis. Accessed 22 October 2020.
71. Conversation with the author, 4 February 2019.
72. See http://paulrosero.com/index.php/portfolio/audiopoiesis. Accessed 22 October 2020.
73. Randerson, *Weather as Medium*, 84.
74. The work was first shown as part of an exhibition entitled *Rafael Lozano-Hemmer: Recent Works* at the Galerie Guy Bärtschi, Geneva, between 14 May and 5 September 2009.
75. Guzik, *Cordiox*, 15.
76. Grosz, *Chaos, Territory, Art*, 61.
77. Grosz, *Chaos, Territory, Art*, 61.
78. Grosz, *Chaos, Territory, Art*, 28.
79. Grosz, *Chaos, Territory, Art*, 26.
80. Grosz, *Chaos, Territory, Art*, 62.
81. Grosz, *Chaos, Territory, Art*, 62.
82. See http://volcano.si.edu/volcano.cfm?vn=352050&vtab=Weekly. Accessed 22 October 2020.
83. The first version of *Stornato* was shown in the Premio Nuevo Mariano Aguilera exhibition at the Centro de Arte Contemporáneo de Quito, between 1 August and 20 September 2015.
84. Merleau-Ponty, 'Eye and mind', 125.
85. Butler, 'Merleau-Ponty and the touch of Malebranche', 189.
86. Merleau-Ponty, 'Eye and mind', 121, 123.
87. Merleau-Ponty, 'Eye and mind', 123.
88. Parikka, *A Geology of Media*, 12.
89. Rosero Contreras, *From Light to Light*, 110–21.
90. The installation was part of the *Pensamiento Salvaje* exhibition shown at the Casa Nacional del Bicentenario in Buenos Aires, from 15 September to 18 October 2017.
91. Rosero Contreras, 'The Andean Pavilion', 422.
92. Conversation with the author, 4 February 2019.
93. See an interview recorded by BIENALSUR during the exhibition, at https://www.youtube.com/watch?v=lxso_JqpqGc. Accessed 9 November 2020.
94. With the exception of Japan, the 10 most earthquake-prone countries in the world are all located in the Global South.
95. Clark, *Inhuman Nature*, xi.
96. Clark, *Inhuman Nature*, xvi.
97. Morton, *Ecology without Nature*, 151, 154.
98. Nixon, *Slow Violence and the Environmentalism of the Poor*, 2–3.
99. Nixon, *Slow Violence and the Environmentalism of the Poor*, 15.

100. Ballard and Linden, 'Spiral jetty, geoaesthetics, and art', 143.
101. Ballard and Linden, 'Spiral jetty, geoaesthetics, and art', 146.
102. Ballard and Linden, 'Spiral jetty, geoaesthetics, and art', 143; emphasis in original.
103. Boetzkes, *The Ethics of Earth Art*, loc. 2189.
104. Mackenzie, *Transductions*, 18.
105. Ballard and Linden, 'Spiral jetty, geoaesthetics, and art', 143.
106. Andermann, *Tierras en trance*, loc. 6352.
107. Andermann, *Tierras en trance*, loc. 6427–9.
108. Pratt, *Imperial Eyes*, 29–30.
109. Pratt, *Imperial Eyes*, 37.
110. Clark, *Inhuman Nature*, xviii.
111. Grosz, *Chaos, Territory, Art*, 86.

2
The atmosphere as a planetary commons

In *En el aire* (*In the Air*, 2003), by the Mexican artist Teresa Margolles, bubbles float down from the ceiling, bursting softly on the skin and clothes of gallery-goers. The beauty of the spectacle, as the light glints off the tiny spheres as they fall, belies the gruesome origin of the bubbles. Although it has since been disinfected, the water from which they are formed was used to wash corpses in a morgue in Mexico City. In a related piece by Margolles, *Vaporización* (*Vaporization*, 2001), the gallery is filled with a fog created through the condensation of water from the morgue. These works touch us and permeate us with the deaths of others, many of them violent. The air contained within a confined gallery space also became the medium of a recent work by the Cuban artist Tania Bruguera. As part of an exhibition on global migration entitled *10,148,451* (2018),[1] Bruguera created an 'empathy room', in which a chemical compound in the air forced tears from visitors. The experience of 'crying' in public was intended to encourage visitors to think about their response to media representations of migration, but also to break down social barriers and to create a sense of solidarity with others in the room.

These installations work with air as a medium for the intermingling of chemical compounds, beyond the illusory boundaries of the body: a medium of contamination, but also potentially one of solidarity. In all cases, however, there is an element of compulsion that heightens the works' transgressive power and complicates the construction of that solidarity. Margolles's visitors are unwitting and possibly even unwilling participants in an intimate encounter with death that she has orchestrated, as the placing of the explanatory text inside the gallery room meant that visitors may have breathed in or touched the water before they were aware of its provenance. Bruguera describes her work

as creating a 'forced empathy', as it induces tears in her visitors, whose physiological response is not based on emotion but on the effects of chemicals infused in the air.[2] Our utter dependence on the air around us makes us vulnerable to the actions of others; that shared vulnerability may be the basis for an empathetic, ethical orientation towards the other, but it is also a condition from which we cannot escape.

The question of a possible solidarity born of our common dependence on the air is central to the works by Rafael Lozano-Hemmer discussed in part I of this chapter, which turn more explicitly to the biochemistry of respiration and the phenomenon of turbulence in their exploration of air as a medium. Like Margolles and Bruguera, Lozano-Hemmer understands chemical diffusion as a starting point from which to reflect on – and create – social interconnections. This relationship is not metaphorical but material, stemming from the nature of the atmosphere as a shared resource, a natural commons that is both finite and necessary for the survival of all. Setting works by Lozano-Hemmer alongside a number by Tomás Saraceno allows me to explore in greater depth how their projects bring into view the question of the air as a (global) commons, and how they succeed in connecting up our different understandings of what a commons may mean in the contemporary world.

Many of the works in this chapter are a powerful expression of the interconnections between three ways in which we can understand the commons: as a natural resource (in this case, the atmosphere), as a set of principles for sharing data, and as a community that uses a resource and regulates its use. These definitions are interdependent: the commons is a way of thinking about the management of resources, of which the knowledge commons – the open-source sharing of data without copyright – is currently one of the most widespread and successful examples. But the commons also emerges from, and constructs, communities that form a consensus on how relationships between humans and non-humans should be conducted. Andreas Weber maintains that 'the commons describes an ontology of relations that is at the same time existential, economic and ecological'.[3] Indeed, as David Bollier and Silke Helfrich argue,

> the commons can be seen as an intellectual framework and political philosophy; it can be seen as a set of social attitudes and commitments; it can be seen as an experiential way of being and even a spiritual disposition; it can be seen as an overarching worldview. But the truth of the matter is that the commons consists of all of the above.[4]

The works by Lozano-Hemmer and Saraceno brought together in this chapter embody this broad understanding of the commons as a phenomenon that transcends distinctions between the intellectual, the biological, the social, the economic and the cultural.

When compared with the projects of many other artists discussed in this book, those explored in this chapter are strikingly less rooted in a specifically Latin American context, whether discursive or material. This is hardly unexpected, as Lozano-Hemmer and Saraceno have been resident in other countries for most or all of their artistic careers, although Saraceno often describes his experience of exile as a child (his family moved to Italy to avoid persecution by the military regime in Argentina) as a defining influence on his interest in inventing airborne cities that would transcend national borders. Migration is also a theme in many projects created by Lozano-Hemmer, who approaches his work as 'something that can and should travel'.[5] But these projects are also less informed by national or regional experience because they engage specifically with the global or planetary commons, focusing on global common-pool resources (the atmosphere), commoners (collaborative projects bringing intellectuals, artists and amateurs together across the world), and commoning practices (the development of open-source technologies).

These are urgent issues to explore in an era in which commons – including airspace and even outer space – are increasingly coming under private control. Antonio Lafuente recognizes the 'profunda relación' (deep relationship) between new technologies and new forms of patrimony: with increasing speed, new possibilities appear every day to enclose or abuse commons, whose value we often truly realize only when they come under threat.[6] This is particularly the case with 'global commons' such as the oceans, the atmosphere, space and the electromagnetic spectrum, which, as Charlotte Hess and Elinor Ostrom observe, are now subject to capture through new technologies. This creates 'a fundamental change in the nature of the resource, with the resource being converted from a nonrivalrous, nonexclusionary public good into a common-pool resource that needs to be managed, monitored, and protected, to ensure sustainability and preservation'.[7] Saraceno and Lozano-Hemmer develop alternative technologies with the aim of drawing our attention to the growing threat of enclosure and creating new relationships with global commons that are not ones of capture. In doing so, they demonstrate how commons thinking and practices may erode the divisions between culture and nature, human and non-human, that have underpinned the

rise of technological modernity, and usher in a more post-anthropocentric understanding of our shared existence on the planet.

I. Breathing a common air

While many of Lozano-Hemmer's works are concerned with the relationship between media technologies and public space, some of them engage directly with the biology and chemistry of the atmosphere and of respiration. His installations *Vicious Circular Breathing* (2013), *Babbage Nanopamphlets* (2015) and *Atmospheric Memory* (2019) encourage visitors to become aware of the extent to which the air is a common medium which connects us all through the act of respiration, in which the air we breathe in and expel is shared with those around us. The works open up a sense of a shared vulnerability, on the basis of which more collective modes of experience and action might be imagined.

'The air itself is one vast library'

For *Babbage Nanopamphlets* (2015), a quotation from Charles Babbage's *Ninth Bridgewater Treatise* was printed on two million nanoparticles of 24-carat gold in a nanotechnology laboratory at Cornell University.[8] A proportion of these were released into the museum ventilation system, to be inhaled by the public (gold is an inert substance and is not absorbed by the human digestive system). The rest floated in a small glass flask full of clear liquid (see Fig. 2.1), in which the periodic spins of a small magnetic stirrer created sudden swirls, allowing the tiny flakes of gold to be seen as they caught the light. Displayed alongside the flask were images taken with an electronic microscope, showing the imprinted citation from Babbage on the gold nanoparticles, and a facsimile of the passage used from the text.

The English polymath Charles Babbage (1791–1871) invented the mechanical forerunner of the modern electronic computer. His 1837 text, *The Ninth Bridgewater Treatise*, sets out a case for natural theology, arguing that religion and science need not be opposed if we posit God to be a divine creator who programmed the laws of evolution into nature. The passage Lozano-Hemmer chose is taken from Chapter 9 of the *Treatise*, entitled 'On the permanent impression of our words and actions on the globe we inhabit'. Founding his reasoning firmly on 'the principle of the equality of action and reaction', Babbage explains

Figure 2.1 Rafael Lozano-Hemmer, *Babbage Nanopamphlets*, 2015. *Pseudomatismos*, Museo Universitario Arte Contemporáneo, Mexico City (photograph by Antimodular Research).

that 'the pulsations of the air, once set in motion by the human voice, cease not to exist with the sounds to which they gave rise', but become the causes of uncounted effects, as the movement of one particle acts upon another, gathering a breeze that sweeps across the waves of the ocean.[9] He affirms, poetically, that '[t]he air itself is one vast library, on whose pages are for ever written all that man has ever said or woman whispered':[10] everything we say, stirring the air around us, remains for ever imprinted on the world and could be traced back to its origin, if only we had sufficiently powerful technologies to track the almost infinite branching of causalities. Babbage's rather beautiful allegory serves his overall thesis: that if we, as intellectually inferior humans, can through reason understand how our actions ripple through the course of time in myriad cause-and-effect relationships, with how much more accuracy

would an infinitely intelligent God be able to set in motion the events of history.

Babbage's argument from design rests on a Newtonian confidence that nature operates according to a system of laws that are both knowable and reversible. It is a determinism that had been described in a similar manner by Pierre Simon Laplace, a contemporary and friend of Babbage, in his 1814 *Essai philosophique sur les probabilités*:

> Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it – an intelligence sufficiently vast to submit these data to analysis – it would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it, *nothing would be uncertain and the future, as the past, would be present to its eyes*.[11]

Like Laplace, Babbage articulates an Enlightenment fantasy of a universe whose course could be minutely predicted, if only we had a better knowledge of mathematics. Writing in 1837, he was naturally untroubled by the discoveries relating to thermodynamics and entropy that would be made later in the century by Rudolf Clausius and James Clerk Maxwell (among others), which would shake the foundations of Newtonian reversibility and predictability, or the establishment of Heisenberg's uncertainty principle, which would state the impossibility of measuring the position and the velocity of a particle at any single point in time.

Placed in the context of the twenty-first century and understood within Lozano-Hemmer's *oeuvre* as a whole, though, *Babbage Nanopamphlets* acquires a different resonance. It is not the determinism or the linearity of *The Ninth Bridgewater Treatise* that strikes us as much as its intimations of complexity. '[W]hat a strange chaos is this wide atmosphere we breathe!' exclaims Babbage.[12] Lozano-Hemmer's exhibit emphasizes turbulence, mixture and unpredictability over linear causality. Babbage's 'vast library' is as unreadable as Borges's 'Library of Babel': if there is an order, it is beyond human capability to discern it. For Lozano-Hemmer, the work demonstrates the extent to which the atmosphere surrounds us is not 'neutral', but always already charged with the words and actions of others: that it is not a 'tabula rasa' but 'una enorme grabación' (a vast recording) in which we coexist with everything that has been 'written' on it in the past.[13] For Michael Hardt and Antonio Negri, 'A democracy of the multitude is imaginable and possible only because we all share and participate in the common'; in this

they include air, water and the bounty of nature, but also 'those results of social production that are necessary for social interaction and further production, such as knowledges, languages, codes, information, affects, and so forth'.[14] *Babbage Nanopamphlets* brings these two ideas of the common together, as we literally breathe in the words of others.

A sense of the shared vulnerability that arises from breathing a common air, which comes impregnated with the traces of those who surround us and have gone before us, is heightened in another installation by Lozano-Hemmer, *Vicious Circular Breathing*.[15] The exhibit invites visitors to breathe air that has been inhaled and exhaled by previous participants, within a hermetically sealed apparatus. The visitor steps into a glass cubicle (via a decompression antechamber), connected via a large tube to four giant motorized bellows, and from there to 61 brown paper bags, hanging from the gallery ceiling at the end of smaller ribbed plastic tubes, in appearance rather like the cartilage-ringed bronchi that carry air to the lung (see Fig. 2.2).[16] The airflow is directed around the system by means of electromagnetic valves, causing the bags to inflate and deflate around 10,000–15,000 times a day, representing the average respiratory rate of an adult.

Figure 2.2 Rafael Lozano-Hemmer, *Vicious Circular Breathing*, 2015. *Pseudomatismos*, Museo Universitario Arte Contemporáneo, Mexico City (photograph by Oliver Santana).

Vicious Circular Breathing alerts us to the risks of sharing the air around us with others. A list of warnings explains that the system contains no filters for bacteria, viruses or pollutants, and participants are told that they enter the chamber at their own risk. There are also warnings about contagion and asphyxiation, although these risks are no higher than those to which they would be exposed in a lift. The presence of a panic button in the glass chamber reinforces the sense of danger that participants are expected to feel at the prospect of sharing air in this way. Participants are asked to spend no longer than 10 minutes in the cabin, as there is a limited supply of oxygen in the system; however, sensors detecting the levels of oxygen and carbon dioxide will cause the sliding doors to open automatically if they reach a dangerous point.

Lozano-Hemmer explains that the work is 'a reflection on the idea of the commons'. As he observes, it is 'different from typical media artworks, which promise somehow that participation is going to be something positive, something that empowers the user, or gives him or her agency. This piece, in fact, if you participate too much, you die.'[17] Among the many artistic antecedents to his work that he lists, which include Marcel Duchamp's *50 cc of Paris Air* (1919), he mentions the performance piece *Breathing In, Breathing Out*, by Marina Abramović and Ulay (1977), in which the artists press their mouths together and breathe each other's exhaled breaths until they verge on asphyxiation. The exhibit highlights the decision we as individuals may choose to make to enter a social space in which we are more than usually exposed to the risks that others may pose to us, while subjecting others to risk in turn. It also reminds us that we cannot, in fact, entirely isolate or immunize ourselves or others from such risk. Breathing, as Monica Bakke affirms in her study of art that uses air, is 'ecstatic', in the sense that 'it allows us to participate in something bigger than ourselves. It keeps us necessarily open to what is more than we can confront, perhaps more than we can process.'[18] For Lozano-Hemmer, the work demonstrates that 'the boundary between the public and the private is very porous': the air circulates within the 'private space' of your lungs and then, as you exhale, it becomes 'something social'.[19] Like many of his artworks, it is strongly related to ideas of interpenetration and co-presence.[20]

Surprisingly, perhaps, there is often a long line of visitors wanting to enter the glass chamber: a measure, perhaps, of our willingness – at least when we are not in the throes of a pandemic – to experience that 'co-presence', to recognize and deepen our shared vulnerability, despite the risks it may carry for us as individuals. *Vicious Circular Breathing* asks us to consider the atmosphere, not merely as a common resource, but also

as the shared space of social existence, binding us together in a co-fragility that is born of our cohabitation with each other and with the elements. It allows us to borrow Judith Butler's notion of precariousness, developed within the context of war and political violence, for the purposes of an atmospheric or an environmental ethics. For Butler, precariousness 'implies living socially, that is, the fact that one's life is always in some sense in the hands of the other. It implies exposure both to those we know and to those we do not know; a dependency on people we know, or barely know, or know not at all.'[21] This condition of 'generalized precariousness' calls into question 'the ontology of individualism'.[22] Lozano-Hemmer's exploration of vulnerability likewise explores the intermeshing of the physiological and social, but its focus on the atmosphere as a finite resource situates his work explicitly within a philosophy of the commons.

Memory and the atmosphere

The complex interplay between the chemical and the social that characterizes the atmosphere, as a space of shared vulnerability and potential solidarity, was explored in greater depth in *Atmospheric Memory* (2019), an exhibition held in Manchester in the UK that brought together many of Lozano-Hemmer's works on the theme.[23] These highlighted the different ways in which the atmosphere 'remembers'. Some works expanded on Babbage's notion of the indelible imprint of our words on the movement of air molecules, while others picked up the theme of airborne contagion explored in *Vicious Circular Breathing*. Still others focused on the increasing use of digital surveillance devices recording our words and actions, and the concentrations of carbon dioxide in the atmosphere, growing with every atom of carbon burned. As Babbage reminds us, 'No motion impressed by natural causes, or by human agency, is ever obliterated.'[24]

A series of contrasting pieces in the exhibition explored ways in which our words can be understood to have a material effect on the atmosphere. In *Weather Vanes* (2019), a forest of little brass arrows spin round when set in motion by a participant speaking into a turbulence generator. Participants were encouraged to articulate what they considered to be the 'greatest hope' and the 'greatest threat', in an illustration, perhaps, of Babbage's sense of 'every atom impressed with good and with ill'.[25] The vast images and sequences projected onto the hangar's walls and ceiling included a rising count of atmospheric carbon dioxide since the mid-nineteenth century. A bookshelf contained a series of public reports on the environment, human rights

and (counter-)surveillance devices, including the *Greater Manchester Air Quality Action Plan, 2016–2021*, the text of a United Nations declaration on free expression, and articles on drone detection systems and interactions between clouds and aerosols. *Volute 1: Au Clair de la Lune* (2016) materialized a single spoken sentence, capturing in a steel bubble the air turbulence ejected during speech; thinking about words as 'shaped breath', as David Abram suggests, helps us to grasp the air as the medium for all (human) communication.[26]

These works by Lozano-Hemmer thus find a variety of ways to render visible the unseen turbulences of the air, set in motion by our breath, our words and – increasingly – carbon emissions from agriculture and industry, as well as the radio and electromagnetic waves that transport data swiftly and indiscernibly around us. It is the invisibility of the air and the unpredictability of its 'ever-shifting flux' that have made it easy for us to take its value for granted, Abram suggests: we have forgotten that we belong to a 'Commonwealth of Breath'.[27] He asks, 'What is climate change if not a consequence of failing to respect or even to notice the elemental medium in which we are immersed?'[28] The strongly participatory elements of Lozano-Hemmer's works also emphasize the atmosphere as a medium for social interaction: several of the pieces required more than one participant to make them work as intended, and in the enclosed space of the hangar, our whispered words became audible and visible to everyone around us through magnification and the use of word-recognition software.

The concept of immersion is treated ambivalently in the exhibition, however. Lozano-Hemmer professes to be suspicious of 'manipulative' immersion techniques in contemporary art, which should not be about creating an illusion or offering an alternative reality; he prefers to cite a famous phrase uttered by Subcomandante Marcos, Zapatista leader: 'En este país todos sueñan. Ya llega la hora de despertar' (Everyone is dreaming in this country. Now it is time to wake up).[29] There are frequent moments of rupture and reversal in *Atmospheric Memory*, when the screens suddenly switch to black, or the faces of those watching are unexpectedly projected onto them, via the surveillance cameras that have been tracking our progress around the hangar. Lozano-Hemmer creates these interruptions not only to snap the spectator out of a mesmerized state, but also to 'create a sense of connection to fellow humans', as we realize our common predicament, becoming the observed, rather than the observers.[30]

Atmospheric Memory thus presents the atmosphere simultaneously as a physical and a social medium, as a battleground on which individual rights to privacy come into conflict with commercial data collection

through surveillance, as a repository of human-generated pollution, as a space for individual expression and collective experience, and, not least, as a source of astonishing aesthetic beauty, captured in the swirling trails of vapour that periodically animate the hangar's screens. When Babbage wrote almost two centuries ago, 'earth, air, and ocean, are the eternal witnesses of the acts we have done',[31] he could not have foreseen the intricate web of meanings those words would generate today. *Atmospheric Memory* impresses on us the importance of safeguarding the atmosphere as a vital common resource, but it does so while recognizing that it is not a sphere that is separable from human activity, past, present or future: it is continually imprinted with the acts, the conflicts, and the negotiations that govern any shared social space, the consequences of which we then draw into our bodies with every breath. It is not simply a natural resource but a commons, which – as Weber states – 'is always an embodied, material, perceptible, existential and symbolic negotiation of individual existence through the Other and the whole'.[32]

II. From the Anthropocene to the Aerocene

Many of the projects Tomás Saraceno has undertaken since 2008 have constructed possible future post-terran habitats that would reduce the damaging effects of human activity on the Earth and its atmosphere. These take the form of models and prototypes, constructed on an architectural scale and often suspended from gallery ceilings and walls, but inspired by delicate, buoyant forms within nature, such as bubbles, foams, clouds or spiderwebs. His airborne sculptures often re-create the phenomenon of spider ballooning and kiting, in which spiders are able to travel long distances and colonize new territories, attached to gossamer silk threads that are lifted by the wind, thermal currents and electrostatic force. Like Lozano-Hemmer's works, Saraceno's lighter-than-air sculptures help us to understand the commons as a phenomenon that is simultaneously physiological, ontological, social, economic, ecological and cultural.

As I will show, the works created for *Cloud Cities*, *On Space Time Foam* and *In Orbit* envision forms of airborne living for a future period Saraceno has named the 'Aerocene', to mark its difference from the 'Anthropocene', which designates a period of unprecedented human impact on the Earth's ecosystems. Along with *Aerocene Explorer* and the *Museo Aero Solar* – community-based projects initiated by Saraceno – these installations experiment with extremely lightweight, inflatable structures that are suspended above the ground, either inside galleries

or on gallery rooftops, or elevated in wide-open spaces, such as plains, desert sands or salt flats. They are often powered by solar energy and the wind. These structures allow us to imagine a new nomadic mode of living in floating cities that would transcend national frontiers, unshackling humans from their earthbound existence, while making them more aware of their reliance on the elemental forces that govern the universe. Drawing on Bronislaw Szerszynski's work on the dynamics of 'drift', I will explore how Saraceno's lighter-than-air sculptures trace an aesthetics and an ethics of free movement for a post-anthropocentric era.

Co-fragile bodies in space

This freedom is paradoxically based on a notion of co-fragility. A 'visual essay' composed by Saraceno for the *Cloud-Specific* exhibition catalogue cites extensively from the third volume of Peter Sloterdijk's monumental trilogy *Spheres* (1998–2004), in which the properties of bubbles, the globe and foam become ways of thinking about how humans live together, starting from the premise that human existence is quintessentially a shared one, rather than one of loneliness.[33] Foam for Sloterdijk becomes a way of expressing the abandonment of 'the all-gathering monosphere […] the orb-shaped One' of classical metaphysics and a way of embracing a new understanding of society as 'an aggregate of microspheres (couples, households, businesses, associations) of different formats that, like the individual bubbles in a mountain of foam, border on one another and are layered over and under one another, yet without truly being accessible or effectively separable from one another'.[34] Sloterdijk considers this turn towards a 'pluralistic ontology' to have been prefigured in modern biology, and by Jakob von Uexküll's work in particular.[35] He cites Uexküll's theory of *Umwelten*, through which 'we gain an entirely new view of the universe: it consists not of a single soap bubble that we have blown up beyond our horizon into the infinite, but of countless millions of narrowly bounded soap bubbles that overlap and intersect everywhere'.[36] The foam-like clusters of polyhedrons and bubbles Saraceno has constructed for several exhibitions are a conscious materialization of Sloterdijk's concept. They show how life 'unfolds multifocally, multiperspectivally and heterarchically' and express the notion of co-fragility that recognizes the extent to which all lives are intertwined with other lives.[37]

Saraceno's models, such as the ones developed for *Cloud Cities*, bear strong affinities with the speculative projects – built and unbuilt – of a post-war generation of architects who experimented with mobile, alterable forms of dwelling as ways of expressing or producing new

social relations.[38] He has acknowledged their influence repeatedly and even paid explicit homage to them in his own projects. His bubbles and clusters are reminiscent of the space-frame structures developed by Yona Friedman, for example, which allowed maximum freedom and flexibility for adaptation and recombination. These were to be among the building blocks of a new 'mobile architecture' in Friedman's *Spatial City* (1956–2020), which also expanded upwards into the sky. Saraceno also inherits something of the nomadic quality of the hypothetical projects developed by the neo-futurist London-based group Archigram in the 1960s and by Constant Nieuwenhuys in his *New Babylon* (1959–74), and of their belief in the power of technology to liberate individuals to be playful and creative.

What differentiates Saraceno's work from many of these precursors is a new understanding of the importance of using technology to minimize resources rather than to stimulate further consumption, and a renewed commitment to life-in-common, rather than an elevation of the individual's interests and right to freedom. In this respect, his approach is closer to that of an earlier precursor, Buckminster Fuller, who had explored the efficient use of materials to construct dwellings in the context of finite resources. His *Dymaxion House* (1930) embodies many of the principles Saraceno adopts in his own constructions, including the use of lightweight materials and the harnessing of solar energy and the wind to heat and cool the domed property. In many ways, Saraceno's *Cloud Cities* is a materialization of Fuller's design idea for airborne habitats in *Cloud Nine* (1960), huge geodesic spheres that could be made to float by heating the air inside.

Yet Saraceno's interest in embodied interaction also suggests a strong debt to an Argentine artist whose work he has long admired: Gyula Kosice (1924–2016), whose pioneering experiments with kinetic art are clear forerunners of Saraceno's own. Both make use of plexiglass and aluminium to create artworks and installations that draw on elemental forces – water in the case of Kosice – to imagine new forms of existence, elevated from the Earth, as in Kosice's *La ciudad hidroespacial* (*The Hydrospatial City*, 1946–72). Kosice's sculptures were among the first to invite visitors to participate by moving them. Like other works by artists associated with the Arte Madí movement in 1940s Argentina, the manipulable mobiles Kosice produced were intended to reduce the distance between artist and spectator. The motion of his hydrokinetic sculptures altered visitors' sense of equilibrium, modifying their experience of space.

A number of Saraceno's installations create unique environments that modify our experience of space and movement in a similar way. *On Space Time Foam* (2013) was the result of collaboration with engineers specializing in the development of aerostatic materials, such as balloons, which are lifted via the buoyant force of the surrounding air.[39] Visitors were invited to clamber over three transparent membranes suspended high above the gallery floor, which formed a billowing multi-layered landscape. They were able to explore the feeling of moving without gravity, but their sense of freedom was checked by a visceral sense of insecurity, as the unpredictable heaves and pitches of the membranes challenged their spatial perception and coordination. They also became aware of how their own movements affected the whole space, as their weight caused depressions in the membranes that destabilized other participants and sometimes brought the membranes themselves into contact. These collisions were intended to form a dynamic visual representation of the contact between cosmic membranes which – according to string theory – may have triggered the genesis of the universe, and also to serve as a broader picture of the interrelations between humans, climate and matter. Saraceno's stated aim in *On Space Time Foam* was to provide 'a physical demonstration of how individuals form space by relating to each other': the unique properties of the membranes create a superb example of a co-dependent space, in which 'any of my movements will condition yours and those of everybody else'.[40] *In Orbit* (2013) provides a similar space for airborne exploration, this time constructed of nets held apart by a series of reflective silver PVC spheres.[41]

The dynamics of drift

These explorations of how unfamiliar experiences of space may produce new kinds of interaction are extended in Saraceno's co-development of air-fuelled sculptures made of ripstop fabric. Saraceno broke world records in 2015 when his solar-powered vehicle carried seven passengers for over two hours, without the use of propane.[42] Claims that the flights of his *Aerosolar* sculptures are 'free from fossil fuels'[43] are perhaps misleading: while they do not require fuel to fly, the specialist nylon material from which they are made takes a heavy toll on the environment. Nylon is made from petroleum, and its fabrication creates emissions of nitrous oxide that are significantly more damaging to the atmosphere than carbon dioxide. That said, Saraceno's fuel-free flights clearly point to the potential for developing a more sustainable future for transport across the globe. They

contrast the fuel-thirsty velocity of jet air travel with the slow and erratic progress of atmospheric drift. The *Aerosolar* sculptures are particularly inspired by the stratospheric MIR balloons used since the 1970s by the Centre National d'Études Spatiales (France) for long-distance flights to record meteorological data. Their aim was to 'complete' a history of solar ballooning that had been abandoned before its true potential was realized.[44]

The *Aerosolar* sculptures manifest the unpredictability of atmospheric conditions, which shape the dynamics and aesthetics of its flight. They become in this way a kind of anti-Icarus, bereft of soaring ambition and hubris. Indeed, the text released on the occasion of a launch from the huge salt flats of Jujuy, Argentina (August 2017), explicitly discards the Icarus myth as a symbol of the Anthropocene and 'our attempt to emancipate ourselves from nature', to objectify it, to exceed it, and ultimately to rule it.[45] Instead, the flying sculpture is given the Quechuan name 'Tata Inti' (Father Sun) referring to the highest deity in Andean cosmology, the Giver of Life. Its flights are intended to return agency to nature and to map the thermodynamic interplay of elements in the patterns traced by the kites. As we are told, 'When Tata Inti flies, it traces a narrative thread in the terrestrial tapestry that allows us to read the interlacement of the world, the entanglement of different forces that create the condition of life, becoming an interpreter of one of the many languages of the ecosphere.'[46] The surging and billowing airborne sculptures become 'aeroglyphs', their trajectories 'inscriptions that compose a codex', revealing to us the interaction of unseen cosmic bodies and elements.[47] These co-compositions attain a sublime beauty that is heightened by the other-worldly, seemingly infinite landscapes often chosen as launch sites, such as salt flats, plains and desert sands.

For Tim Ingold, wind helps us to understand that agency is not something that objects *have*: the kite and the flyer are able to interact because of their common immersion in the fluxes that characterize the medium of air. In other words, 'life is not *in* things; rather, things are *in* life, caught up in a current of continual generation'.[48] For his part, in an essay entitled 'Drift as a planetary phenomenon', Szerszynski ponders what the uncertain drift of a child's balloon through the air may tell us about the elements that have shaped the Earth through time. He suggests that 'drifting can lead us to a deeper understanding of the way that *all* things move'.[49] Unlike the directed flight of engine-fuelled machines, Saraceno's kites and balloons are subject to the unpredictable tugs and twists of air currents, but they also interpret these according to the particular properties of their own shape and substance, which create friction and different pressure gradients in the air around. Szerszynski

explains that in drift – unlike in locomotion – there is no simple division between active matter and passive environment; 'the resulting motion is a *single motion*, one which results from the immersion of the body in the medium, and is the conjoined achievement of all'.[50] For this reason, '"floating" thus knows what "flight" has forgotten: motion cannot fully be understood in the active voice, action is always a collaboration […], and all our powers are powers of the Earth's planetary commons'.[51] While only a small fraction of the planet moves through locomotion, drift should be understood as a far more common way of moving through and occupying space, characteristic even of the formation of rock over billions of years.[52]

Commons practices against the colonization of the atmosphere

As Heather Davis states, 'In the face of the colonization of the atmosphere by commercial industry and the military, by the everyday and ongoing weaponization of the air through emissions of carbon dioxide and methane that are the legacies of advanced capitalism, Saraceno is offering a vision of the atmosphere as a commons'.[53] The notion of the commons, and of life-in-common, is fundamental to Saraceno's work, in its emphasis on shared environmental resources and on new possible spaces for habitat and community. It is also embodied in the practices of making the technologies developed fully available to other scientists and to the general public and of providing opportunities for what Saraceno calls 'do-it-together' projects. These are clearly located within a broader trend towards citizen science, which has recently been catalysed by crossovers with the maker movement. They also recall the synthesis of utopian ideas and aesthetic practices that characterized Joseph Beuys's 'social sculptures'.[54]

The projects that have emerged from Saraceno's *Aerosolar* sculptures create new, transnational communities of amateurs and aficionados who share data and knowledge freely in the quest for better, more sustainable forms of living on (or often above) Earth. The *Aerocene Backpack* is a fully open-source sculpture produced and developed by the Aerocene community, which brings together 'artists, geographers, philosophers, thinkers, speculative scientists, explorers, balloonists, and technologists, and other enthusiasts' from across the world.[55] Complete instructions are given online for anyone to make and fly their own.[56] The *Museo Aero Solar* project allows for an even greater level of participation from communities worldwide. Individuals at different sites across the world come together to donate plastic carrier bags and glue them together to form a vast balloon structure that is launched at dawn,

with the help of the sun's rays. As one of the project's websites states, the project brings together people who are interested in 'contributing to the visibility and reduction of the human footprint by constructing flying museums', but more broadly it is 'a new means of encouraging togetherness worldwide'.[57] Balloons have been launched from well over 20 sites across the world, from Colombia to Denmark and the United Arab Emirates. From the Aerocene website you may download instructions for how to construct and launch a balloon within your own community.[58] A forum on the website allows community members to advertise launch events, swop advice on flight tracking and share adaptations of the original design. Many of the sculptures also carry cameras and sensors to measure air pollution or detect meteorological changes.

Saraceno's visions of new forms of life-in-common are markedly idealistic in their erasure of territorial boundaries and social exclusions. He presents his prototypes as a new form of liberation, explaining that we have so far seen freedom of movement for capital, but not for people.[59] Promoting 'free access to the atmosphere', the Aerocene 'imagines space as a commons and becomes a physical and imaginative place cleared from corporate control and government surveillance'.[60] However, his projects are not devoid of practical politics. His team lobbies the Federal Aviation Administration (FAA) to define a category for solar flights, pressing for the recognition of aerosolar technology as a viable new form of mobility.[61] This legimitization is seen as a vital step towards a 'reclamation of the airspace from corporate interests' and the 'paradigm shift' that is needed to take us into a new 'era of decarbonization'.[62]

These prototypes point very clearly to the obstacles that stand in the way of the kind of freedoms and forms of collective life they trace. Saraceno worked with a team from MIT's Department of Earth, Atmospheric and Planetary Sciences who developed the 'Float Predictor' to simulate global wind patterns using wind forecast data, allowing solar flights to be planned and executed in accordance with wind strengths and directions. Saraceno explains in a TED talk that one of his flying sculptures made a fuel-free journey of 375 miles from Germany to Poland in 12 hours. However, the negotiations required to cross the border were 'much more complicated' than they could have imagined, as airspace is just as regulated and militarized as land. Exploring the possibilities of living suspended between the clouds is not only a technological challenge; rather,

> es una manera de reexaminar la libertad de los movimientos entre los países, y de superar las restricciones políticas, sociales, culturales

> y militares de las sociedades contemporáneas. Porque en el último lugar, el aire es de todos, y no depende de ninguna soberanía.[63]
>
> (it is a way of re-examining freedom of movement between countries, and of overcoming the political, social, cultural and military restrictions of contemporary societies. Because in the end, the air belongs to everyone, and it is not subject to any sovereignty.)

In this way, the cross-border performances of Saraceno's *Aerosolar* sculptures reveal that the political barriers to a new era of decarbonization are manifestly much greater than the technological challenges to be overcome.

Saraceno's sculptures derive their power to lift from the earth through their 'openness to elemental media and cosmic forces', as Szerszynski notes in his reflection on the artist's work: they harness electromagnetic energy from the sun and the Earth and use pressure differentials in the atmosphere in order to move.[64] The *Aerocene Manifesto* claims that 'building a less anthropocentric relationship with the environment' is about becoming 'weather-dependent' in the Aerocene epoch, learning how to 're/entangle ourselves with the surrounding milieu'.[65] The specialist materials and techniques Saraceno co-develops are a far cry from the technological bid to geoengineer climate by shooting microparticles into the atmosphere. His projects propose instead that we should use climate science to work *with* the atmosphere, not to alter it or to protect ourselves from it, to recognize our exposure to the unpredictable elements as part of our shared existence on the planet rather than something that should or could be eradicated. His projects sketch out the need for what Szerszynski calls 'a planetary ethic' or a 'socio-ecological theory of drift', that 'ask[s] not how drift can be eradicated, but how the world can be made safe, hospitable, just, for drifting things, ideas and beings', and that recognizes 'the debt that all moving things owe' to the planetary commons that enable motion.[66] They make visible the agencies and forces that surround us and traverse us in ways that encourage us to imagine enterprises of co-navigation and co-creation.

Planetary commons and the ethics of a shared ecology

The installations discussed here invite their visitors to participate in ways that heighten their sense of an embodied entanglement with their environment and with others. Lozano-Hemmer's works invite us to breathe in air into which chemicals have been deliberately introduced,

while Saraceno's encourage us to take part in the launch of ultralight sculptures or to float together on membranes that mimic the effects of zero gravity. These experiences allow us to grasp the nature of a commons, or commoning, as embodied and collective practices that recognize our prior enmeshment with the environment and seek to transform that relationship, creatively and sustainably. At the same time, these works provoke wider reflections on the governance of the Earth's shared resources, allowing us to see – as Weber maintains – that '[a] commons is a way of entering into relationships with the world, both materially and conceptually' that 'fuses theory and practice'. It is moreover a way of eroding the 'dualistic concepts of the Enlightenment', such as the oppositions between culture and nature and animate and inanimate.[67]

Key to all of these projects is a recognition of our dependence on the elements, and our interdependence with others who share that resource with us. Szerszynski proposes that 'the open body of Aerocene reminds us of the openness of our *own* bodies',[68] porous to the environment and to others around us. In a future in which 'we will all, in a sense, be climate refugees', he affirms: 'We will have to develop new forms of solidarity and security, predicated not on closure and independence but on the recognition of vulnerability and exchange with nature.' As we move into an era of increasing meteorological uncertainty, he surmises that '[c]limate technics would have their place, but not as soteriological gestures; instead, they will have to be grounded in specific social projects that bind humanity together in new relations of interdependence. The weather will have reminded us of the openness of existence, and the impossibility of autonomy.'[69]

These invocations to openness – on the part of Szerszynski, but also of Lozano-Hemmer and Saraceno – resonate strongly with Butler's understanding of an ethics based on shared vulnerability. Like Szerszynski, Butler finds in that very vulnerability the basis for 'our collective responsibility for the physical lives of one another'.[70] She argues: 'To foreclose that vulnerability, to banish it, to make ourselves secure […] is to eradicate one of the most important resources from which we must take our bearings and find our way.'[71] While the violent, dispossessing acts of war and terrorism are foremost in Butler's mind, Lozano-Hemmer and Saraceno explore the much less visible threats of atmospheric contamination and privatization. In a similar manner, though, their response is not to tame nature to make it 'safer', but to expose ourselves consciously to what it means to coexist within a common medium, and to understand the ethical demands and opportunities this creates. The commons emerges in their work as an important paradigm for thinking about our management of the atmosphere, as a global

resource, in ways that are confined neither to scientific investigation nor to economic management. Bollier and Helfrich affirm the importance of exploring 'commoning as a social form, moving beyond economistic notions of the commons as a mere resource to be managed'.[72] Lozano-Hemmer and Saraceno stage embodied and collective experiences of the atmosphere that emphasize in a similar way how commons operate as a social practice, revealing and deepening the profound relationships that tie us to each other and to our environment.

Notes

1. The title of the exhibition represents the number of migrant fatalities worldwide; the number changes in line with data updates released by the International Organization for Migration (see https://missingmigrants.iom.int, accessed 22 October 2020).
2. See https://www.tate.org.uk/whats-on/tate-modern/exhibition/hyundai-commission-tania-bruguera. Accessed 22 October 2020.
3. Weber, 'Reality as commons', 770.
4. Bollier and Helfrich, 'Introduction', loc. 258–60.
5. Fortin, 'The light that blinds', 277.
6. Lafuente, 'Los cuatro entornos de los bienes comunes', 64.
7. Hess and Ostrom, 'Introduction', 10.
8. *Babbage Nanopamphlets* was first exhibited as part of *Pseudomatismos*, at the Museo Universitario Arte Contemporáneo (MUAC), Mexico City, between 28 October 2015 and 17 April 2016.
9. Babbage, *The Ninth Bridgewater Treatise*, 108.
10. Babbage, *The Ninth Bridgewater Treatise*, 112.
11. Laplace, *A Philosophical Essay on Probabilities*, 4; my emphasis.
12. Babbage, *The Ninth Bridgewater Treatise*, 111.
13. Álvarez Romero, *Pseudomatismos/Pseudomatisms*, 23–5, 185–7.
14. Hardt and Negri, *Commonwealth*, viii, loc. 26–9.
15. *Vicious Circular Breathing* was first exhibited at Borusan Contemporary in Istanbul, between 14 September 2013 and 16 February 2014.
16. Lozano-Hemmer explains that the number of paper bags correlates with the usual number of keys on an organ manual (keyboard); the bellows and valves used were also inspired by the workings of the pipe organ.
17. Installation video produced for the MUAC exhibition (2015–16), available to view at http://www.lozano-hemmer.com/vicious_circular_breathing.php. Accessed 22 October 2020.
18. Bakke, 'Introduction', 23.
19. Installation video produced for the MUAC exhibition (2015–16), available to view at http://www.lozano-hemmer.com/vicious_circular_breathing.php. Accessed 22 October 2020.
20. Álvarez Romero, *Pseudomatismos/Pseudomatisms*, 86, 96.
21. Butler, *Frames of War*, 14.
22. Butler, *Frames of War*, 33.
23. *Atmospheric Memory* was exhibited in a purpose-built hangar at the Science and Industry Museum, Manchester, between 6 and 21 July 2019, as part of the Manchester International Festival.
24. Babbage, *The Ninth Bridgewater Treatise*, 114.
25. Babbage, *The Ninth Bridgewater Treatise*, 111–12.
26. Abram, 'Afterword', 308.
27. Abram, 'Afterword', 301, 311.
28. Abram, 'Afterword', 301.
29. Conversation with the author, 15 July 2019. The oft-cited phrase is recorded in an essay written by Subcomandante Marcos in 1992, with the title 'Chiapas: El sureste en dos vientos, una tormenta y una profecia' (Chiapas: The southeast in two winds, a storm and a prophecy).

30. Conversation with the author, 15 July 2019.
31. Babbage, *The Ninth Bridgewater Treatise*, 112.
32. Weber, 'Reality as commons', 793.
33. The *Cloud-Specific* exhibition was held at the Mildred Lane Kemper Museum at Washington University in St Louis, Missouri, between 9 September 2011 and 9 January 2012.
34. Sloterdijk, *Foams*, 58, 56.
35. Sloterdijk, *Foams*, 59.
36. Uexküll, *Kompositionslehre de Natur*, 355; cit. Sloterdijk, *Foams*, 60.
37. Sloterdijk, *Foams*, 23; cit. Saraceno, 'Visual essay', 49.
38. Images of Saraceno's 'cloud cities' may be viewed at https://studiotomassaraceno.org/stillness-in-motion-cloud-cities and https://studiotomassaraceno.org/on-the-disappearance-of-clouds. Accessed 23 October 2020.
39. *On Space Time Foam* was installed at the Hangar Bicocca in Milan, from 26 October 2012 to 17 February 2013. Images of the installation may be viewed at https://studiotomassaraceno.org/on-space-time-foam and a video showing how participants interact with it is available at https://www.youtube.com/watch?v=G_3luQuhTro. Accessed 23 October 2020.
40. Ramos, 'Where is everybody?' (interview with Tomás Saraceno).
41. *In Orbit* has been installed since 25 March 2017 in the Kunstsammlung Nordrhein-Westfalen at K21, in Düsseldorf, Germany.
42. See http://aerocene.org/flightshare. Accessed 23 October 2020.
43. See https://aerocene.org/ and https://arts.mit.edu/aerocene/. Accessed 23 October 2020.
44. The *Aerocene* website sketches out a history of solar balloon flights at https://aerocene.org/history-of-ballooning/. Accessed 18 May 2020.
45. See http://aerocene.org/aerocene-argentina-cck. Accessed 23 October 2020.
46. See http://aerocene.org/aerocene-argentina-cck.
47. See http://aerocene.org/aerocene-argentina-cck.
48. Ingold, 'Earth, sky, wind, and weather', S30, S31.
49. Szerszynski, 'Drift as a planetary phenomenon', 136; emphasis in original.
50. Szerszynski, 'Drift as a planetary phenomenon', 140; emphasis in original.
51. Szerszynski, 'Drift as a planetary phenomenon', 143.
52. Szerszynski, 'Drift as a planetary phenomenon', 139.
53. Davis, 'To breathe in the cosmos', 10.
54. Confident in the power of art to effect social transformation, Beuys considered all human beings to be artists and architects of their own society. His 'social sculptures' involve human participants in shaping society or the environment.
55. See http://aerocene.org/home-3. Accessed 23 October 2020.
56. See https://aerocene.org/how-to-build-the-explorer-envelope. Accessed 9 November 2020.
57. See http://museoaerosolar.weebly.com. Accessed 23 October 2020.
58. See http://aerocene.org/buildit. Accessed 16 November 2020.
59. Interviewed for the *Our Interplanetary Bodies* exhibition held at the Asia Culture Center, South Korea, between 17 July 2017 and 25 March 2018. See https://www.youtube.com/watch?v=iojVxrCNVOY. Accessed 23 October 2020.
60. See https://aerocene.org/wp-content/uploads/2019/04/Aerocene_Manifesto-1.pdf. Accessed 23 October 2020.
61. See https://aerocene.org/history-of-ballooning. Accessed 18 May 2020.
62. See https://aerocene.org/a-brief-solar-ballooning-and-aerocene/. Accessed 23 October 2020.
63. See https://www.ted.com/talks/tomas_saraceno_would_you_live_in_a_floating_city_in_the_sky. Accessed 23 October 2020.
64. Szerszynski, 'Up'.
65. See https://aerocene.org/wp-content/uploads/2019/04/Aerocene_Manifesto-1.pdf.
66. Szerszynski, 'Drift as a planetary phenomenon', 136, 143.
67. Weber, 'Reality as commons', 785–86.
68. Szerszynski, 'Up'; emphasis in original.
69. Szerszynski, 'Reading and writing the weather', 25.
70. Butler, *Precarious Life*, 30.
71. Butler, *Precarious Life*, 30.
72. Bollier and Helfrich, 'Finale', 822.

3
Art and environmental change: beyond apocalypse

Artists across the world are finding compelling and affective ways to communicate the existential risks of which we are increasingly being warned by environmental scientists. While artworks that convey the current scale of environmental devastation may raise much-needed public awareness, they may also slide into media clichés of apocalypticism without questioning what ideas about humans, or about the environment, underpin the insistent depiction of climate change as catastrophic, accelerating and irreversible. Discourses that emphasize the precarity of the biosphere may lead us to assume that its survival is dependent on us, for example, rather than the reverse. Urgent calls to address the crisis may ultimately reassert those humanist values that have led to widespread environmental damage and the exploitation of the natural world. They may do this by casting humans as saviours or (conversely) as doomed to extinction, along with human culture as we know it, or by advocating ever greater technological interventions to reverse climate change.

Rather than lamenting the 'end of Man' prophesied in the apocalyptic discourses of the Anthropocene, Joanna Zylinska wonders if we might welcome it, seeing it as an opportunity to challenge the technicist, humanist, capitalist and masculinist projects that have impelled us towards social and environmental crisis. Such projects, she proposes, far from being threatened by visions of catastrophe, are often reinforced by them.[1] Zylinska argues that the apocalyptic narrative of the Anthropocene calls for humanity to overcome calamity through ingenuity, bringing forth 'a temporarily wounded yet ultimately redeemed Man who can conquer time and space by rising above the geological mess he has created'.[2] She proposes instead a 'feminist counterapocalypse' that would resist the 'masculinist and

technicist solutions' offered to secure the salvation of humanity.[3] This counterapocalypse would be founded on the notion of precarity as the shared condition of life in the post-industrial world, a concept Zylinska develops from the work of Anna Tsing.

This chapter focuses on art–science projects created by Joaquín Fargas (Argentina) and Paul Rosero Contreras (Ecuador) that also explore the possibilities and limits of technological responses to environmental crisis. In comparing their projects, I will ask to what extent they challenge or complicate the apocalyptic narratives that, for Zylinska, ultimately shore up 'man's fictitious authority'.[4] I will argue that renouncing commonplace depictions of climate change as catastrophic allows these artists to dislodge the humanist and anthropocentric perspectives that are often embedded in such apocalypticism. The ironic treatment of technological solutions to climate crisis in Fargas's work subjects solutionist narratives to critique, while leaving intact broader beliefs in human transcendence through technology. Rosero's emphasis on strategies of cross-species collaboration and adaptation has the effect of returning to the natural world beyond the human the agency and subjectivity that are often stripped from it in the apocalyptic tenor of imagined environmental futures.

Rosero's approach to ecological crisis counters, in some respects, the centrality accorded to the notion of precarity in the work of Tsing and Zylinska. Both scholars explore precarity as a way of understanding 'the condition of our time', tracing connections between environmental and economic precarity in the context of global capitalism. In my discussion of Rosero's work, however, I will propose that this notion may have limited value as a basis on which to imagine 'the coexistences and collaborations' that might be created in the wake of a crisis generated by the humanist and imperialist logic of capitalism.[5] Discourses that emphasize the precarity of the biosphere tend to portray biological life as eked out in invariably harsh and competitive conditions. These visions feed into a Darwinian understanding of nature as a struggle for survival in which species are pitted against each other. This conception has successfully reinforced representations of capitalism as an economic system that is based on the competitive relations inherent in nature. In place of precarity, Rosero's work draws our attention to the logics of abundance, cooperation, and coevolution that are everywhere in evidence in ecological systems. It also encourages us to abandon those biological metaphors of the 'survival of the fittest' that have been used to naturalize capitalism and consider instead whether alternative systems based on forms of cooperation and the commons might indeed be more

paradigmatic in the natural world. This approach may more effectively contest the logic of a capitalist system that is closely involved, for both Zylinska and Tsing, with the structural production of precarity.[6] Drawing on the work of Andreas Weber, Eduardo Gudynas and Raquel Gutiérrez Aguilar, among others, I suggest ways in which biosemiotic approaches, together with the biocentric perspectives and commoning practices theorized by a number of Latin American scholars, may bring an important perspective to the 'counterapocalypse' Zylinska proposes.

I. Art and geodesign for climate change

Based in Buenos Aires, Joaquín Fargas is extensively involved in educational programmes that promote creative and artistic approaches to the study of science and technology, within academia and the public sphere. He trained as an engineer and pursued a career in industry before going on to work as an artist. He develops art projects that combine elements of digital media, biotechnology and robotics; some of these examine the possible role of technology in reversing climate change, bringing this topic to the attention of wider audiences through exhibitions and other forms of public engagement and education. His work includes a number of site-specific installations in Antarctica. The poles have become 'both the proving ground and the advanced warning system' for scientific research on climate change, acting rather like the 'canary in the coal mine' of global warming.[7] In recent years, Antarctica has also become a privileged space for artists engaging with the science and the politics of climate change. The meteorologists, climatologists, astronomers and marine biologists who carry out research there every year have been joined by a growing number of artists from around the world on residency programmes. Latin American artists have been well represented in such schemes, as they were in the first Antarctic Biennale, held in 2017.

A quixotic effort to refreeze the Arctic

Fargas's contribution to the Biennale was *Glaciator*, an installation comprising a number of solar-powered robots with rotating 'feet' (see Fig. 3.1). As the robots move across the snow, they help to compact and crystallize it, turning it into ice and adding mass to the glacier. *Glaciator* is thus designed to reverse the ice thaw that has provided some of the most alarming evidence of global warming, and that is in turn speeding

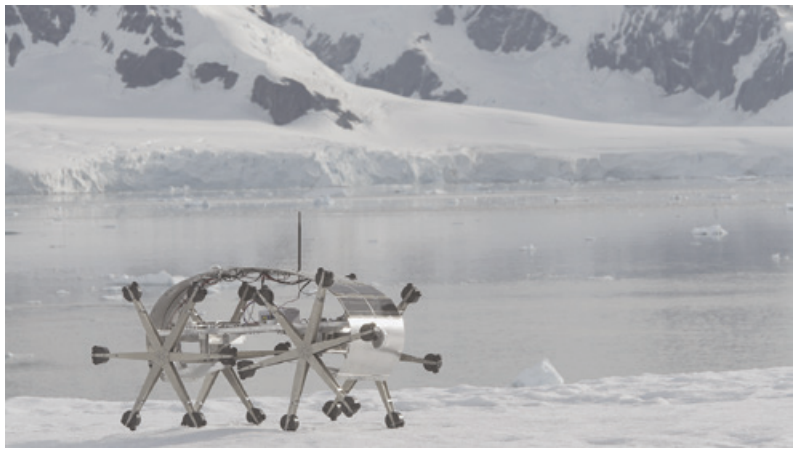

Figure 3.1 Joaquín Fargas, *Glaciator*, 2017. Site-specific installation, First Antarctic Biennale (photograph by the artist).

up the rise in temperatures. Around the same height as a toddler, the robots move with a similar lack of grace: the primitive design of their six-pronged wheels leaves them lurching clumsily over the uneven snow, appearing to stumble at every small dip or mound.[8] If they are watched at length, however, what is most striking is their indomitable progress towards the horizon. Wholly inadequate for the task ahead of them, the robots are nevertheless on a clear and dogged mission.

Fargas had already undertaken work in Antarctica as part of *Proyecto Utopía* (2011), a collaborative project in which artists from Spain and Argentina developed site-specific interventions on the theme of combating climate change. For the work *Don Quijote contra el cambio climático* (*Don Quixote against Climate Change*), Fargas installed three windmills that generated the electricity to operate thermoelectric Peltier cells with a cooling function (see Fig. 3.2). The aim was to demonstrate the possibility of creating ice to replenish the polar ice caps and to slow down the rate of melting. The reference to Don Quixote in the work's title opens up at least two possible meanings. It may refer to the futile endeavour to combat climate change, in what becomes a quixotic – utopian, romantic, impractical, self-delusional – effort to reverse the effects of global warming. On the other hand, it may refer to Don Quixote's misidentification of windmills as giants to be slain in a battle, to his propensity to imagine adversaries where there are none. If there is a battle here, then technology, Fargas appears to suggest, is not the enemy.

Figure 3.2 Joaquín Fargas, *Don Quijote contra el cambio climático*, 2011. Site-specific installation, Proyecto Utopía, Sur Polar Programme (photograph by the artist).

Fargas's piece is poised between these two possible readings. Set against the vast and indifferent expanses of the Antarctic glacier on which they are erected, the thin struts and short blades of the windmills look deliberately puny. The work seems to register the impracticality of any attempt to preserve glacier ice in rapidly warming global temperatures, mocking the 'masculinist-solutionist' approaches Zylinska denounces.[9] Although these are not 'prototypes' designed with mass production in mind, they do function, drawing attention to the fact that replenishing the world's melting ice would indeed be a difficult task but not an impossible one. Ambitious proposals for the global management of the polar ice caps through new technologies have started to emerge in earnest. In 2016, a team led by the physicist Steven Desch published a proposal to 'refreeze' the Arctic with the aid of ten million wind-powered pumps, which would add seawater to the ice to create a thicker layer, protecting it from temperature increases. They estimate that it would cost about US$500 billion each year for the next 10 years to deploy such devices over the entire Arctic, a price they consider to be 'expensive but […] economically achievable'.[10]

Desch prefers the term 'geodesign' to 'geoengineering', recognizing that 'geoengineering' is often used pejoratively by those who argue that

altering the world's climate system is morally irresponsible, as it will disincentivize a reduction in greenhouse gas emissions; what is more, the effects of such actions on the climate system as a whole would be unknown.[11] As Desch explains, the alternative term 'geodesign' reflects an understanding that 'the climate is a highly integrated system that may be impossible to "fix" simply through application of a technology, yet which might be improved by viewing the climate as a planetary system, accepting the role of humans in the climate, and designing a new role for humans in the climate'.[12] Desch and his team explicitly call for such speculative geodesign projects to be carried out 'in parallel with a public discussion of the morality and ethics and politics of the approach'.[13]

There is a clear danger, as Naomi Klein points out, that the need to act quickly in the case of a climate emergency will preclude that discussion.[14] Quite apart from the enormous risks involved in tinkering with a biosphere whose workings we do not yet understand, she claims, looking to geoengineering as a solution simply bolsters 'our culture's most intoxicating narrative: the belief that technology is going to save us from the effects of our actions'.[15] The prospect of reversing climate change in this manner perpetuates a belief in human exceptionalism through the technological transcendence of our environment. Janine Randerson is also suspicious of the 'neopositivist optimism' that pervades the confidence that technology will be able to compensate for the effects of greenhouse gases.[16] She maintains that '[t]he delusion that we can control the weather is a manifestation of the continued will to govern nonlife by humans'.[17] Fargas's speculative ice-generating works bolster a similar sense of human exceptionalism: indeed, he considers an 'espíritu trascendental' (transcending spirit) with respect to nature and the environment to be innate in humanity.[18] However, the works themselves introduce a crucial ambivalence. On one hand, they bear witness to the ingenuity of humans and their power to intervene in the most extreme environments on the planet, recovering something of the Romantic vision of the scientist-as-explorer. On the other, the ludic qualities of these works, together with their clunky do-it-yourself aesthetics, point to the enormity of the task, its quasi-fantastical nature, and the hubris of undertaking it.

Nicola Triscott points out that 'an aesthetic of an idealized – albeit threatened – landscape of ice sheets, icebergs and glaciers' prevails in the artistic imaginary of the polar regions, whose remote, fragile and forbidding vistas are suspiciously devoid of people or politics.[19] In his discussion of Antarctic works and performances by Andrea Juan and other artists, Jens Andermann likewise finds their appeal to the sublime

problematic, as it drives a wedge between non-human nature and the world of politics and culture and posits nature as 'un mundo-objeto autosuficiente' (a self-sufficient world-object).[20] In a similar way, Fargas's Antarctic works are usually filmed alone against the empty expanses of ice, interacting only with the elements in a setting that seems other-worldly and beyond the heat of human debate. Intrepid invaders in a bleak and lonely landscape, they stand in for humanity's ingenuity and imperialist intent. In doing so, however, they demonstrate that Antarctica is certainly not set apart from human politics but increasingly the focus of technomodernity's continually renewed promises to control and rationalize nature. On the other hand, the photographic and video documentation of the installations and their circulation as artworks rather than scientific prototypes creates space for the kind of public discussion on geoengineering that Klein fears is being excised.

The technological enframing of climate change

While uncovering important changes in the planet's systems, climate science 'conditions our response in a way that means that the baton has always already been passed to technology', Bronislaw Szerszynski claims.[21] Following meteorology, which developed as 'a science of measurements, instruments and standardization', our response to the changing weather has been conceived as one of technological calculation and control.[22] A precursor to Fargas's ice-making machines was, naturally enough, his *Sunflower: Centinela del cambio climático* (*Sentinel of Climate Change*), a giant robotic flower designed to monitor atmospheric variables such as air pollution, UV radiation and temperature.[23] As Szerszynski suggests, approaching climate change by framing it technologically, as a phenomenon that can be calculated and made coherent, 'invites us to extend rather than withdraw our enframing of the play of nature'.[24] Paradoxically, then, at a time at which climate change challenges us to recognize the damage caused by the unchecked exercise of human power over the natural world, climate science may lead to an 'extraordinary hypertrophy of hubris concerning the possibilities of predicting and controlling natural processes',[25] the logical expression of which is geoengineering to reverse climate change.

Fargas's works might, in the end, evade this charge of hubris, through their ludism and their evident unscalability. He remains convinced, however, that 'ahora no queda otra que una solución tecnológica' (technology is the only solution left now),[26] and it is certainly the case that his projects do not approach climate change in a way that

would lead us to question our technological framing of it. *Glaciator* and *Don Quijote* were conceived as a challenge to science to come up with its own technologies to control or reverse climate change. Fargas considers that the relative freedom of artists – unlike scientists, artists do not have to follow strict protocols or write peer-reviewed papers – allows them to move into the vanguard of experimentation;[27] this freedom may then act as a 'disparador' (trigger) to generate serious design proposals from within the field of science, as art explores ideas that seem fantastical today, but may become reality in the future.[28] This conception of the relationship between art and science steers us towards a less ambivalent reading of Fargas's works that would ultimately find in them the expression of a commitment to a technological solution to climate change. The fantastical character of *Glaciator* and *Don Quijote*, rather than allowing room for a chink of doubt concerning the capacity of geoengineering to restyle our climate's future, simply casts a vote for the imaginative power of art to stimulate technological progress. Rather than offering a distinctive perspective, art in this case effectively accommodates itself within the normal logic of technological development under capitalism, whereby today's fanciful invention is tomorrow's lucrative new technology.

Although the utopian qualities of Fargas's works appear to lead us away from the apocalyptic visions of climate change that shape media discourse, then, they follow the same fundamental logic: one that posits 'Man' as 'the maker and destroyer of worlds', in Zylinska's words.[29] As Erik Swyngedouw observes, 'the apocalyptic imaginary is one that generally still holds on to a dualistic view of nature and culture', as it is founded on the understanding that humans have disturbed the ecological balance of the planet, but this can be restored through action on our part.[30] Even the starkest warnings of impending catastrophe, Swyngedouw argues, convey 'an unbridled optimism in the species capacities of humans to act if urgency requires it' and in the scientific and technological ingenuity of some to deliver the right solutions.[31] Fargas's Antarctica works retain both this dualism and the linear temporality of apocalypticism, as they represent attempts to turn back the clock and recover, through human inventiveness, something that has been lost, in this case melting polar ice. While leaving undisturbed the humanist teleology that underpins narratives of both apocalypse and salvation, however, Fargas's works do raise questions about the scalability of technological solutions to climate change and cast doubt on that 'unbridled optimism'. Whimsical and quixotic, his projects remain mere gestures towards the kind of unprecedented intervention that discourses of catastrophe seem to

demand, deliberately falling short of the overweening ambition that would be required.

II. Environmental futures beyond precarity: symbiosis and resilience

Both the humanism and the linear temporality of apocalyptic Anthropocene discourses are more directly challenged in the work of Paul Rosero Contreras. Rosero has collaborated with natural scientists and designers in a number of transdisciplinary projects; many of his projects are developed at sites that have become iconic indicators of environmental change, such as coral reefs, glaciers and polar ice caps. Rather than lamenting the devastating effects of human activity, however, they more often stage an encounter with the multiple entanglements that sustain life through continual processes of coevolution.

Plant life and the long history of evolution

Rosero also participated – alongside Fargas – in the first Antarctic Biennale of 2017, but with a very different vision of a polar future. *Arriba!* was a site-specific intervention composed of a glass 'time capsule' containing a cacao plant, audio recordings of a cacao harvest, and a generous supply of chocolate bars, enough to feed the Biennale ship's staff and passengers.[32] The work's play with temporalities beyond the human prompts us to consider the past and future of Antarctica in a way that circumvents both the apocalyptic narrative of climate change and the utopian belief in the potential of human technologies to reverse it, focusing instead on the extraordinary evolutionary capacity of plants to adapt and evolve. Having survived the journey from its native Ecuador, the cacao plant – still in its sealed capsule – was placed in Paradise Bay, where fossil findings have revealed that Antarctica was once part of the same land mass as Australia and shared its tropical climate (see Fig. 3.3). The sense of spatial and temporal disjunction between today's icebound landscape and the presence of the tropical plant was heightened by the work's other performative elements. Over breakfast on the Biennale boat, recordings of a cacao bean harvest and the singing of birds in the Amazonian rainforest were played at a high volume, immersing the passengers in an environment that was entirely alien to the one in which they found themselves. As cacao is now thought to have been first

Figure 3.3 Paul Rosero Contreras, *Arriba!*, 2017. Site-specific installation, First Antarctic Biennale (photograph © Paul Rosero Contreras/Dos Islas Studio; courtesy of the artist and TAtchers' Art Management).

cultivated in the rainforests that are part of Ecuador today, and chocolate is one of Ecuador's most important exports, depositing a cacao plant in Antarctica makes playful reference to the tradition of planting a national flag as well as to narratives of Antarctic exploration: until the invention of the energy bar, chocolate was a favoured source of energy for polar explorers. Rosero's work thus performs couplings in space and time – between the tropical and the polar, the prehistoric and the present – that initially seem to confound the logic of ecology, but actually make precise references both to human histories of exploration and conquest and to vegetal histories of colonization, past and future.

On the wrappers of the chocolate bars, passengers found the words 'and new trees will be born out of glaciers, into the vertigo of eternity'. Rosero's work is a speculative experiment in the use of technology – the climate-controlled capsule – to cultivate plants in extremely cold environments; it is, in part, a fictional intervention into current research on food production in space being conducted in Antarctica by the EDEN ISS project, for example.[33] But it could also be read as a prediction of a different environmental future for Antarctica, or as a creative mash-up of temporalities beyond the human. While taking us back to a time

many aeons ago when there was no ice in the Antarctic, Rosero's work simultaneously projects us into a future in which the region might once again warm to tropical temperatures (and might even be colonized by cacao plants). It references the capacity of human technology to transcend the exigencies of climate and biological milieu, but it also sketches out a vision of the emergence, the flourishing and the eventual extinction of different life forms within the deep time of climate cycles, which dwarf human history.

Work had started several months before the Biennale to obtain the permissions necessary to bring a tropical plant to Antarctica; having visited the region beforehand with a researcher's permit, Rosero knew what would be needed to negotiate authorization to bring in a foreign species, even one that would be hermetically sealed in a container. His case was helped by the fact that cacao plants are notoriously difficult to reproduce, being pollinated only by a particular species of midge found in the tropical rainforest. The elaborate negotiations form part of the performative element of the work. They call attention to the narrative of Antarctica as a region of pristine, untouched nature that the international community has decided to accord a high degree of protection, and that takes on the role of the Romantic wilderness: increasingly idealized as it shrinks beyond the advancing frontiers of civilization. The almost fanatical sense of a duty to preserve the delicate balance of the ecological status quo in Antarctica is rendered anachronistic as Rosero's work brings us face to face with the deep time of climate change over millions of years.

Does *Arriba!* lend force, then, to the arguments of those who seek to question the impact of human activity on climate change? Climate change sceptics often claim that the rising temperatures recently recorded are simply a result of the Earth's natural cycling through warmer and cooler epochs. Certainly, Rosero's brazenly sanguine vision of a tropical Antarctica confounds us by providing no expected moralistic message about the dangers of global warming, no heralding of catastrophe. The green leaves of the small cacao plant stand out brightly against the inhospitable icy slopes of Paradise Bay; the plant lives on today in evident health in a corner of Rosero's studio in Quito, although given the higher altitude and lower temperatures of the city, it will never grow to full height there.

If a warming Antarctic is a fate we have been taught to fear, Rosero's tropical time capsule is a disconcertingly cheery intruder into a panorama of doom. Not all species will be at greater risk on a warming planet: some will advance and recover territories that once belonged to their

ancestors, and the Antarctic could revert to a lush green land, supporting much greater biodiversity than at present. *Arriba!* thus complicates over-simplistic narratives of conservation, revealing the extent to which climate apocalypticism veils an investment in the status quo that cherry-picks from the findings of environmental science. Climate change tends to be a driver for the formation of new species as well as the extinction of other ones, and plant diversity is generally greater in warmer environments. In whose interest, and for what purpose, therefore, should climate change be stalled or even reversed? The presence of the real plant in Rosero's capsule ultimately diverts our attention from the technological feats of transporting a tropical tree to Antarctica and growing plants in space; it symbolizes the colonizing, self-regenerating, adaptive capacity of plants themselves, which existed on the continent before humans and will almost certainly survive our extinction.

Coral reefs: collaboration and coevolution

The resilience and adaptability of other species are also central to Rosero's video installation *Purple Haze* (2018), which was shot underwater near the fumaroles of the active volcanic island Roca Redonda, in the Galápagos archipelago.[34] It formed part of a collaborative research project into the resistance mechanisms of a particular species of coral, on which Rosero worked together with marine biologists Margarita Brandt and Nataly Guevara. Like *Arriba!*, *Purple Haze* is a work of speculative fiction that superimposes different temporalities and locations, questioning how environmental futures are constructed. Its own particular version of a counterapocalypse does not rest on a recognition of 'precarity', as Zylinska's does; it enters into closer dialogue with the 'collaborative survival' that Tsing chooses as a related paradigm, and resonates strongly, as I will suggest below, with the notions of abundance and excess that allow Andreas Weber to trace his own connections between ecology and the economy from a biosemiotic perspective.

For many scientists, corals act as a historical recorder of climate change, a barometer for the current health of oceans and an early warning system for potential future damage to other systems. Harbouring the greatest biodiversity of any ecosystem, coral reefs have been subject to periodic mass extinctions over the ages and are currently among the ecosystems that are most endangered by global warming. In recent years, images of bleached, lifeless reefs have become a harrowing emblem of environmental destruction in media reports and documentaries. *Purple Haze* deliberately deviates, however, from the imagery, narrative

structure and stylistic conventions of the marine life documentaries that have attracted sizeable television audiences in recent years. The video's long takes, full of effervescent life, are not ordered according to the classic narratives of discovery or apocalypse: human divers are totally absent from the camera frame, and we are shown no images of dying coral reefs.

The camera takes up different positions in and around the rocks, loosely alternating between close-ups of different species and wider shots of the larger ecosystem, in which we also see the fish it supports. The immobility and long duration of the shots emphasize how much within the frame is rippling, gliding, gushing, swelling, churning. The video allows us to encounter something of the complexity of coral reef ecosystems. In the exuberant, luxuriant world that Rosero films, it is hard to disentangle activity from passivity, or organism from environment: which creatures are moving of their own volition, and which are being ruffled by bubbles and eddies? We start to grasp something of the multiple entanglements that mark the engagement of species with their environments, and the extent to which agency is distributed across a bewildering range of forces and life forms.

The large format of the screen and the use of high-volume surround sound stage an affective, mesmerizing spectacle that cannot be reproduced by most living-room televisions. However, like Rosero's other works, *Purple Haze* is not an example of ecomimesis in art, designed to promote an immersive, unmediated encounter with the environment. What distances the video both from a conventional nature documentary and from immersive environmental art is its flirtation with science fiction. Its vivid hues, enhanced by colour correction during the editing process, create a phantasmagoric effect, heightened by the twisting columns of bubbles escaping from the fumaroles (see Fig. 3.4).[35] The first overhead shot, in which we descend into one of the vents, resembles the landing of a spacecraft in the trenches of a distant planet. The sound of the bubbles we see is supplemented by extra-diegetic bubbling and an eerie humming, layered over with low portentous groans and subtle synthesized glissandos that evoke the song of alien species or perhaps the distant fly-bys of UFOs. The title *Purple Haze* comes from Jimi Hendrix's 1967 song, which includes the line: 'Is it tomorrow, or just the end of time?' These references, along with the quasi-psychedelic colours, lend a retrofuturistic tone to the work that heightens its self-conscious embedding within the science fiction genre.

Featuring the highly reverberant calls of marine animals, along with other sounds from glaciers and icebergs recorded by Rosero in other locations, the synthesized audio track creates a strongly

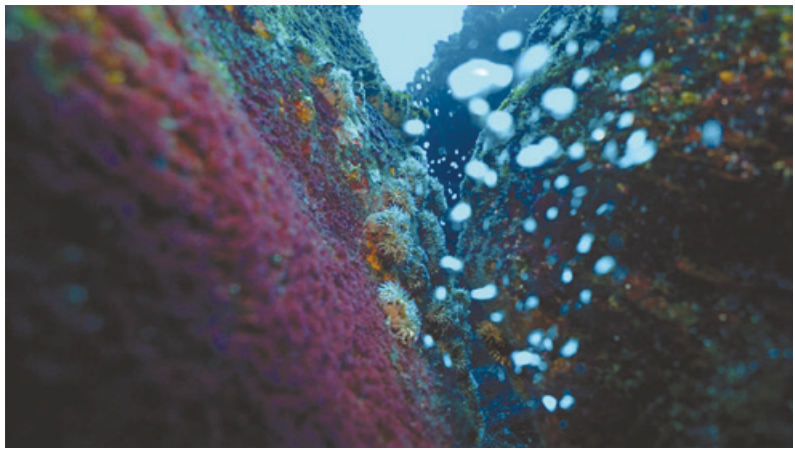

Figure 3.4 Paul Rosero Contreras, *Purple Haze*, still from video, 2018 (photograph © Paul Rosero Contreras/Dos Islas Studio/Ivan Cargminiani; courtesy of the artist, TAtchers' Art Management and the Universidad San Francisco de Quito).

deterritorializing effect. The sweeping electronic glissandos that seem to evoke spaceship landings might be identified by a marine biologist as the striking vocalizations of Weddell seals. Weddell seals are the southernmost species of seal in the world, found mostly on ice in or near Antarctica; they rarely migrate, and usually remain within a few miles of their birthplace. Very dependent on sea ice, they would be extremely vulnerable to rises in sea temperature. Their disembodied, spectral presence on the soundtrack of a film shot near the equator suggests a kind of being-together that is scientifically unimaginable, or that would require thousands if not millions of years of evolutionary change. Or perhaps these are the ghostly premonitions of an extinction to come; it may be that we are viewing – as in *Arriba!* – the future landscape of a tropical Antarctica, haunted by marine animals that have long since disappeared. Rosero's remixing work – like the relocating of the cacao plant in *Arriba!* – is an act of dislocation that demonstrates how art may take us beyond the time and space of the ecological here and now, creating new imaginaries of climate pasts and futures. In this case, however, it also conveys a crucial ecological truth, which lies in the inseparability of the fates of polar ice, Antarctic seals and coral reefs: all are vulnerable to rising sea temperatures and bound together in a global ecosystem in which tiny changes may have sweeping effects across the planet.

In fact, the video's futuristic aesthetic is entirely in keeping with the objectives and the findings of the wider scientific investigation that provided the context for its production. The fumaroles lying beneath the water at Roca Redonda are among a very few in the world that are not too deep to be examined by divers. The carbon dioxide bubbles naturally emitted from the volcano vents here increase the acidity of the water, an effect that will be increasingly seen across the world as the oceans absorb rising amounts of CO_2. Roca Redonda is therefore a site at which the likely future of coral species can be observed, and where their mechanisms of defence and adaptation can be studied. However, we are not shown images of the ashen expanses of bleached coral reefs of the kind that frequently punctuate the narratives of sea life documentaries. The riot of different textures and colours in Rosero's film attests instead to the evident flourishing of corals in the area. The particular species the team has come to study is the orange cup (*Tubastraea coccinea*), which is adapting successfully to greater acidity. It is shown alive and well in the video, and was found to be present there in higher numbers than on a previous trip undertaken by one of the researchers.[36]

Corals provide a particularly good example of interspecies symbiosis, exchanging nutrients with algae and numerous microbes.[37] The bright colours of corals come from the pigment-producing algae living inside them, which are visible through the clear bodies of the polyps. The study of symbiosis in corals and other organisms has led to a 'paradigm change' in biology, which has replaced an emphasis on individual species with the study of multicellular organisms as holobionts, consisting of a host and a microbiome, connected by means of myriad forms of collaboration and coevolution.[38] Microbiomes have been shown to play a vital part in the resilience and adaptation of their host, by helping them to adjust more quickly to changes in environmental temperature or acidity.[39]

Changing paradigms of evolution

It is fitting that the Galápagos Islands, where Charles Darwin made some of the crucial observations that would lead to his theory of evolution by natural selection, should be the site for contemporary research that complicates and questions some of the legacies of his work, which include an over-emphasis on individualism and genetic determinism. Many biologists believe that hydrothermal vents of the kind Rosero films in *Purple Haze* may hold the secrets of the origins of life. The microbes that live in fumaroles are generally thought to be very closely

related to the first organisms to have evolved on the planet. But their study has also confounded genealogical trees of life, giving evidence of horizontal gene transfer as a potent evolutionary force, and showing the extent of entanglement between life forms that had previously been classified as different species, and even between different domains. These recombinations and symbioses present new ways of understanding biological relatedness and interspecies cooperation. Focusing on species as composites and communities undermines the notion of individuality that has held sway in much evolutionary thought since Darwin. Lynn Margulis and Dorion Sagan remind us that '[a]mong the most successful – that is, abundant – living beings on the planet are ones that have teamed up', with cooperation vital to the early spread of life on Earth.[40] Species do not live or evolve in isolation: life is instead 'a network of cross-kingdom alliances'.[41]

The biologist Esperanza Martínez, who has founded and directed a number of associations and networks promoting the defence of the environment in Ecuador, similarly affirms a shift towards rethinking evolution in a way that emphasizes cooperation over competition and symbiosis over the 'survival of the fittest'. She explains that 'La visión de una Naturaleza hostil, patentada en el pensamiento occidental, en donde sobrevive solo el más fuerte, está siendo superada' (the vision of a hostile Nature, patented by Western thought, in which only the strongest survives, is being superseded). In its place are arising theories that attempt to understand forms of cooperation in nature.[42] Much of the knowledge that is relevant to such studies, she contends, is to be found 'en los pueblos ancestrales, que mantienen vínculos directos con la Naturaleza' (in ancestral peoples, who maintain direct relations with Nature).[43] Specifically, she connects the new emphasis on relationality in biology with the (much older) principles that underpin the concept of *sumak kawsay* (often translated as 'good living') in Andean thought, which is founded on an integration between the natural, social and spiritual realms.[44]

Martínez's suggestion that new relational paradigms in biology could inform thinking about alternative forms of social and economic organization is echoed by biologists, philosophers, economists and anthropologists across many regions of the world who are promoting models of the commons. Their arguments challenge the 'mutually reinforcing' metaphysics of neo-Darwinism and capitalism by shifting the terms of comparison.[45] Weber points out: 'The idea of universal competition unifies the two realms, the natural and the socio-economic', and 'validates the notion of rivalry and predatory self-interest as

inexorable facts of life'.[46] He proposes instead that we consider nature 'the paradigm of the commons'.[47] Key to his argument is an understanding of the biosphere that is not governed by the dynamics of competition, property, scarcity, efficiency and optimization, but rather cooperation, symbiosis, abundance and excess. The biosphere as a whole is founded on a 'donation' (solar energy), and the workings of nature are 'highly redundant' rather than efficient, relying instead on 'generosity and waste'.[48] These protect species to a significant degree from the precarity that might otherwise result from environmental change and provide opportunities for other species. Weber argues that a higher number of species in a niche does not lead to increased competition and the dominance of the 'fittest' ones, but rather 'to richer permutations of relationships among species and thus to an increase in freedom, which is at the same time also an increase of mutual dependencies'.[49]

This is very much the imaginary of the biosphere that underpins Rosero's work, one in which forms of life are intimately, reciprocally and multiply interwoven, and in which the wild profusion of different colours, forms and textures clearly exceeds mere strategies of survival. The vision accorded to us by *Purple Haze* is not one of precarity, the need to eke out an existence in the context of a scarcity of resources and a constant threat of environmental change. It is one of successful adaptation, drawing on the abundant resources made available through the myriad symbiotic relations that connect species together in a given ecological niche, and which help organisms respond quickly to change. *Purple Haze* demonstrates the techniques of 'collaborative survival' that Tsing explores in her study of matsutake mushrooms, in which 'cross-species coordinations' are key to riding out the hazards of environmental disturbance.[50] But 'survival' is too meagre a term to describe the flourishing coralscapes of *Purple Haze*. As Zylinska observes, Tsing 'challenges the traditional view of precarity as "an exception to how the world works" and proposes we instead accept precarity as "the condition of our time"'.[51] What new paradigms in biology and biosemiotics point to as the condition we share with other species is not precarity, however, so much as the cooperation, abundance and generosity that characterize many relationships in the natural world: the opportunities for self-transformation and coevolution that arise from close collaborative interrelations with other species.

Ruins and regeneration

This is also a major theme of another work by Rosero, a sculpture entitled *Anticipación a una ausencia (o Yasuní 2.0)* (*Anticipation of an Absence (or*

Figure 3.5 Paul Rosero Contreras, *Anticipación a una ausencia (o Yasuní 2.0)*, 2017. *Sierra Negra*, Import Projects, Berlin (photograph © Paul Rosero Contreras/Dos Islas Studio).

Yasuní 2.0), 2015).[52] To create it, he prepared a biological substrate that could be dispensed by a 3D printer, combining biodegradable plastic filament and a fungus growing in agar. This mixture was deposited in layers to generate a group of skeletal 'trees'. The resulting 'forest', crystalline and largely white, looks other-worldly, bringing to mind both a barren post-apocalyptic landscape and a fairytale kingdom made of ice (see Fig. 3.5). The muted monochrome presentation of *Anticipación* seems a far cry from the vibrant palette of *Purple Haze*; the two works are nevertheless strongly linked in their interest in forms of biological resilience and regeneration. More sober and stark in its expression, *Anticipación* demonstrates the potential of organisms to withstand even the most extreme environmental destruction.

The work was developed by Rosero as a reflection on the failure of a long-standing campaign to prevent oil extraction in the Yasuní National Park in Ecuador. The park is one of the most biodiverse places on Earth, holding multiple world records for its richness in flora and fauna; in 1989 it was designated a UNESCO biosphere reserve. But Yasuní also holds around 40 per cent of Ecuador's oil reserves. President Rafael Correa had pledged in 2007 to leave the oil untapped in exchange for compensation from the international community; in 2013, however, he declared that

the international response had been insufficient, and that drilling would commence, as it did, in 2016. The extraction continues to be widely contested by environmental activists and by the indigenous communities living in Yasuní.

In its seemingly sterile appearance, Rosero's piece acknowledges the horror of the potential loss of an extremely valuable tranche of Amazonian forest. And yet his own artificial forest is certainly alive, the delicate mushroom fronds twisting and tangling around the 'trees' to form their foliage, demonstrating the capacity of natural organisms to adapt and survive even in the most adverse environments. The fungus, lion's mane (*Hericium erinaceus*), often lives in and feeds off dead trees, digesting and decomposing the wood, and thereby breaking it down to make nutrients available to insects and other organisms. These nutrients then make their way into the soil and are reabsorbed by plants. Mycelium, the vast underground network of which mushrooms are the visible fruit, is responsible for making soil by breaking down organic and inorganic compounds, including pollutants, and even – most relevantly – the hydrocarbons in petroleum in oilfield waste pits. It also plays an important role in the maintenance of biodiversity. The mushroom thus becomes here a powerful symbol of hope in nature's capacity for renewal.

The title of Rosero's work anticipates a future in which the natural riches of Yasuní have been entirely exploited, leaving only a post-natural landscape, and yet also manages to convey a sense of hope of regeneration. It unsettles the apocalyptic logic that would have delivered images of a lost paradise or a future wasteland, creating instead a more equivocal future that neither prophesies catastrophe nor professes a mindless trust in the power of ever-advancing technology. The '2.0' is partly ironic, as it is clear that this version is in no sense an improvement on the original, but it does suggest a second chance, a way in which technology might henceforth be used to promote the flourishing of life and not just the extraction of resources. It could also be read as a recognition of an important continuity between the past management of the Yasuní and an imagined future one. As Macarena Gómez-Barris reminds us, the area is not 'a pure space of untamed wildness' but one that has maintained its ecological riches 'precisely because of the ingenuity of Indigenous seed selection, interplanting, and the meticulous cultivation and maintenance of biodiversity over a thousand years of systematic care'.[53] Scientific knowledge and technology are figured here neither as a cause of environmental catastrophe nor as a tool for its redemption; nature and culture are not opposed but tangled together in a coevolutionary process that may lead to a range of possible environmental futures.

Anticipación a una ausencia is an invitation to notice the world-makings of other species that persist despite, and in the midst of, the large-scale ecological disruption wreaked by humans. It also presents an encounter between two different kinds of project with respect to the world, which Tsing classifies as 'scalable' and 'nonscalable'. Scalable projects are those that can be expanded without altering their basic elements.[54] The artificial production of the forest evokes the logic of a plantation, which for Tsing represents 'the triumph of technical prowess over nature', as indeed modernity does more broadly.[55] The plantation, as a quintessential form of colonial production, was conceived as a scalable project; in order to maximize yields, all 'entangling claims' had to be extinguished, allowing nature to be brought under control.[56] In reality, this is never fully possible, as '[e]cological complexity is nonscalable'.[57] Tsing calls instead for 'a nonscalability theory' that would pay attention to 'the mounting pile of ruins that scalability leaves behind' and help us understand how multispecies landscapes work.[58] Rosero's mushrooms represent the crucial entanglements that plantations attempt to eradicate, to the ultimate cost of biodiversity and ecological health, but also inevitably fail in that aim. They demonstrate, as Tsing affirms, that '[m]any projects for life – both human and otherwise – take place in the ruins of scalability designs'.[59]

The failure of the Yasuní conservation initiative dealt a particularly heavy blow as it came only a few years after an extremely significant step forward in the protection of the environment in Ecuador. In 2008, it became the first country in the world to inscribe the rights of nature into law, in a series of amendments to its constitution. Drawing on indigenous perspectives on more-than-human communities, the new provisions reposition nature beyond the capitalist language of 'natural resources' for social and economic growth. As Eduardo Gudynas affirms, they recognize that nature possesses intrinsic value beyond its usefulness to humans.[60] Adopting a moral stance of protection towards threatened species and ecosystems is not enough to challenge an anthropocentric ethic: only a recognition of the rights of nature, and the very different values it embodies, may question such an ethic.[61] Acknowledging the intrinsic value of nature means recognizing the subjecthood and agency of other species, and defending their right to pursue their own 'proyectos de vida' (life projects).[62] Despite the inclusion of these significant protections, however, the new constitution has not resolved the tensions between development and conservation in Ecuador.[63] During the later years of his presidency (2007–17), Correa reversed many of the pro-conservation policies he had adopted in his first term. Far from defending

the rights of nature, he increased the exportation of raw materials within a neo-extractivist development agenda.[64] Indeed, Gómez-Barris goes so far as to suggest that in government policy, '"good living" has provided rhetorical cover for extractive ends'.[65]

Nature, culture and technology

Rosero's *Anticipación a una ausencia* does not explicitly allude to the issue of indigenous rights over the land to be drilled in the Amazon, thereby omitting reference to an important dimension of the Yasuní conflict. The disappearance of what we might identify as the political here becomes a way of emptying environmental futures of the humanist and the apocalyptic. Nevertheless, in his use of technology, Rosero avoids any attempt to evoke a natural world untouched by humans, which is the nostalgic corollary to the apocalyptic imagery of climate change. A concept of nature that is not separated from human activity is also central, Gudynas explains, to Andean perspectives on nature that informed the new Constitution in Ecuador. Far from representing the lost idyll of premodern harmony often implied in catastrophic narratives of climate change, the concept of Pachamama prevalent in Andean cultures is not one of an untouched Nature, but one that is worked and cultivated by humans in the context of relationships of reciprocity, complementarity and correspondence.[66] It is thus opposed to those Western dualisms that separate humans from non-humans, and culture or technology from nature.[67]

This understanding of the imbrication of nature and technology and the importance of relationships of reciprocity is also key to the '*política en femenino*' (feminine politics) advocated by the Mexican sociologist and activist Raquel Gutiérrez Aguilar. This is a politics organized around 'la producción y defensa de lo común, que a su vez es la garantía de la reproducción de la vida humana y no humana' (the production and defence of the common, which guarantees the reproduction of human and non-human life).[68] Gutiérrez Aguilar's understanding of the common, which derives from – but is not limited to – indigenous communitarian practices, does not distinguish between nature and technology in the way modern Western thought so often does. It refers to the 'acción colectiva de producción, apropiación y reapropiación de lo que hay y de lo que es hecho, de lo que existe y de lo que es creado, de lo que es ofrecido y generado por la propia Pachamama y, también, de lo que a partir de ello ha sido producido, construido y logrado por la articulación y el esfuerzo común de hombres y mujeres situados histórica

y geográficamente' (collective action of production, appropriation and reappropriation of what there is and what is made, of what exists and what is created, of what is offered and generated by Pachamama herself and, too, what has been produced, constructed and achieved from this through the coordination and common effort of men and women who are historically and geographically situated).[69]

Szerszynski claims that our technological framing of the climate leads us to ask 'a very narrow set of questions. "Is it changing? How fast? Are we to blame? Can we alter it?"'[70] In place of these questions, Rosero invites us to ask: What stories are left out in our narratives of climate apocalypse? What can we learn from nature's own response to environmental change? How might technology make collaboration between species more visible, and even facilitate it? Rosero's work gestures towards what climate science can teach us about renewal and resilience, not just tipping points and catastrophe; it seeks an understanding of the cyclical, adaptive and relational nature of life itself, beyond questions of (human) security and risk, survival and extinction.

Environmental futures beyond precarity

While both Fargas and Rosero engage with the science of climate change and deploy technology as a medium through which to imagine and create environmental futures beyond apocalypticism, profound differences emerge in their approaches. Fargas's works reinforce the linear conception of time that underpins narratives of climate apocalypse and redemption, while Rosero's open our perspective to the contingent, multiple temporalities of interspecies encounters; Fargas is arguably invested in maintaining the climate status quo (the one in which human populations have thrived), while Rosero entertains visions of environmental futures in which humans may be sidelined or even absent, while other species thrive. Fargas's work allows us to witness the potential resurgence of humanism from the ashes of climate apocalypticism, a humanism that (re-)creates humans as stewards of the planet, sustaining the biosphere through geoengineering feats of unprecedented dimensions. The irony that characterizes his Antarctic projects does succeed in holding a mirror to such techno-optimism, however, subjecting it to critique and returning to the public sphere discussions that are often confined to geoengineering conferences. Rosero refuses to endorse unambiguously what Szerszynski calls 'a soteriological dream of security':[71] his work does not frame environmental change as a set of challenges that can be

resolved by technological means, nor does it necessarily present a return to climate stability as essential or desirable.

In the scientific models of relationality that have informed the work of Donna Haraway, Karen Barad and Anna Tsing, Zylinska finds a possible basis for a feminist counterapocalypse. Relationality, as she states, 'challenges the de facto masculinist subject that disinterestedly looks at the world as his possession and playground'.[72] I have suggested two related frameworks through which we might extend or revise the important counterapocalyptic vision developed in the work of Tsing and Zylinska. First, if Tsing and Zylinska draw on the notion of precarity to forge connections between the environmental and the economic in world-makings eked out in the interstices of global capitalism, Weber's biosemiotic approach suggests that such connections might just as easily – and with greater biological accuracy – be forged on the basis of the forms of cooperation, generosity and abundance that are everywhere at work in complex ecosystems. These principles also underpin a growing number of theories of the commons, in which forms of continual exchange integrate humans more tightly within the more-than-human world and provide the conditions for biological life and social relations to thrive.

Second, this biosocial perspective gains much from the concept of the expanded community central to many indigenous ontologies in Latin America (and elsewhere), which is founded on biocentrism but does not draw an *a priori* distinction between nature and technology. Between the 'technicist solutions', 'technocratic promises', 'technical fixes' and various forms of 'technological escapism' that Zylinska criticizes as responses to planetary crisis,[73] there is little space for a more pluralized conception of technological practice that would include technologies that are not inimical to life or that do not posit an ontological distinction between the technologies of humans and of other organisms. In Rosero's work, technology becomes a means not only to decentre human perspectives and to derail the linear narratives of environmental catastrophe, but also to reveal and even promote the life projects of other species.

Catastrophic depictions of nature in the images and discourses of environmental apocalypse that are common in the Anthropocene lead us to misread the nature of the current crisis. Val Plumwood observes that this crisis is often identified as one of ecology, suggesting 'a crisis or failing of nature'. 'In reality,' she argues, it is 'a crisis or failing of reason and culture, a crisis of monological forms of both that are unable to adapt themselves to the earth and to the limits of other kinds of life.'[74] While their irony points to the over-reaching quest for domination over

nature that fuels geoengineered solutions, Fargas's Antarctica projects largely leave intact a belief in human reason and its eventual potential to respond, via technological means, to the climate emergency. Rosero's work, in contrast, shows us a nature that is far from failing, modelling instead ways in which we could 'adapt ourselves to the earth' and to the needs of other kinds of life in the way that Plumwood suggests. The principles of creativity, collaboration, plurality and reciprocity his projects demonstrate are central to many of the commons practices studied by Gutiérrez Aguilar and others, which offer a viable alternative to the 'dominación y explotación capitalista y neoliberal de la vida' (capitalist and neoliberal domination and exploitation of life). These paradigms allow us to envision a future that is not anti-technological but one in which we may increasingly engage with other species in finding creative and collaborative ways of promoting life of all kinds.[75]

Notes

1. Zylinska, *The End of Man*, 14–15.
2. Zylinska, *The End of Man*, 15.
3. Zylinska, *The End of Man*, 2.
4. Zylinska, *Exit Man*.
5. Tsing, *The Mushroom at the End of the World*, 20; Zylinska, *The End of Man*, 56, 59.
6. See Zylinska, *The End of Man*, 55; Tsing, *The Mushroom at the End of the World*, 20, 60, 98.
7. Marsching and Polli, 'Introduction', 11, 9–10.
8. A video of *Glaciator* in action may be viewed at https://www.youtube.com/watch?v=PlEHoYRHPQ0. Accessed 23 October 2020.
9. Zylinska, *The End of Man*, 14.
10. Desch et al., 'Arctic ice management', 120.
11. Desch et al., 'Arctic ice management', 111.
12. Desch et al., 'Arctic ice management', 111.
13. Desch et al., 'Arctic ice management', 124.
14. Klein, *This Changes Everything*, 261.
15. Klein, *This Changes Everything*, 255.
16. Randerson, *Weather as Medium*, 169.
17. Randerson, *Weather as Medium*, 158.
18. Conversation with the author, 17 April 2019.
19. Triscott, 'Curating contemporary art in the framework of the planetary commons', 377–80.
20. Andermann, *Tierras en trance*, loc. 6066.
21. Szerszynski, 'Reading and writing the weather', 20.
22. Szerszynski, 'Reading and writing the weather', 21.
23. See http://www.joaquinfargas.com/obra/sunflower-centinela-del-cambio-climatico. *Sunflower* was installed in Ushuaia in 2007 as part of the Bienal del Fin del Mundo (Biennial of the End of the World). Accessed 23 October 2020.
24. Szerszynski, 'Reading and writing the weather', 21.
25. Szerszynski, 'Reading and writing the weather', 22.
26. Conversation with the author, 17 April 2019.
27. Conversation with the author, 17 April 2019.
28. See Joaquín Fargas, 'Proyecto Utopía' at https://www.joaquinfargas.com/wp-content/uploads/2016/02/proyectoutopiaespanol.pdf. Accessed 24 October 2020.
29. Zylinska, *The End of Man*, 66.
30. Swyngedouw, 'Apocalypse now! Fear and doomsday pleasures', 15.

31. Swyngedouw, 'Apocalypse now! Fear and doomsday pleasures', 9.
32. *Arriba* is the name given to a variety of cocoa beans native to Ecuador.
33. See https://eden-iss.net (accessed 24 October 2020). Rosero has been invited, with Barbara Imhof, to develop an artwork in response to the EDEN ISS greenhouse project; he presented a project entitled *Across Time* that would involve the artificial manufacture of stromatolites, made from biowaste material from the EDEN ISS greenhouse.
34. *Purple Haze* formed the centrepiece of Rosero's solo show, *The Origins of Color*, held at the Who I Am Gallery in Moscow between 4 November and 7 December 2018. A fragment of the video may be viewed at https://vimeo.com/306812116. Accessed 24 October 2020.
35. Colour correction would have been necessary in any case, as water has the effect of bleaching colours, particularly red; but Rosero intentionally left time before editing the video so that his memory would have faded, in order to allow space for fiction to enter what would otherwise have been documentary images. Conversation with the author, 7 February 2019.
36. Conversation with the author, 5 February 2019.
37. See, for example, Bang et al., 'Metaorganisms in extreme environments'. The research conducted by Rosero's team in 2018 has, at the time of writing, yet to be published.
38. Rosenberg and Zilber-Rosenberg, 'Microbes drive evolution of animals and plants', 5.
39. Rosenberg and Zilber-Rosenberg, 'Microbes drive evolution of animals and plants', 1.
40. Margulis and Sagan, 'Sentient symphony', 350.
41. Margulis and Sagan, 'Sentient symphony', 340–1.
42. Martínez, 'Prólogo', 15.
43. Martínez, 'Prólogo', 15.
44. Martínez, 'Prólogo', 9–11, 14–16.
45. Weber, *Enlivenment*, 23.
46. Weber, *Enlivenment*, 25–6.
47. Weber, 'The economy of wastefulness', loc. 635.
48. Weber, *Enlivenment*, 27.
49. Weber, *Enlivenment*, 27.
50. Tsing, *The Mushroom at the End of the World*, 4, 155, 156.
51. Tsing, *The Mushroom at the End of the World*, 20; Zylinska, *The End of Man*, 56.
52. The work was first exhibited in the 2015 *CalArts MFA Show*, Mercantile Centre/Cooper Design Space, Los Angeles, between 5 and 25 June 2015.
53. Gómez-Barris, *The Extractive Zone*, 20.
54. Tsing, 'On nonscalability', 505.
55. Tsing, 'On nonscalability', 513.
56. Tsing, 'On nonscalability', 513.
57. Tsing, 'On nonscalability', 509.
58. Tsing, 'On nonscalability', 506, 523.
59. Tsing, 'On nonscalability', 515.
60. Gudynas, *Derechos de la naturaleza*, 102.
61. Gudynas, *Extractivismos*, 434.
62. Gudynas, *Derechos de la naturaleza*, 55.
63. Gudynas, *Derechos de la naturaleza*, 135.
64. Toro Pérez, 'Prólogo', 18.
65. Gómez-Barris, *The Extractive Zone*, 27.
66. Gudynas, *Derechos de la naturaleza*, 146.
67. Gudynas, *Derechos de la naturaleza*, 97.
68. Gutiérrez Aguilar, *Horizontes comunitario-populares*, 85–6.
69. Gutiérrez Aguilar, *Horizontes comunitario-populares*, 75.
70. Szerszynski, 'Reading and writing the weather', 23.
71. Szerszynski, 'Reading and writing the weather', 23.
72. Zylinska, *The End of Man*, 53.
73. Zylinska, *The End of Man*, 2, 1, 51, 31.
74. Plumwood, *Environmental Culture*, 15.
75. Gutiérrez Aguilar, *Horizontes comunitario-populares*, 65.

4
Science in an ecology of knowledges

In recent years, the rationalist models of Western science have increasingly been subjected to critique in a broader questioning of modernity's abstractions and exclusions that is taking place both within and beyond global centres of scientific advance. This critique has been vigorously articulated in the work of Isabelle Stengers. She observes that the 'symbiosis' that has developed between science and industry has 'privileged disembedded knowledge and disembedding strategies abstracted from the messy complications of this world'.[1] Abstracted from reality, science has gained a greater power to intervene in it; in attempting to eradicate 'messiness', however, 'we discover that we have messed up our world'.[2] In advocating a 'slow science', Stengers calls for a kind of learning that would again create relationships with others that 'are not those of capture', reconnecting with the realms from which science separated in its quest for frictionless speed, and 'reweaving the bounds of interdependency'.[3] The first stage of this 'reweaving' might be to understand how scientific knowledge has been constructed under modernity in relation to a certain notion of 'truth' as objective and universal, as if knowledge could be abstracted from specific political and economic contexts, such as capitalism or colonialism.

A historicized understanding of the alliances between Western science, modernity, coloniality and capitalism is being developed with particular force by Latin American decolonial thinkers. It emerges from a critical engagement – sustained over many decades – with liberalism and globalization, which have reconstructed the world in alignment with the values of individualism, rationality, private property and the market.[4] In its attempt to build a single, unified world, Arturo Escobar describes globalization as 'una *ocupación mono-ontológica* del planeta' (a *mono-ontological occupation* of the planet).[5] This 'one-world' ontology, which has produced multiple social and ecological crises, is being

challenged by indigenous, peasant and Afro-descendant communities in Latin America that do not subscribe to dualist conceptions of the world that separate nature from culture, or the natural from the supernatural.[6] The rising impact of their views can be seen, Escobar affirms, in the growing visibility of battles to defend mountains, forests and other landscapes and territories that are being fought on the basis of an understanding of life that is relational and in which subjecthood is not limited to the human.[7]

The art–science projects collated in this chapter develop a critique of Western science by resituating it in relation to forms of knowledge and experience that it has excluded. In doing so, they do not reject science's claim to truth, but simply its claim to present the sole truth. Both in the constellations of the different ontologies and epistemologies they present and in their own collective practices of creation and curation, these artists explore how relational ontologies and communal frameworks may generate a critical response to the universalizing, capitalist and liberal foundations of modern science, and how they may help to reconnect science with other forms of knowledge and experience.

The challenge of representing (inter)planetary space and time beyond human perception, the major theme of the projects discussed in Chapter One, is also taken up in the artworks and performances by Lina Mazenett and David Quiroga presented in this chapter. However, some important differences separate these artistic projects from the ones explored earlier. Rather than staging the dynamics of geological and cosmic forces beyond human influence, Mazenett and Quiroga infuse the cosmos with human and spiritual significance. If colonial science is based on the Cartesian dualism that separated humans from nature, allowing the latter to be objectified, measured, commodified and traded, these works promote a very different understanding of that relationship. They find ways of bringing modern Western science into dialogue with other forms of knowledge that are often dismissed in the adherence to a certain notion of objectivity. They reposition both science and indigenous knowledge within a broader and more pluralistic constellation of different knowledge practices.

Part II of this chapter examines a series of artworks and exhibitions that focus on the theme of transgenic maize in Mexico. Maize, the most important crop grown in the country, has taken centre stage in a conflict that pits the genetically modified seeds and monocrop practices of American agrotech companies against the local seed varieties and methods of polyculture farming that have been developed over centuries by indigenous groups. While artists from the BIOS Ex

MachinA collective also experiment with transgenesis and other forms of biotechnology, they do so in ways that connect advances in genetic engineering with wider issues of biological diversity and cultural plurality, promoting debate on the privatization of knowledge and of life itself. Seeds, Donna Haraway suggests, 'are brought into being by, and carry along with themselves wherever they go, specific ways of life as well as particular sorts of dispossession and death'.[8] BIOS Ex MachinA takes a decolonial approach to examining those relations, refusing to reduce life to genetics and developing instead a situated critique of the geopolitical, cultural, ecological and social dimensions of transgenic maize in Mexico.

I. Indigenous cosmologies and cognitive justice

Projects developed by the artist duo Lina Mazenett and David Quiroga, based in Bogotá, Colombia, reflect on the material and spiritual relationships between Earth and the wider cosmos. Using natural minerals such as meteorites or rocks drawn from deep below the Earth's crust, their projects heighten our awareness of the deep time of the planet and the universe, compressed into geological and cosmic matter. The artists explain that one of the questions that has motivated them is '¿Cómo ver y experimentar el tiempo a través de la imagen?' (how to see and experience time through an image?).[9] Timothy Morton affirms: 'What we call Nature is really just solidified history that we aren't studying closely enough'.[10] In a similar way, Mazenett and Quiroga help us to glimpse the long history of cosmic collisions and geochemical transformations that are given material expression in the metals and rocks of which our planet is composed.

In exploring the connections between the terrestrial and the celestial, however, they draw not only on Western science but also on indigenous astronomy and cosmology. They create constellations that connect the material with the mythical, or complement linear conceptions of geological time with the cyclical paradigms that are more common in Amerindian cosmologies. In the context of the increasing environmental damage caused by mining in Latin America, these works point to other ways of knowing about and valuing minerals that are not tied to their market worth. I will propose that they respond to the need to create an 'ecology of knowledges', to use the term employed by Boaventura de Sousa Santos, and that they suggest possible ways of valuing indigenous knowledge beyond the exclusionary models of (neo)colonial science.

Culture, cosmic matter and the 'congealing of agency'

The deep time of planetary formation is the subject of an early work by Mazenett and Quiroga, *Visceral/Sideral* (Visceral/Sidereal, 2014).[11] The work was exhibited in three glass cases: the first contained a casting, made of pitch, of the famous meteorite found near Santa Rosa de Viterbo, Boyacá, Colombia, in 1810, while each of the other two contained half of a mould of the meteorite, made out of animal fat (see Fig. 4.1). Most meteorites are substantially older than the oldest rocks on Earth. The meteorite is thus a form of 'memoria sideral' (astral memory), its form and composition bearing witness to 'sucesos celestes' (celestial events), namely collisions between asteroids, many of which took place before the Earth was formed.[12] Unlike the Earth's rocks, which have been shaped by erosion and other forces, meteorites have remained largely unchanged since their formation. This being so, they preserve parts of the solar system's earliest history and provide clues to the formation of Earth and other planets. *Visceral/Sideral* brings together three kinds of matter

Figure 4.1 Lina Mazenett and David Quiroga, *Visceral/Sideral*, 2017. *Inframundo*, Instituto de Visión, Bogotá (photograph by Juan Camilo León Machicado).

(mineral, vegetable, animal) in a way that expresses the profound ways in which these are materially entwined over time. Although the elements of the work as exhibited are undeniably solid and immobile, they represent in their form the dynamism of the long history of cosmic matter. Karen Barad reminds us that matter is 'not a thing but a doing, a congealing of agency', forged through a 'process of ongoing intra-activity'.[13] In *Visceral/Sideral*, the meteorite has (literally) given shape both to the pitch – a substance created over millennia through the decomposition of organic matter such as plants, algae and bacteria – and to the animal fat, of much more recent extraction. Each of these is stamped with the profile of the meteorite, as an expression of how the biological matter of our day has been imprinted over millennia with the laws of extraterrestrial physics and the biochemical evolution of the Earth's crust. *Visceral/Sideral* alludes to the fact that, as Barad explains, matter is not a 'fixed essence', constituted by a series of independently existing objects; it is instead '*the materiality/materialization of phenomena*'.[14]

A series of other works by Mazenett and Quiroga deploy visual analogies to explore the material entanglement between Earth and the cosmos. In *Dodecaedro* (Dodecahedron, 2015), a two-dimensional shape that could be folded to make up a 12-sided polyhedron is created out of black pitch studded with shiny fragments of iron pyrites and quartz that glint as they catch the light. Matter pulled deep from the earth thus takes on the appearance of a starry night sky.[15] As the artists observe in their exhibition text, pitch connects us with the ancient time of its formation as well as its everyday contemporary use as tar in road surfaces. The significance of the work's title lies in the fact that for the ancient Greeks the dodecahedron symbolized the mysteries of the heavens, within the sacred geometry that structured the universe.[16] It is the structure of iron pyrites, which forms crystals shaped like dodecahedra, that is thought to have provided the inspiration for the geometrical models that underpinned early Greek cosmology.

Formal and visual analogies linking the earth to the sky and the material to the divine are also developed in *Todo el cielo es mineral* (The Entire Sky is Mineral, 2015).[17] Mazenett and Quiroga explain that the title refers to the belief held in many cultures that the sky was made of rock, a theory that seemed to be confirmed by the fall of meteorites from the dome of rock suspended above the Earth. Although this is not an account that would be credited within Western science, it is certainly the case that geologists and astronomers are paying increasing attention to the intertwining of celestial and terrestrial forces and matter. In many ways, the Earth is indeed a material reproduction of the sky, its rocks formed

from the same elements and processes as the asteroids that also circle the sun.

This broader truth about the material origins of Earth in the wider cosmos is also the theme of *Piedra de Sol* (Sun Stone, 2017).[18] The work is composed of a large piece of anthracite, the type of coal that contains the highest proportion of carbon, sourced from a mine in the Boyacá region of Colombia (see Fig. 4.2). In the accompanying exhibition text, Mazenett and Quiroga specify the rock's age as 320 million years. A projection onto the rock's lustrous dark surface takes the form of an analema, a diagram tracing the trajectory of the sun's position in the sky over the course of a year (as seen from Bogotá, in this case). The rock is thus likened in appearance to the space through which the sun moves. This visual analogy, in which a similarity (darkness) unites two things separated in space (the rock and the sky), also points to the role of the sun in the formation of the Earth. The most plausible current scientific hypothesis suggests that the Earth's rocky core was formed from the collision of heavy elements from the cloud of dust and gas that once made up the solar system and that remained after the sun formed, the sun's gravity then helping to bind these materials together. The continuing influence of the sun is also signalled in *Piedra de Sol* by the use of a solar panel to power the projector and a light box that displays an enlarged photograph of the sun. This points to a 'circuito cerrado' (closed circuit) in which the sun's energy is used to power images of the sun,[19] but also reminds us that the energy of coal – the substance of *Piedra de Sol* – is simply the energy of the sun captured via photosynthesis by plants, which have decayed over millions of years to form the organic basis of fossil fuels.

The title of the work, *Piedra de Sol*, recalls the famous carved stone that displays the astronomical knowledge developed by the Mexicas before the arrival of the Spanish. The stone depicts cycles of creation and destruction associated with the five worlds, or suns, of many Mesoamerican cultures. This cyclical and ongoing relationship between the Earth and the sun, narrated in Aztec creation myths, is given material expression in Mazenett and Quiroga's piece. The insistent entwining of cultural and material histories throughout their *oeuvre* does not allow us to separate culture from nature. Whether for the Greeks, who formed a philosophy of the heavens that was inspired by the shape of a mineral crystal, or for the indigenous peoples of the Americas, who based their understanding of the cycles of time on astronomical observations, how matter coalesces, moves and collides has continually shaped ontologies and cultural practices in the human world. These, in turn, interrupt, alter or accelerate the evolution of matter, as they do in the mining practices

Figure 4.2 Lina Mazenett and David Quiroga, *Piedra de Sol*, 2017. *Energ(ética): Arte y energía sostenible*, Monumento a Los Héroes, Bogotá (photograph by the artists).

sanctioned by some (but not all) cultures. Barad argues in a similar vein that '[p]ractices of knowing and being' are 'mutually implicated' and that '[t]he separation of epistemology from ontology is a reverberation of a metaphysics that assumes an inherent difference between human and nonhuman, subject and object, mind and body, matter and discourse'.[20] Paying attention to 'onto-epistemology', Barad proposes, is a better way to understand the entangled processes of materialization as the intra-actions between forces that may be labelled 'social', 'cultural', 'psychic', 'economic', 'natural', 'physical', 'biological', 'geopolitical' or 'geological'.[21] This attention is clearly promoted in the works of Mazenett and Quiroga.

The artists' understanding of Amazonian worldviews has been deepened through postgraduate studies based at a satellite campus of the Universidad Nacional de Colombia in Leticia, a port on the River Amazon that marks the triple frontier between Colombia, Brazil and Peru, where they were able to work with indigenous groups living in the area. Recent projects have sought to integrate Amazonian mythologies with modern industrial processes and meld together contemporary urban and rural realities. An example would be *Hombre jaguar* (Jaguar Man, 2019), in which typical protective suits used in industry were painted with jaguar spots and distributed to workers. They were collected later and exhibited, complete with the stains they had acquired. The project plays on the importance given in many indigenous American cultures to the jaguar, an animal that is omnipresent in stories and images and strongly associated with humans, often acting as a point of connection between humans and nature. In *Hombre jaguar*, representations of the jaguar are not fixed in a past mythology, but (literally) marked with everyday practices, as paint, grease and other chemical stains were added to the animal's own spots. In this way, the ancestral is shown to cohabit with the contemporary, the natural with the technological, the rural with the urban, as indeed they do in many Amazonian, Andean and Mesoamerican cultures.

Mining and mineral mythologies

One of the contemporary concerns that bring Western science and indigenous culture together in Mazenett and Quiroga's work is the destruction of habitats through mining in the Amazonian region and beyond. In *Arquitectura celeste* (Celestial Architecture, 2018), a concrete sculpture, painted ultramarine blue, is given the form of a constellation identified as a jaguar by several indigenous cultures in Mesoamerica, the Andes and the Amazon.[22] Small holes representing the major stars in

the constellation are filled with glass spheres containing liquid mercury. Here, again, Mazenett and Quiroga emphasize the specular relationship between Earth and the sky that underpins many indigenous beliefs: 'De la misma forma que en la piel del jaguar esta el cielo estrellado, también en el firmamento nocturno se halla el jaguar' (just as the starry sky is to be seen in the fur of the jaguar, so the jaguar is to be found in the night sky).[23] The sculpture is inspired by the carved stones used as astronomical instruments by pre-Hispanic societies in America, in which particular groupings of stars were reflected in holes filled with water.

The replacement of water with mercury in *Arquitectura celeste* bears a more earthly and contemporary significance, however. Mazenett and Quiroga explain that they intended to allude not only to its meaning in classical mythology – Mercury was the Roman god of trade, commerce, trickery and thieves – but also to its current use in mining in areas that are home to the jaguar, across a number of countries from Mexico to Argentina, creating a serious threat to its survival as a species in many regions.[24] Mercury is often used in small-scale, illegal gold mines to separate gold from rock or soil, and it pollutes rivers, with toxic effects on humans and wildlife. Colombia has one of the highest levels of mercury contamination in the world; a 2016 study found that 180 tonnes of mercury are dumped in the country every year.[25] A companion piece by the artists, *Río Atrato en mercurio* (River Atrato in Mercury, 2018), consists of a glass tube containing mercury that reproduces the route of an important river in Colombia.[26] Severe degradation had led, in May of the previous year, to the award of legal rights to the River Atrato by Colombia's constitutional court. A ban on the use of mercury in gold mining came into force in the country in July 2018, but enforcement will be far from straightforward.

Mazenett explained to me that many people in the indigenous communities she has worked with believe that shamans send illnesses underground; mining will disturb them and bring them to the surface again.[27] Western scientists would certainly concur that the extraction of minerals releases poisons into river systems and the atmosphere that are extremely harmful to life. If the indigenous version of events is 'unscientific' in its understanding of causality, it is arguably more effective in preventing the enormous damage to the environment produced by large-scale mining. It is also a powerful way of communicating the idea – which the West has been extremely slow to recognize – that the ruthless exploitation of nature will inevitably rebound on the health of humans. In another project that performs an explicit reversal of mineral extraction, *Reinserción en circuitos ecológicos* (Reinsertion in Ecological

Circuits, 2019), Mazenett and Quiroga coated cassava leaves with gold leaf (an inert, non-toxic substance). These were carried by leaf-cutter ants underground to their nests, completing a cycle by returning the gold to the ground from which it had been mined.[28] *Sun Disc* (2019) takes up the theme of gold mining by explicitly opposing its extraction for economic profit with its veneration as a symbol of the divine. The engraving on one side of the gold-plated disc shows an azimuthal map projection, perforated to indicate the main sites of gold mines across the world. On the reverse side, the perforations take on the appearance of stars in a star chart, reminding us that all the gold found on Earth comes from stars.[29]

An ecology of knowledges

The theme of cosmic interconnection that traverses the work of Mazenett and Quiroga allows them to recognize, and to promote, what Boaventura de Sousa Santos calls an 'ecology of knowledges'. In the 'abyssal thinking' of Western modernity, de Sousa Santos argues, modern science has been granted a monopoly over truth, while other forms of popular, lay or indigenous knowledge are excluded and dismissed as 'beliefs, opinions, intuitions, and subjective understandings'.[30] An 'ecology of knowledges', on the other hand, 'lies in the idea of radical copresence'.[31] Bringing different forms of knowledge into a relationship of contemporaneity, as many works by Mazenett and Quiroga do, asserts the value of indigenous knowledge for the present, rather than relegating it to a past that has been, or will be, replaced by modern science. What is particularly effective about the challenge Mazenett and Quiroga mount to the 'abyssal thinking' de Sousa Santos describes is not that they claim that indigenous knowledge 'got there first' in its grasp of the entangled histories of our planet and the wider solar system to which it belongs, that indigenous communities knew beforehand what scientists were only later able to prove. Such a statement would only confirm the superior value of Western scientific knowledge, presenting as a matter of curiosity the idea that indigenous groups had somehow intuited these facts through other (mystical) means, or even by suggesting that they had a much more advanced understanding of geology and astronomy than had previously been realized. Instead, works such as *Arquitectura celeste* and *Sun Disc* ask us to evaluate other forms of knowledge on the basis of the different relationships they promote with other species and our material environment.

Given the exclusionary way in which Western science has set itself up as the sole arbiter of objective truth, and its wholesale dismissal of

alternative forms of knowledge – together with the grave injustices that have resulted over time from that rejection – it appears both illogical and unethical to measure indigenous knowledge against the true/false dichotomy established by the West's own rationalist epistemology. De Sousa Santos proposes instead that we measure knowledge not on the accuracy with which it *describes* the world, but on the basis of what it *does* in the world. 'For an ecology of knowledges,' de Sousa Santos contends, 'knowledge-as-intervention-in-reality is the measure of realism, not knowledge-as-a-representation-of-reality. The credibility of cognitive construction is measured by the type of intervention in the world that it affords or prevents.'[32] In other words, while modern science has made many beneficial interventions, this should not prevent us from recognizing the value of other kinds of intervention: the real-world effects that flow from different kinds of knowledge. One example de Sousa Santos gives is that of the preservation of biodiversity, made possible by indigenous knowledge, and now 'under threat because of increasing science-ridden interventions'.[33] An Amerindian emphasis on the subjectivity and agency of things, the intimate connections between the sacred and the everyday, the intensely relational nature of the universe, and the 'composite character of all life forms'[34] promotes a form of knowing that is not based on objectivity and appropriation, but on a reverence for non-humans that embraces them within a social community based on reciprocity and care.

This kind of knowledge is referenced in works such as *Semillas de estrellas* (Seeds of Stars, 2015), which directly counterposes the different relationships constructed between knowledge and nature by colonial science and indigenous cosmologies. Samples and seeds from seven different plants are displayed in a showcase, moulded out of bronze and coated in gold, using pre-Hispanic goldsmithing techniques (see Fig. 4.3).[35] Their presentation brings to mind the botanical classifications of Western science, while the species chosen are from trees that are considered sacred by different ethnic groups in Colombia. Although beautiful in their abstraction, the apparent neutrality and objectivity of the samples dissected, presented and classified appear an inadequate, reductivist response when juxtaposed with the richness of the indigenous cosmologies these native trees represent. Quiroga and Mazenett explain that the display cases become a way of preserving not only biological but also cultural diversity, as many of the indigenous cultures represented in it are now at risk of extinction.[36] Deforestation and mining have not only caused environmental harm but also taken over land inhabited by indigenous groups: this has eroded their ability to live off the land according to traditional practices.

Figure 4.3 Lina Mazenett and David Quiroga, *Semillas de estrellas*, 2015. Jardín Botánico de Bogotá José Celestino Mutis, Bogotá (photograph by the artists).

Works such as *Semillas de estrellas* and *Arquitectura celeste* demonstrate that questions of epistemology are inseparable from those of ethics. As de Sousa Santos argues, 'there is no global social justice without global cognitive justice'.[37] In their work, Quiroga and Mazenett denounce the terrible environmental damage that is the corollary of modern science's bid to control and exploit nature, while putting into circulation alternative ways, inspired by indigenous cosmologies, of understanding the value of minerals and of perceiving the broader relationship between humans and nature. The political, ethical and ecological urgency of this decolonial approach to knowledge is also brought sharply into focus in the work of Arte+Ciencia and BIOS Ex MachinA, explored below.

II. Transgenic maize: between the *milpa* and the monoculture

In the anteroom, warnings about toxicity and contamination are delivered by white-coated assistants, who hand out protective blue masks and surgical gloves. Only one person at a time may enter the next

room, a darkened space illuminated by ultraviolet strip lights. It must be crossed barefoot through shallow water, with a sense of insecurity and vulnerability deepening as the body is exposed. A sinister music, composed of clusters of deadened clinking notes, accompanies the route to a central aperture in the low ceiling. Within the aperture, a view extends of *Arabidopsis agamous* seedlings, a mutant variant of a plant created in a laboratory. Mirrors create an unsettling interplay of plants, reflections and gazes, as rows of plants stretch out, multiplied to infinity.

The installation, expansively entitled *Transparencia acumulada. Arabidopsis AG:GUS (¡Sí, es azul! ¡Tiene que ser azul! Un coagulado azul de lontananza)*,[38] aimed to introduce the theme of transgenesis with reference to the dystopian, paranoid imaginary with which it is so often associated in the cultural sphere. A retro science fiction ambience was created through the use of furniture from the 1950s in the rooms adjoining the central chamber; this was juxtaposed with a live computer feed from the laboratory in which a transgenic variant of *Arabidopsis thaliana* had been developed for the exhibition (but was not legally permitted to leave the laboratory).[39] The warnings of contamination, the use of structures of confinement, and the presence of laboratory glassware and neon lights all contrasted with the innocuous appearance of the young seedlings.

Transparencia acumulada was developed by the artistic collective BIOS Ex MachinA, whose works emerge from a transdisciplinary art and research group, Arte+Ciencia, which has been operating in the Universidad Nacional Autónoma de México (UNAM) since 2011. Its members are drawn from biology, anthropology, the history of art, philosophy, mathematics, art and design.[40] *Transparencia acumulada* formed part of the first exhibition Arte+Ciencia produced in Mexico City, *Sin origen/Sin semilla* (*Without Origin/Seedless*, 2012–13), in which present-day debates about transgenic maize in Mexico emerged as an important theme.[41] This became the exclusive subject of a second version of the exhibition, entitled *Bioartefactos: Desgranar lentamente un maíz* (Bioartefacts: The Slow Dehulling of a Maize Plant) and held in Oaxaca, Mexico, the following year.[42]

If the use of transgenesis in biotechnology has been subject to fierce ethical debate, the same is true of its use in art. With respect to Eduardo Kac's *Gene(sis)* (1999), for example, which demonstrates the extent to which genetic processes are now reprogrammable, N. Katherine Hayles asks: 'Does Kac's intervention in the genetic sequences of bacteria contest the notion that humans have dominion or

reinforce it? The ambiguity inheres in any artistic practice that uses the tool of the master to gain perspective on the master's house.'[43] For Carol Gigliotti, no ambiguity remains: biogenetic art arises from a worldview that 'still posits human beings as the center and rationale of all endeavors' and 'sees all of nature as available for human intervention'.[44] This is too simplistic an approach that does not take into account how the genetic manipulation of life in art may be interrogated through its framing within an exhibition that addresses a wide range of associated social and cultural issues. I will suggest that the development of a transgenic plant by BIOS Ex MachinA, when viewed in the context of its exhibitions, goes a long way to counterbalance a view of life as solely determined by genetic codes.

One of the effects of *Transparencia acumulada* was to draw attention to the 'discurso doble de la bioseguridad' (the double discourse of biosecurity) at work in the field of genetically engineered organisms, whereby the transgenic *Arabidopsis* is strictly confined to the laboratory, while transgenic maize seeds circulate with considerably less restraint around Mexican territory.[45] The wider exhibitions made clear that it is not the existence of genetically modified organisms that we should fear, but the unsustainable logic that lies behind many advances in genetic engineering, which pursue high yields and commercial profit at the expense of local communities and ecosystems. As part of their preparation for the work of curation, the Arte+Ciencia group studied previous projects on the theme of cross-contamination that have emerged from the US, such as *Free Range Grain* (developed by Critical Art Ensemble with Beatriz da Costa and Shyh-shiun Shyu, 2003), in which a portable lab offered to test foods for genetically modified organisms, and Claire Pentecost's *Greetings from the Cornbelts* (2012), a series of postcards documenting the spread of transgenic maize from the Midwest to rural communities in Mexico. In contrast to both of these works, however, Arte+Ciencia opted to place the issue of cross-contamination in the context of much broader conflicts: first, between the contemporary practices of industrial agriculture and traditional forms of polyculture as a more sustainable method of farming, and second, between the privatization of life for commercial gain and a commons-based approach to cultivating crops and sharing knowledge. They sought to demonstrate the extent to which, in the words of the Indian scholar and activist Vandana Shiva, 'uniformity and diversity are not just patterns of land use, they are ways of thinking and ways of living'.[46]

Genetic engineering in agriculture and in art

The primary crop and main food staple in Mexico, maize also plays a foundational role in social and cultural life, stretching back to indigenous creation stories. In more recent years, it has become the subject of widespread activism against the introduction of genetically modified varieties and particularly the risks of cross-pollination. Transgenic maize has been found to have contaminated native varieties in many areas of the country, despite the fact that only limited grants were issued in 2009 for the growth of genetically modified (GM) maize for research purposes. In 2013, the Mexican government placed a complete ban on the planting of GM corn in the country, obliging Monsanto and other American agrochemical and agricultural biotechnology companies to halt all pilot projects. Monsanto, now owned by Bayer, continues to challenge the ban in a court battle that has lasted for many years.

Contemporary varieties of maize in Mexico are the result of centuries of selection and domestication, a history that is emphasized in the exhibition text for *Sin origen/Sin semilla*, in which maize is described as 'la más grande proeza de ingenio y creatividad de los grupos étnicos de Mesoamérica' (the greatest feat of ingenuity and creativity accomplished by Mesoamerican ethnic groups).[47] There is thus no attempt here to stage the conflict as one between the synthetic and the natural. Indeed, the Oaxaca exhibition text presents maize as a 'bio-artefact', that is, 'algo vivo modificado artificialmente según deseos y necesidades humanas' (something living that is artificially modified according to human needs and desires). An understanding of maize as a 'bio-artefact', together with its significance across many spheres of experience, are particularly prominent themes in the video installation *Polinización cruzada* (*Cross-Pollination*, 2012), produced by BIOS Ex MachinA for the exhibitions. Right from the start, it is made clear that there is no state of pure nature to which a return would be possible (or desirable) for maize, given its history of selective breeding since ancient times. A key contrast is drawn, however, between the indigenous engineering of maize – which increased its diversity so that it could be planted in many different environments, including highlands as well as lowlands – and the tactics of contemporary genetic modification, which result in homogenized crops, decreased diversity, and therefore a greater vulnerability to disease or climate change.

The three-channel video switches repeatedly between different camera angles on the interviewees and sets colour sequences alongside black-and-white ones, its aesthetic diversity and dissonances signalling

broader controversies at work. Talking heads are placed alongside images of maize fields, science labs and indigenous protest groups, anchoring the debate within the realities of the countryside as well as spaces of scientific experimentation. The interviewees, including biotech engineers, researchers, artists and activists, are left unnamed on the film; this has the effect of centring our attention on the views they express rather than their institutional affiliations, allowing their arguments to circulate, coincide and conflict more freely. The shots of interviewees are sometimes destabilized through the deliberate use of interference effects or unsteady camerawork. This visual 'noise' symbolically complicates the transmission of ideas within the debate and lends a home-grown look to the film that is entirely in keeping with its subject.

While some interviewees raise questions of biosecurity and 'una contaminación que no tiene retorno' (a contamination from which there is no return), others suggest that transgenic maize is really just an acceleration of the evolutionary process or emphasize the importance of high yields to feed a growing population. The video presents a diversity of views with the aim of opening up debate; in fact, the exhibition was criticized for not openly condemning transgenic maize in the way that other artists and activists would have expected.[48] But the inclusion of plural, dissenting voices expresses a crucial understanding that the genetic manipulation of maize is as much a political and a cultural phenomenon as a biotechnological one.

T. J. Demos contrasts the vision of emancipation developed in Shiva's work with that of Haraway, condemning what he sees in the latter as a philosophical commitment to hybrid ontologies that may – even unwittingly – endorse the logic of commercial biogenetics.[49] He rejects the enthusiasm for transgenic experimentation apparently expressed in Haraway's acknowledgement that she finds herself 'especially drawn by such engaging new beings as the tomato with a gene from a cold-sea-bottom-living flounder'.[50] Haraway readily concedes, however, that her curiosity should not distract attention from her main objective: that of reinserting the political into questions that seem merely technical, such as the potential risk to human health posed by GM foods.[51] Driving a wedge between the political and the technical is, she affirms, 'a central function of narratives of the Scientific Revolution and progress'. Challenging this, Haraway's own stated goal is precisely 'to help put the boundary between the technical and the political back into permanent question as part of the obligation of building situated knowledges inside the materialized narrative fields of technoscience'. In the case of transgenic food, she insists that it is vital to explore the implications for '[h]unger, well-being,

and many kinds of self-determination' that are at stake in the clash between large commercial interests and other agricultural ways of life.[52]

The position adopted by BIOS Ex MachinA is closely aligned to Haraway's in this respect. The collective does not take a philosophical stance against the mixing of 'pure' entities, and indeed expresses its own curiosity about the possibilities of genetic engineering in developing a new strain of *Arabidopsis* for *Transparencia acumulada*. Its primary objective is to return to public and political debate a question that has often been confined to the technical, scientific sphere, and to insist on the social and cultural dimensions of conflicts over the ownership and cultivation of seeds. Dominique Lestel argues that objections to new biotechnologies are really political rather than ethical or metaphysical. Pointing out that the manipulation of life is in any case inherent in nature, she affirms that '[t]he question is not whether we should manipulate living organisms, but who is authorized to do so, and under what democratically controlled conditions'.[53] The existence of genetically modified organisms, which predate human presence on the Earth by millions of years, 'is less problematic than the privatization of living organisms, accomplished by means of patents owned by a select number of multinational companies'.[54] This is very much the emphasis of Arte+Ciencia's exhibitions, which do not question the ethics of transgenesis per se, but the geopolitical inequalities that allow the biological and cultural diversity of some regions to be destroyed or sold off for the benefit of others.

Polyculture and the commons

Activists' opposition to transgenic maize in Mexico is motivated by an interest not only in protecting the thousands of native varieties that grow in the country, but also in defending local agricultural practices, which are much less harmful to the environment than the intensive monocultures for which transgenic crops are being developed. The sociologist Armando Bartra states that 'los mesoamericanos no sembramos maíz, hacemos milpa, con toda la diversidad entrelazada que esto conlleva' (we Mesoamericans do not sow corn, we make cultivated plots, with all the intertwined diversity that entails).[55] Importantly, the *milpa* is not just a maize field, but a mixed plot that results from the ancient practice of planting other crops, such as beans and squash, alongside maize. This is a more sustainable method of farming as it maintains a greater ecological balance and helps to regenerate the soil. Traditionally, the *milpa* has been at the heart of a community, with working the land a collective

activity. Local maize varieties have largely been developed through the free exchange of seeds between farmers.

The *Sin origen/Sin semilla* and *Bioartefactos* exhibitions draw out three key oppositions in approaches to maize production. The first is between polyculture as a method of conserving biodiversity and crop resilience and the intensive monoculture approach, which may produce higher yields of a single crop but causes greater damage to ecosystems and increases the dependence of crops on pesticides. The second contrasts the free exchange of seeds to increase biodiversity and the monopolization of the seed market to increase homogenization. And the third differentiates between the free sharing of knowledge as a commons within farming communities and the patenting of genomes for private profit. The monocrop system of 'modelling the diversity of the living forest on the uniformity of the assembly line'[56] constitutes a clear case of ecocide; it also has a profound effect on food security and community practices. Bartra argues that the defence of the *milpa* as a form of polyculture is not only a struggle for sovereignty and food security; 'es también una batalla, aun más profunda y decisiva, por preservar la pluralidad cultural y la diversidad biológica, de las que depende no sólo el futuro del país sino también el futuro de la humanidad' (it is also a battle, an even deeper and more decisive one, to preserve the cultural plurality and the biological diversity on which not only the future of the country but also the future of humanity depends).[57]

A critique of monoculture logic and the patenting of life in GM crops is most clearly evident in *Milpa polímera* (Polymer Maize Field), a work created for both exhibitions by Marcela Armas and Arcángel Constantini in collaboration with other BIOS Ex MachinA members. A miniature tractor was designed to circle slowly on a pivot, dropping seeds at intervals onto the soil below (see Fig. 4.4).[58] These seeds will never grow because they are artificial, composed of a thermoplastic biopolymer deposited by the 3D printer carried on the tractor. The tight circles repeated endlessly by the tractor, reploughing the same grooves in the earth, underline the notions of sterility, absurdity and entrapment in an industrial agricultural process from which there is no escape. The insistent pitch patterns of the 3D printer and the whirr of the tractor's motor add to the artificiality of the piece. Its robotized repetitiveness echoes Shiva's understanding of how the spread of dominant Western scientific knowledge has brought about the 'exclusive and undemocratic' erasure of ecological and cultural richness. It produces 'a monoculture of the mind' by erasing alternative local approaches, just as monocultures of

Figure 4.4 Marcela Armas and Arcángel Constantini, *Milpa polímera*, 2012. *Sin origen/Sin semilla*, Museo Universitario Arte Contemporáneo and Museo Universitario de Ciencias y Artes Roma, Mexico City (photograph by the artists).

modified crops introduced into a particular region lead to the destruction of local diversity.[59]

The polylactic acid (PLA) from which the seeds are created is made from fermented cornstarch. Most of the maize used to produce PLA is – the artists remind us in the exhibition text – genetically modified. They wished to contrast the technology of PLA production, patented for multiple industrial applications, with the technology used in their custom-built 3D printer, which is open source and has been developed collectively by coders who freely share their knowledge.[60] *Milpa polímera* thus opposes two approaches to the circulation of knowledge, one which is privatized for commercial gain, and the other which is based on a commons framework.

The spread of monocultures over the past few decades is a stark reminder of the extent to which an entire global economy has been built without reference to the operation of the ecosystems on which it depends. Enrique Leff argues that, in modernity, nature became the object of scientific knowledge and the raw material for production, but it was at the same time effectively excluded from the economic system, owing to a lack of understanding of the complex organization of

ecosystems.[61] The 'fundamental flaw' of global capitalism lies in the fact that 'the economy was built on a clear divorce from, and ignorance of, [the] natural, ecological, geophysical, and thermodynamic conditions within which it operates – that is to say, by self-destroying its conditions of sustainability'.[62] Although such knowledge is now increasingly available, commercial agriculture often continues to disregard its own conditions of sustainability. As *Milpa polímera* suggests, this condemns us to the repetition of practices that could ultimately lead to widespread homogenization and infertility.

Life beyond genetics

An important role played by a number of works in the exhibitions curated by Arte+Ciencia was to expand our appreciation of the cultural, social and aesthetic meanings of maize beyond its genetic make-up, and to contrast these with an impoverished, reductionist understanding of maize as an agricultural commodity. The sterile aesthetic of *Milpa polímera* contrasted sharply with the expressive qualities of *Desmodium máquina* (Desmodium Machine, 2012) in the first exhibition, which was redeveloped as *Zea Mays y los otros sentidos* (Zea Mays and the Other Senses, 2014) for the second. Created by the Media Lab at the Centro Multimedia in Mexico City, a laboratory for collaborative experimentation, this piece registered variations in carbon dioxide, humidity and temperature in the gallery – all affected by the presence of human visitors – by recording a plant's electrical responses. These were then traced in graphic form by a mechanical needle on a copper disc. Like many of the works in *Sin origen/Sin semilla*, it is an exercise in visualizing the invisible. It also demonstrates the extent to which plants are sensitive to human actions and their environment, converting them from laboratory specimens to sentient beings and fostering a broader understanding of plants as organisms that does not reduce them to their genetic code or their yield-producing capacity. Reversing the gaze of the spectator, the artists also intended the piece to provoke a reflection on how plants perceive us, and how we may enter an embodied relationship with them.[63]

For María Antonia González Valerio, director of the Arte+Ciencia group, art has a vital role to play in broadening debates that might initially seem to be confined to questions of scientific possibility or economic interests. *Sin origen/Sin semilla* was conceived as a way of challenging the reductionism of certain approaches in biology that break living organisms down into small units that are 'acrónicas y lineales,

estáticas y no relacionales, medibles y cuantificables' (achronic and linear, static and non-relational, measurable and quantifiable).[64] Against the mechanicist view of life as the sum of such units – such as genes, cells, organisms, crops – BIOS Ex MachinA proposes an ecological one, in which no part is separable from a complex, dynamic whole. It demonstrates how thoroughly debates over transgenic maize in Mexico transcend divisions between the social, the cultural, the economic, the ecological and the biotechnological.

In her thoroughgoing censure of gene art exhibitions in the US, Jacqueline Stevens points to 'a curious alliance of artists, curators, and biotech advocates' at work in promoting the idea that genes are the key to understanding life.[65] Even exhibitions that adopt a critical perspective on gene therapies effectively reinforce the 'gene narrative', with the result that 'the audience cannot avoid the message that, love it or hate it, theirs IS a genetic age' and that 'the enemy within us has already won'.[66] Stevens makes an exception for a handful of artists – she names Beatriz da Costa, Natalie Jeremijenko and Critical Art Ensemble – who are able to employ 'art's power to create new truths' rather than simply affirming dominant narratives or offering 'more or less obvious critiques'.[67] The works curated by Arte+Ciencia would also merit such an exception, in their refusal to reduce life to genetics and in their purposeful exploration of the geopolitical, cultural and social dimensions of new biotechnologies.

Bioart and science beyond the laboratory

Working with genetically modified seeds and plants presents a particular challenge for artists, as modified versions are visually indistinguishable from the unmodified ones: transgenetic material is normally detectable only through laboratory analysis. However, in their installation *Serán ceniza, mas tendrá sentido (ligeramente tóxico)* (2012),[68] BIOS Ex MachinA experimented with another way of making transgenesis perceptible, thus drawing attention to the invisible but very present risk of cross-pollination in Mexico. In a space arranged to look like a greenhouse, with rectangular troughs laid out in lines, they grew maize seeds gleaned from different sources in the country, which were also displayed in rows of glass jars (see Fig. 4.5). In a performance carried out every Sunday by members of the BIOS Ex MachinA collective dressed in lab coats, the plants were sprayed with glyphosate, a herbicide, of which the best-known example is Roundup. Brought to the market in the 1970s by Monsanto, glyphosate became widely used in weed control in farming, particularly after the introduction (by Monsanto) of glyphosate-resistant

Figure 4.5 BIOS Ex MachinA, *Serán ceniza, mas tendrá sentido (ligeramente tóxico)*, 2012. *Sin origen/Sin semilla*, Museo Universitario Arte Contemporáneo and Museo Universitario de Ciencias y Artes Roma, Mexico City (photograph by Minerva Hernández Trejo).

crops. This allowed farmers to spray their fields to kill weeds without destroying the crops themselves. The herbicide should therefore have killed the non-transgenic maize plants in the installation, while leaving any transgenic plants alive, as proof of cross-pollination in different regions across Mexico.

The experiment had worked when González Valerio tried it at home: the plant she sprayed with glyphosate lived on, revealing itself to have grown from a transgenic seed. The plants grown in the museum all died, however, during the course of the exhibition. This could of course have indicated that none of them were genetically modified to resist glyphosate, but it was far more likely to be the result of a lack of regular watering in the museum. In a sense, then, the experiment failed: it did not clearly demonstrate the cross-contamination of transgenic corn. This 'failure' is fully documented in the *Sin origen/Sin semilla* book, published afterwards, and provides an opportunity to reflect more deeply on the relationship between art and science. Museums are rarely able to provide the consistent conditions and daily maintenance required for many artworks that involve living organisms. Rather than placing the blame at their door, however, González Valerio points out that we should not expect a museum to be able to replicate the controlled conditions of a science laboratory. Considering the differences between the two spaces leads to a broader understanding of distinctions between science and

art. She states: 'La ciencia siempre trabajará con el tema de la vida dentro de condiciones controladas. La vida es eso que rebasa siempre esas condiciones' (science will always work with life under controlled conditions. Life is what always exceeds those conditions).[69] An art–science project may therefore deliberately expose science to the messiness of life beyond the laboratory.

This line of thought also opens up different perspectives on what we consider to be 'reliable' scientific evidence. Thinking about life as subject to multiple factors, not all of which are controllable, is not just a more effective way of approaching a multidimensional phenomenon such as transgenic maize, but also of identifying how art may contribute to a different kind of knowledge, rather than simply reproducing knowledge generated in a laboratory. Once experiments leave a controlled environment, results lose reliability; the only way of regaining reliability, Stengers suggests, would be 'to weave new relations proper to each new environment, and to welcome new objections – no longer just from colleagues, but also from those for whom this new environment is a matter of active concern'.[70] The art museum is a space in which science may find a new kind of 'reliability', in Stengers's sense, born of wider public debate, and in which acts of *discursive* cross-pollination at least may be actively encouraged.

This approach, in which biotechnologies are framed within wider debates, allows BIOS Ex MachinA to sidestep the ethical objections often made to the use of transgenic or other invasive techniques for aesthetic or other artistic aims. The purpose of the transgenic plant developed for *Sin origen/Sin semilla* was neither to provide exotic aesthetic pleasure nor to shock viewers by an encounter with the monstrous, but to encourage reflection precisely on how such techniques are already changing the world beyond the laboratory. As Ingeborg Reichle argues, by taking genetically engineered organisms out of science laboratories and into art galleries and public spaces, artists are drawing attention to the fact that 'many fields of science have long since torn down their laboratory walls and made nature the object of a global experiment'.[71]

Mixed-media curatorial practices such as those developed by Arte+Ciencia are, it could be argued, an ideal form through which to express an ecology of ideas and approaches, demonstrating how the debate stretches across technological, ideological, economic, ecological, social and cultural spheres of experience. Leff calls for an interdisciplinary approach to environmental epistemology that would give space to science, but hybridize its approaches with those of other academic disciplines and with 'los saberes populares' (popular or traditional knowledge), in order

to produce a genuine 'diálogo de saberes' (dialogue of knowledges).[72] In the *Bioartefactos* exhibition held in Oaxaca, works taking a scientific or technological approach to experimentation with seeds were placed alongside others inspired by different kinds of knowledge and experience. These included *Códice del maíz*, an exhibition of textiles collectively embroidered in a traditional manner by a local women's art collective, the Colectivo de Mujeres Artistas y el Maiz (MAMAZ), which afford a glimpse of the rich spiritual, social and cultural meanings maize has acquired in traditional communities. This approach avoids establishing a hierarchy of knowledges and practices; the expression of epistemological and cultural difference in this way reminds us that – as Leff maintains – the ecological knowledge that emerges beyond the bounds of scientific paradigms 'no es reintegrable al *logos* científico, no es internalizable' (cannot be reintegrated into the scientific *logos*, it cannot be internalized), as it may not be quantified and capitalized.[73]

In other important ways, too, artistic creation and curation may be reorganized to embody the communitarian principles rooted in traditional practices of polyculture. Many of the pieces discussed in this chapter were devised and constructed as a result of the free sharing of expertise among artists, engineers, scientists, activists and community leaders. Stengers argues that in the privatization of the commons, 'what was destroyed was practical know-how, along with collective ways of acting, thinking, feeling and living'.[74] The transdisciplinary and collaborative practices of many of the artists whose work features here are a form of resistance to such privatization.

From monocultures of the mind to plural ontologies

The works by Mazenett and Quiroga and by BIOS Ex MachinA explored in this chapter demonstrate how alternative forms of knowledge and practice have been sidelined, delegitimized and even eradicated by the consolidation and expansion of modern Western (techno)science. They contest the dualist assumptions of modern science by bringing it into contact with other ways of understanding and relating to the natural world. They demonstrate the extent to which – Escobar explains – 'environmental conflicts are often at the same time ontological conflicts – that is, conflicts over contrasting ways of existing and making worlds'.[75]

The concept of cosmopolitics as developed by Stengers is a bid 'to activate the possibility of resisting and reclaiming' a logic that has relegated other forms of knowledge to mere belief, and that dispenses with nature as nothing more than a resource. Cosmopolitics has nothing

to do with the pursuit of universal agreement or global harmony. It is the demand that decisions be taken collectively, in the presence of those who belong to worlds that will be affected, and that they be taken 'in the full and vivid awareness of their consequences' for potential victims.[76] The goal for Stengers is not to 'transcend' modernity but to 'regenerate' it in a way that enables us 'to think with other peoples and natures'.[77] In a similar fashion, works by Quiroga and Mazenett and BIOS Ex MachinA do not reject the principles and practices of modern Western science but bring them into a closer, critical relationship with other knowledges. They do so in ways that allow us at times to trace surprising convergences and at others to recognize incommensurable differences. In all cases, the new constellations configured in these art–science projects encourage us to question the epistemological basis on which modern science has embraced certain kinds of thinking to the (sometimes fanatical) exclusion of others, and to attend to the enduring forms of coloniality that underpin that exclusion.

Notes

1. Stengers, *Another Science Is Possible*, 120.
2. Stengers, *Another Science Is Possible*, 120.
3. Stengers, *Another Science Is Possible*, 81–2.
4. Escobar, *Sentipensar con la tierra*, 117.
5. Escobar, *Sentipensar con la tierra*, 139; emphasis in original.
6. Escobar, *Sentipensar con la tierra*, 134.
7. Escobar, *Sentipensar con la tierra*, 140.
8. Haraway, *Modest_Witness*, 89.
9. See http://salonesdeartistas.com/sra-2015-centro (see 'Individual: Lina Mazenett'). Accessed 23 October 2020.
10. Morton, *The Ecological Thought*, 42, loc. 570.
11. The work was first shown as part of the *Cielo Bajo Tierra* exhibition held in the Galería de Santa Fe, Bogotá, between 15 May and 19 June 2014.
12. See https://www.mazenett-quiroga.com/copy-of-fosil-sideral. Accessed 25 October 2020.
13. Barad, 'Posthumanist performativity', 822.
14. Barad, 'Posthumanist performativity', 828, 822; emphasis in original.
15. *Dodecaedro* was shown as part of the *Diálogos con la Colección* exhibition, held in the Museo de Arte Moderno de Bogotá (MAMBO), between 16 October and 4 December 2015.
16. See https://www.mazenett-quiroga.com/copy-of-dodecaedro. Accessed 25 October 2020.
17. *Todo el cielo es mineral* was shown as part of a solo exhibition entitled *Arbor Vitae*, held in the Jardín Botánico José Celestino Mutis, Bogotá, between 21 November and 8 December 2015.
18. *Piedra de Sol* was shown as part of the *Energ(ética): Arte y energía sostenible* exhibition at the Monumento a Los Héroes, Bogotá, from 23 October to 14 November 2017. See https://www.mazenett-quiroga.com/piedra-de-sol. Accessed 25 October 2020.
19. See https://www.mazenett-quiroga.com/piedra-de-sol.
20. Barad, 'Posthumanist performativity', 829.
21. Barad, 'Posthumanist performativity', 829, 810.
22. *Arquitectura celeste* was shown as part of the *Desaparece una cultura* exhibition held at the Instituto de Visión, Bogotá, between 10 February and 6 April 2018.
23. See https://www.mazenett-quiroga.com/arquitectura-celeste. Accessed 25 October 2020.
24. See https://www.mazenett-quiroga.com/arquitectura-celeste.
25. Moloney, 'Colombia mulls bill to tackle mercury contamination from illegal gold mining'.

26. *Río Atrato en mercurio* was shown as part of the *Desaparece una cultura* exhibition held at the Instituto de Visión, Bogotá, between 10 February and 6 April 2018.
27. Conversation with the author, 11 February 2019.
28. See https://www.mazenett-quiroga.com/hormigas. Accessed 25 October 2020.
29. See https://www.mazenett-quiroga.com/sun-disc. Accessed 25 October 2020.
30. De Sousa Santos, *Epistemologies of the South*, 119, 120.
31. De Sousa Santos, *Epistemologies of the South*, 191.
32. De Sousa Santos, *Epistemologies of the South*, 201.
33. De Sousa Santos, *Epistemologies of the South*, 201.
34. Santos-Granero, 'Introduction', 22.
35. *Semillas de estrellas* was shown as part of a solo exhibition entitled *Arbor Vitae*, held in the Jardín Botánico José Celestino Mutis, Bogotá, between 21 November and 8 December 2015.
36. See https://www.mazenett-quiroga.com/sp-bank-seed. Accessed 25 October 2020.
37. De Sousa Santos, *Epistemologies of the South*, 237.
38. The title may be translated as 'Acculumated transparency. Arabidopsis AG:GUS (Yes, it is blue! It must be blue! A faraway coagulated blue)'. It cites lines from José Gorostiza's poem 'Muerte sin fin', which also provided the inspiration for the use of water, mirrors and the colour blue in the piece.
39. *Arabidopsis thaliana*, generally considered to be a weed, is used widely as a model organism. It is the fruit fly of plant biology, and was the first plant genome to be sequenced (in 2000).
40. At the time of the exhibitions discussed here, the members of the BIOS Ex MachinA collective were Marcela Armas, Axel Barceló, Arcángel Constantini, Deborah Dorotinsky, María Antonia González Valerio, Marco Antonio Lara, Jorge Enrique Linares, Sebastián Lomelí, Juan Carlos Martínez, Rosaura Martínez, Lena Ortega and Luisa Valender.
41. *Sin origen/Sin semilla* was curated by María Antonia González Valerio and Liliana Quintero. The exhibition was held in Mexico City, in two venues that are part of the Universidad Nacional Autónoma de México (UNAM), between 22 November 2012 and 27 January 2013: the Museo Universitario Arte Contemporáneo (MUAC) on the central campus and the Museo Universitario de Ciencias y Artes in Colonia Roma (MUCA-Roma).
42. The exhibition was curated by María Antonia González Valerio and produced by Arte+Ciencia. It was held at the Museo de Arte Contemporáneo de Oaxaca (MACO) between 14 June and 15 September 2014.
43. Hayles, 'Who is in control here?', 86.
44. Gigliotti, 'Leonardo's choice', 29.
45. González Valerio, 'Historia a destiempo que narra la creación de hibridaciones', 97.
46. Shiva, *Monocultures of the Mind*, 6.
47. See the text for the *Sin origen/Sin semilla* exhibition, reprinted as BIOS Ex MachinA, 'Serán ceniza, mas tendrá sentido (ligeramente tóxico)', 215.
48. Conversation between María Antonia González Valerio and the author, 20 August 2019.
49. Demos, *Decolonizing Nature*, 239.
50. Haraway, *Modest_Witness*, 88.
51. Haraway, *Modest_Witness*, 89.
52. Haraway, *Modest_Witness*, 89.
53. Lestel, 'Liberating life from itself', 157.
54. Lestel, 'Liberating life from itself', 158.
55. Bartra, 'Hacer milpa', 42.
56. Shiva, *Monocultures of the Mind*, 19.
57. Bartra, 'Hacer milpa', 44–5.
58. The work may be viewed in action at https://www.youtube.com/watch?v=8me8uO1UcxA. Accessed 26 October 2020.
59. Shiva, *Monocultures of the Mind*, 60.
60. The exhibition text is reprinted in BIOS Ex MachinA, 'Milpa polímera (tractora polímera)', 211.
61. Leff, 'La ecología política en América Latina', 25.
62. Leff, 'Latin American environmental thinking', 439.
63. Conversations between the author and Minerva Hernández Trejo (12 August 2019) and Myriam Beutelspacher (19 August 2019).
64. González Valerio and Quintero, 'Sin origen/Sin semilla', 13.
65. Stevens, 'Biotech patronage and the making of homo DNA', 43.

66. Stevens, 'Biotech patronage and the making of homo DNA', 44, 56; among other examples given, Stevens cites the 'blockbuster exhibition' *Paradise Now: Picturing the genetic revolution* (2000), and *Gene(sis): Contemporary art explores human genomics* (2002), both sponsored by a number of biotech companies or major biotech investors. See Stevens, 45–7, 50–1.
67. Stevens, 'Biotech patronage and the making of homo DNA', 56.
68. The work's enigmatic title may be translated thus: 'They will be ashes, but it will make (slightly toxic) sense.'
69. Conversation with the author, 20 August 2019.
70. Stengers, *Another Science Is Possible*, 147–8.
71. Reichle, *Art in the Age of Technoscience*, 4.
72. Leff, *Discursos sustentables*, 43.
73. Leff, *Discursos sustentables*, 198–9.
74. Stengers, *Another Science Is Possible*, 80.
75. Escobar, *Pluriversal Politics*, 25.
76. Stengers, *Another Science Is Possible*, 154.
77. Stengers, *Another Science Is Possible*, 156.

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.

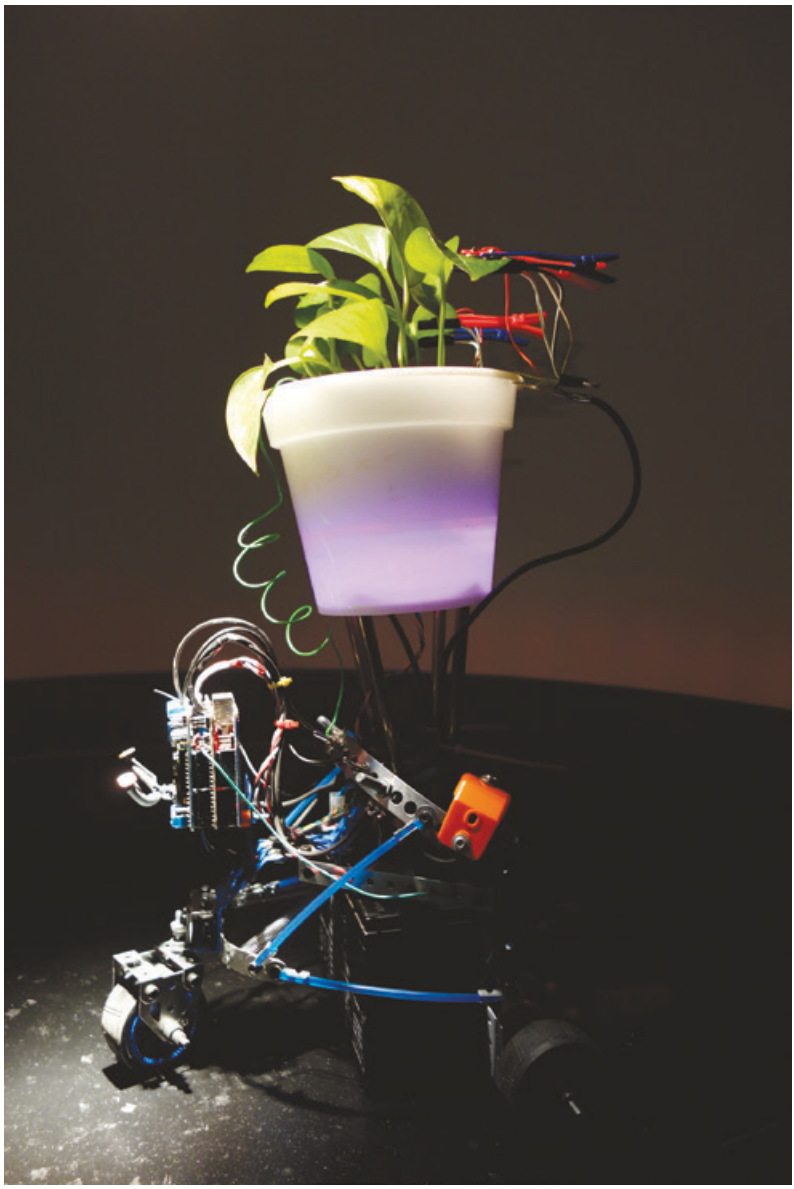

Figure 5.3 Guto Nóbrega, *BOT_anic*, 2013. *Machinarium*, Oi Futuro Ipanema, Rio de Janeiro (photograph by Steve Miller).

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,

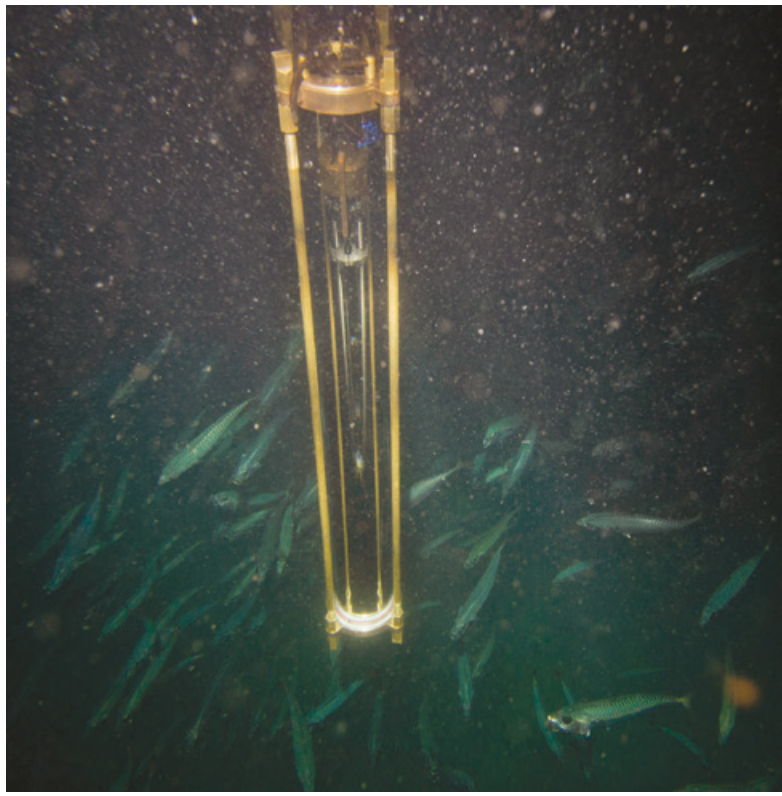

Figure 5.5 Ariel Guzik, *Nereida*, 2007. Site-specific installation/performance, Gulf of California, Mexico (photograph by Raúl González).

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

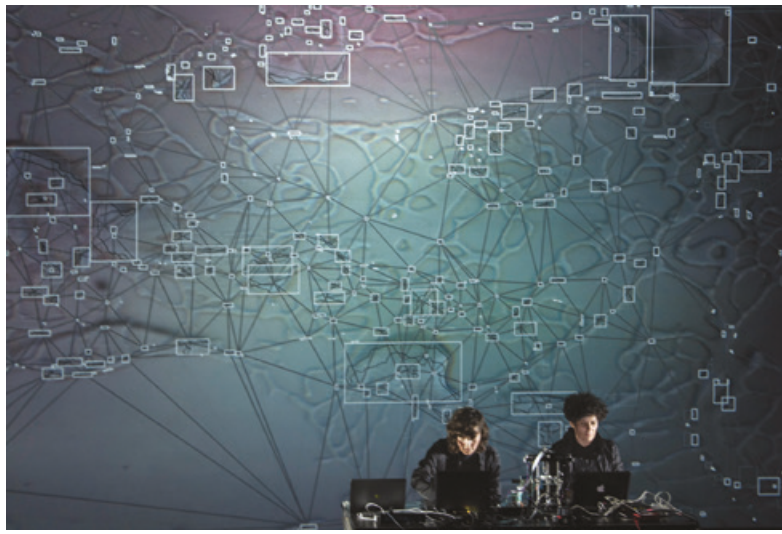

Figure 5.8 Interspecifics, *Speculative Communications*, 2018. Live performance, MUTEK Festival, Mexico City (photograph by Ella Rinaldo for MUTEK Montreal 2018).

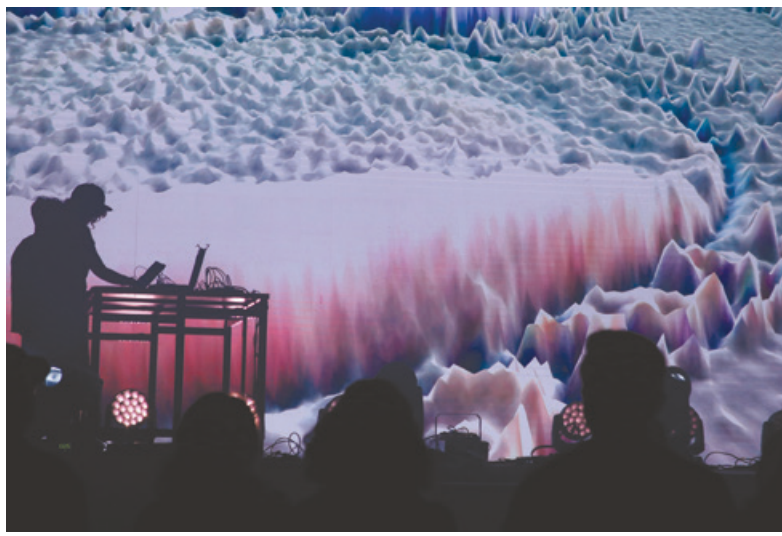

Figure 5.9 Interspecifics, *Speculative Communications*, 2018. Live performance, MUTEK Festival, Mexico City (photograph by Ollin Miranda for Interspecifics MUTEK_MX 2018).

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.

6
Revising systems art: biological time and the ethics of care

Systems art of the 1960s and 1970s brought biological, social and technological elements together to form complex assemblages. Drawing on theories of information and feedback developed in biology and cybernetics, artists and theorists such as Hans Haacke, Jack Burnham and Roy Ascott reflected on the myriad connections between cultural, natural, social, mediatic and other technological forms. Similar interests were also being developed at the time in Latin America, and particularly in Argentina, by a group of artists associated with the Centro de Arte y Comunicación (Centre of Art and Communication, CAyC). Under its Director, Jorge Glusberg, the CAyC facilitated a series of important transdisciplinary collaborations that mediated between art, science and social studies. The 'arte de sistemas' developed by members of the Centre would inspire many subsequent innovations in electronic art, new media art and environmental art in Argentina and throughout Latin America. Building on the analyses presented in the previous chapter, this chapter explores a further series of works by Latin American artists that connect organic and non-organic elements. While those earlier discussions centred on questions of non-human perception and intelligence, here I pay particular attention to how technology may be deployed to promote the health of ecosystems, in a way that fully integrates mechanical and digital devices with nutrient and energy cycles. At the same time, I will explore the important continuities and divergences that these more recent projects establish with systems art of the 1960s and 1970s.

In seminal essays on systems art, Burnham and Glusberg emphasized the shift from objects to systems and matter to energy that characterized this form of conceptualism.[1] This interest can clearly be seen in the work of Luis Fernando Benedit and Víctor Grippo, two of the most important precursors of many of the art–science projects explored

in this chapter and the book as a whole. In Grippo's *Analogía* (Analogy) series, which started in 1970, potatoes act as a battery within a simple electrical circuit. A large-scale piece created for the 1977 Bienal de São Paulo, entitled *Naturalizar al hombre, humanizar a la naturaleza – Energía vegetal* (*Naturalize Man, Humanize Nature – Vegetable Energy*), featured piles of potatoes that were heaped together on a table and linked together with electrodes, with a voltmeter showing the cumulative energy produced. Many of the works exhibited by CAyC in São Paulo that year under the title *Signos en ecosistemas artificiales* (Signs in Artificial Ecosystems) invited a semiotic interpretation, operating as a system of signs based on analogies (however unstable in some cases) of a social or political nature. Indeed, several of them were coded references to the state terror being perpetrated in Argentina at the time. In Grippo's piece, the potato acquired symbolic value as a humble, everyday object, a food staple. The tiny voltage generated by a single potato multiplied as it was connected with others; in the artist's own description of the work, this combined energy became a metaphor for the power of collective human consciousness and its transformative potential for liberation.[2] The operation of analogy and symbolism in Grippo's work marks an important point of contrast with the more recent forms of systems art explored below.

Another key antecedent to the works in this chapter is Benedit's *Phitotron* (1972), an artificial environment created to promote the growth of plants in a hydroponic system (without soil), allowing the viewer to observe the plants' self-regulating processes. Glusberg claimed in the exhibition catalogue that the predictability of the plants' responses allows them to be understood as machines or cybernetic systems, in which a change in conditions produces a change in behaviour within a feedback system.[3] Given more recent revelations about plant intelligence (see Chapter Five), we may now consider such parallels between plants and machines reductive. Crucially, however – Mara Polgovsky Ezcurra observes – in Benedit's work the notion of 'liveness', central in performance art, 'shifts from the limited sphere of the human to the expanded sphere of the non-human'.[4] Many of the projects featured in the last three chapters of this book – including this one – focus in a similar way on the performativity of other species, curated in live 'acts' staged in galleries, private homes or open habitats such as rivers and canals.

This chapter explores how more recent art–science projects in Latin America develop and revise some of the premises and practices of systems art, refitting them for a more post-anthropocentric sensibility. In the first part, I explore how works by Gilberto Esparza (Mexico), Ivan Henriques

(Brazil–Netherlands) and Ana Laura Cantera (Argentina) engage with biological time and questions of autonomy and interdependency. For many of their projects, they design and (re-)create habitats in which bacteria, fungi, plants and other life forms may thrive, giving us insight into how other species build their own worlds. In the second part, I trace the relative withdrawal of human technologies in some of the systems created by Joaquín Fargas (Argentina), Lina Espinosa (Colombia) and Marina Zerbarini (Argentina). In their exploration of art and curation as care, these works often restrict the role of human participants as interactants, pointing either to the need to protect other species from harmful human activity or to the powerful self-renewing capacities of organisms and ecosystems.

Like the systems created by Grippo, Benedit and others, these more recent projects focus our attention on the exchanges of energy and transformations that connect natural organisms with technologies within systems that are always already hybrid. In other ways, however, they allow us to infer a shift in approach. In comparison with the systems art of the 1960s and 1970s, these later projects show less interest in the creation of sign systems that operate as analogies for the workings of human society and more in the material dynamics that bind humans, other living organisms and technologies together in complex socionatural assemblages, as well as the ecological and ethical questions that emerge from such relations. In its demonstration of the multiple relations that bind social, natural and technological systems together, the earlier systems art movement often worked from cybernetic principles of the replaceability and interchangeability of elements within a system. I will show that these later works tend to problematize those relations and challenge those principles, working from a perspective that is more alert to the complexity and fragility of the symbioses that compose the (more than) natural world.

Esparza, Henriques and Cantera point to the vulnerabilities inherent in hybrid systems that result from a disjuncture between biological time and technological time. They do this by designing systems in which the latter is (unusually) made subservient to the former. Henriques and Cantera in particular draw our attention to the asymmetries of interdependence that make humans entirely reliant on plants for survival but render those plants vulnerable to the damaging effects of industrial technologies. Drawing on the work of Leonardo Boff and María Puig de la Bellacasa, I will discuss the ethics of care that emerges from the interdependence and reciprocity that bind us within more-than-human ecosystems. In particular, I will consider how Fargas, Espinosa and Zerbarini succeed in leaving behind anthropocentric illusions of control

or manipulation while exploring the greater 'obligations of care' (Puig de la Bellacasa) that rest on us as humans in our relations with other species.[5] With their deeper understanding of biological time, the coevolution of life forms and technology, and questions of care, these artists demonstrate a greater sensitivity than many of their predecessors to the ethical and environmental implications of the insertion of their own artworks in broader social, economic, technological and ecological systems.

I. Slow robotics and the art of bioremediation

Bioremediation projects and designs have been developed around the world by a number of ecological artists since the 1990s, including Mel Chin, Jan Mun, Frances Whitehead, Georg Dietzler and Alexandra Daisy Ginsberg. Many of these artists have collaborated closely with scientists working in the fields of phytoremediation and mycoremediation, which focus, respectively, on how plants and fungi may be used to detoxify contaminated environments. The development of microbial fuel cells (MFCs), in which bacteria turn chemical energy into electrical energy, has been hailed as a promising source of renewable energy, particularly since the discovery that some bacteria can transfer electrons without the need for an expensive (and often toxic) mediator. The first devices powered by MFCs were produced in 2008; they are currently being used as environmental sensors to detect contaminants in water, for example, or to treat waste water by removing pathogens.[6] One of their great benefits is that they allow energy to be recovered while processing industrial waste.

The environmental futures envisioned in artworks of bioremediation tend to be markedly utopian, especially where they express a faith in the power of new technologies to clean up and regenerate the polluted waterways and old industrial sites that are the legacy of an anthropocentric era. In the projects by Latin American artists discussed here, however, the role of technology is more often explicitly confined to that of enabling or enhancing the capacity of plants or fungi themselves to regenerate toxic environments. They encourage us to reflect on energy cycles in nature and to consider how we might concentrate our efforts on developing technologies that would partner with living organisms to minimize waste and pollution, instead of maximizing production and consumption. Their focus on the role of plants in converting and recycling energy also highlights the extent to which plants are essential for all life on the planet, converting the sun's energy into the forms required by all animals for survival.

These projects share a new interest in plant-based robotics that is becoming evident in several scientific disciplines. Hybrid designs that integrate plants or plant logic into cybernetic systems are currently being developed in several fields, including robotics, engineering and synthetic biology. Here, the potential rewards come from the self-assembling, self-replicating and self-healing capacities of organisms, which allow growth and repair to take place in ways that are not 'top-down', and enable a robot to adapt to 'unstructured' environments whose conditions are not known in advance.[7] The biomachines developed by Esparza, Henriques and Cantera explore these qualities, but their purpose is not to enhance the productivity of robotic systems by decreasing costs or enhancing machine learning. Instead, it is to heighten our awareness of the problems of contamination and habitat destruction, through the design of systems that cultivate life and restore health to ecosystems, and to demonstrate the power of living organisms to regenerate themselves, renew habitats and recolonize territories, if we allow them the minimal conditions they need to do so. In harnessing nature's own capacity for remediation, these projects chart the possibility of a different relationship between nature and technology in which the two would coevolve in a manner that would respect the life cycles and the evolutionary timescales of living organisms. In all cases, they draw attention away from the ingenuity of the human artist or the power of human technology, and towards the endlessly creative and regenerative energy at work in the symbiotic relationships of living organisms.

Together, these works call for a form of ecopolitics based on new relationships between technology and living organisms. In their work on bioart, Iliana Hernández García and her co-authors make a similar call for a politics that would be open to new forms of *bios*. They argue that interventions to defend non-human species and their environments can no longer involve a simple withdrawal from nature to limit the damage we cause, but must embrace the artificial, hybrid forms of life created through synthetic biology and other biotechnologies that may be appropriated for the purpose of bioremediation, without reducing nature to the role of fulfilling our nutritional, emotional and social needs.[8] The biocentric perspective Eduardo Gudynas advocates is also emphatically not anti-technological, but seeks to use technologies more appropriately, in ways that respect the health and integrity of ecosystems.[9] Maristella Svampa explains that 'reconocer universalmente los "derechos de la naturaleza" no supone una naturaleza virgen, sino el respeto integral por su existencia y el mantenimiento y regeneración de sus ciclos vitales, estructura, funciones y procesos evolutivos, la defensa de los sistemas

de vida' (universally recognizing the 'rights of nature' does not assume a virgin nature, but a comprehensive respect for its existence and the maintenance and regeneration of its life cycles, structure, functions and evolutionary processes, the defence of life systems).[10] In these life systems, technology may play an enabling role.

One way in which we can understand these projects as 'decolonizing', Mariela Yeregui claims, lies in their subversion of the hierarchical relationships between nature and technology that have characterized European modernity.[11] They question the investment of Western science in a certain model of progress based on the control and rationalization of nature, opening up alternative forms of knowledge and practice. I will argue that these projects map the way to a 'slow robotics' that would prioritize the logic of plant life – expressed in values of sensitivity, connectivity, symbiosis, integration, distributed agency, adaptability, resilience and regeneration – over the common commercial objectives of robotics, such as speed, power, centralized control, innovation, automation, productivity and efficiency.[12] I will also propose that these works create a 'non-participatory' art that imagines a technology that would be primarily placed at the service of other species and ecosystems rather than that of human users.

Biocentric technologies and 'slow robotics'

Many of Esparza's projects develop salvaging technologies that recycle waste and use energy from unconventional sources. The devices he creates are specifically designed for use in urban and polluted environments. His *Parásitos urbanos* (*Urban Parasites*, 2006–7) are creatures assembled from the electronic circuits and motors of discarded toys or mobile phones and other technological scraps; they move around the city by scavenging energy from overhead electrical cables. In more recent projects, he has explored bioremediation technologies, developing machines that harness the capacity of microorganisms to break down pollutants in contaminated water. Tatiana Cuevas observes that Esparza's hybrid organisms, like all artworks that have incorporated scientific advances into their own processes, 'son simultáneamente un producto y una crítica de los avances científicos y tecnológicos que les son contemporáneos' (are simultaneously a product and a critique of the scientific and technological advances of their day).[13] His work establishes a critical dialogue with current developments in robotics by exploring how technology may be adapted to fit the temporality of biological processes and to serve the needs of other species.

Esparza's projects are highly collaborative and transdisciplinary. He acknowledges the assistance of no fewer than 32 collaborators on the *Plantas nómadas* (*Nomadic Plants*, 2008–12) project, including other artists, philosophers, curators, producers, biologists, mechatronics engineers and activists.[14] Its central objective was the production of a symbiotic biomachine designed to clean water of toxins (see Fig. 6.1).[15] One of the project's broader aims was to draw attention to the social and environmental impact of river contamination. Mexico's water laws and regulations are poorly enforced; waste water from a range of industries is often dumped untreated into waterways, leaving more than half of the country's major rivers heavily polluted. The *Plantas nómadas* are autonomous robots that use the natural capacity of microbes to consume toxins, including hydrocarbons such as oil and other petroleum products. Prototypes were tested at sites in Mexico City and Guadalajara in 2009 and then in 2011, before remaining for a month later that year in the state of Guanajuato, where the notoriously polluted Río Lerma passes directly through the city of Salamanca. The project team spent many days on the riverbank, monitoring the robots and introducing them to school children, university students and residents of the area. In a video documenting the project, inhabitants explain the impact of such high levels of pollution on their health, wellbeing and livelihoods.[16] They have witnessed the river alight from the oil slicks on its surface, or silver in colour from the amassing of dead fish; they talk of chronic illnesses, the incessant smell of sulphur, and the contamination of their crops.

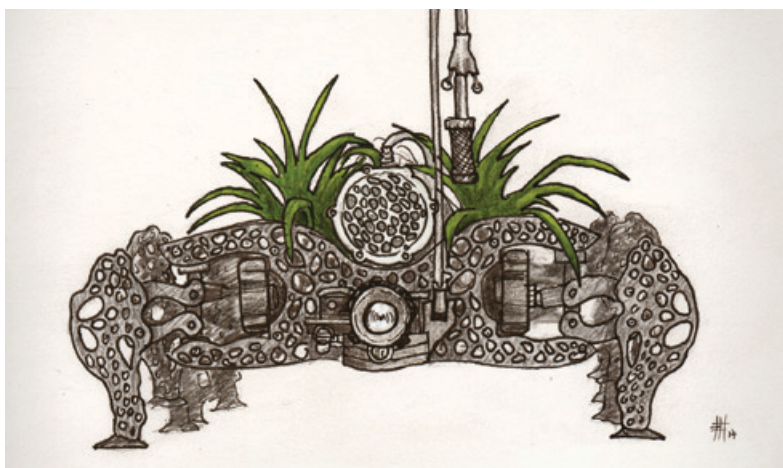

Figure 6.1 Gilberto Esparza, *Plantas nómadas*, 2008-2012 (sketch of design provided by artist).

Esparza's plantbots are able to survey their environment and to move, avoiding obstacles, in order to find polluted river water, which they suck in through a slender trunk. The water filters through a series of microbial fuel cells, where bacteria oxidize the waste, releasing electrons that are harvested to generate small electrical voltages. These are used to power the machine's movement and to provide water for the small plants that also live in it. Additional energy is provided by photovoltaic cells. As it operates in a polluted river, the plantbot creates small oases that attract insects and other organisms, rebuilding a damaged ecosystem. The more polluted the water, the better the machine works, and the longer it can continue to function without needing to move. At such times, when the energy available is greater than the machine's demands, it emits a kind of song as evidence of its wellbeing.[17] If pollution levels were to drop dramatically, it would be unable to survive. It is therefore a creature of its time, existing, Esparza explains, only within a given set of circumstances. It belongs to this specific period in the history of the world and will become obsolete, either when river pollution is a thing of the past or when we have made the planet uninhabitable for humans.[18]

The form and appearance of the *Plantas nómadas* are entirely indivisible from its function and extend the biomimetic qualities of the work. Their 'skeleton' is composed of carbon fibre from which curved shapes have been cut out, in a design inspired by the morphology of cactus stems and the bone structure of birds. The porous frame reduces the weight of the machine and thus the energy required to move it.[19] It moves slowly, supported on no fewer than 12 feet, connected to a single motor, again to save energy. Like the organisms they house – and unlike most technologies in the human world – everything about the design of the *Plantas nómadas* is focused on the sustainable use of minimal energy.

The *Plantas nómadas* have been designed as autonomous systems, with the capacity to take care of themselves, to sense and interpret changes in their environment, to navigate independently, and to be self-sufficient in their use of energy. Robot foraging has been the subject of recent research programmes that focus on biomimetic designs, modelling robots on the intelligence of living organisms to forage for the nutrients they need to sustain life.[20] In many ways, however, the *Plantas nómadas* could be seen as anti-robots. Their careful eking out of tiny voltages contrasts radically with the excessive consumption of energy that usually characterizes robots on display, in constant movement. They abandon the showmanship of speed and ingenuity for the minimal aesthetics of energy conservation. As Esparza explains, his robot does not move to

show what it can do; in fact, 'si se malgasta en hacer un show, se muere' (if it wastes its resources in putting on a show, it dies).[21] He writes:

> La planta nómada, es una especie que proviene precisamente de los procesos alienantes que está sufriendo el planeta. Es un robot de entendimiento inverso, cuyos procesos vitales no obedecen al condicionamiento de la estructura de producción de capital. Su comportamiento, su movimiento y sus tiempos, están determinados por su ciclo vital de existencia, de modo tal, que es un organismo que existe en contradicción a la aceleración del mundo que ha sido impuesta por la dinámica humana.[22]
>
> (The Nomadic Plant is a species that emerges from the very processes of alienation that the planet is suffering. It is a kind of inverted robot, whose vital processes do not respond to the conditioning of the system of capital production. Its behaviour, its movement and its temporalities are determined by the life cycle of its existence, in such a way that it is an organism that exists in contradiction to the acceleration that has been imposed on the world by human dynamics.)

In stark contrast to the pursuit in commercial robotics of ever greater feats of speed and productivity, Esparza's robot cleans just half a litre of water in 20 days and is programmed to move only when it runs short of available energy. The *Plantas nómadas* thus become a bid for a slow robotics, which – like slow food or slow fashion – would emphasize sustainability and promote deeper relationships with what we produce and consume.

Writing about the 'greenwashing discourses' of synthetic biology that advocate the genetic engineering of bacteria for more efficient bioremediation, Jens Hauser is unconvinced by the 'instrumental *biotechnoromanticism*' he finds in them, which holds out the promise that new technologies will provide the solution to the environmental damage caused by old ones.[23] By avoiding engineered organisms, Hauser suggests, Esparza's projects distance themselves from such idealism, pointing instead to the 'natural technical' capacities organisms already possess.[24] I would also propose that the *Plantas nómadas* escape the charge of instrumentalism (the technological harnessing of nature for human ends) on a further count, as their clean-up effort is not ultimately directed for human benefit. The robot is programmed only to satisfy the needs of the plants it hosts; the modest volume of water it detoxifies is the amount of clean water needed to maintain a healthy environment for the plants.[25]

A further project by Esparza, *Plantas autofotosintéticas* (*Autophotosynthetic Plants*, 2013–14), is also centred on microbial fuel cells; its aim is to increase the autonomy and self-sufficiency of the bioremediation system to the extent that it could function even without the energy absorbed from sunlight.[26] It is designed for a gallery space, with 12 slim cylinders hanging from the ceiling. These are linked via tubes to a central glass sphere, containing aquatic plants and microorganisms (see Fig. 6.2). Each cylinder is filled with waste water; when the microbial fuel cells stop producing energy, the water is clean enough to be pumped to the nucleus, to replenish the evaporated water, and new polluted water is pumped from reserve tanks to the cylinders so that energy production continues. The electricity generated by bacterial metabolism is harvested and stored, released in flashes of light that allow the plants to photosynthesize. The energy and light produced modify a sound created by custom-made synthesizers, as a kind of auditory demonstration of the pollution present in the water that is being metabolized. Again, the design of the piece is subordinated to the needs of the system. Esparza had not initially intended it to look so dramatic, and had envisaged a low continuous light; however, as the project evolved, it became evident that the quantity of microbial fuel cells used could not sustain constant light and that flashes of light were in fact assimilated better by the plants.[27]

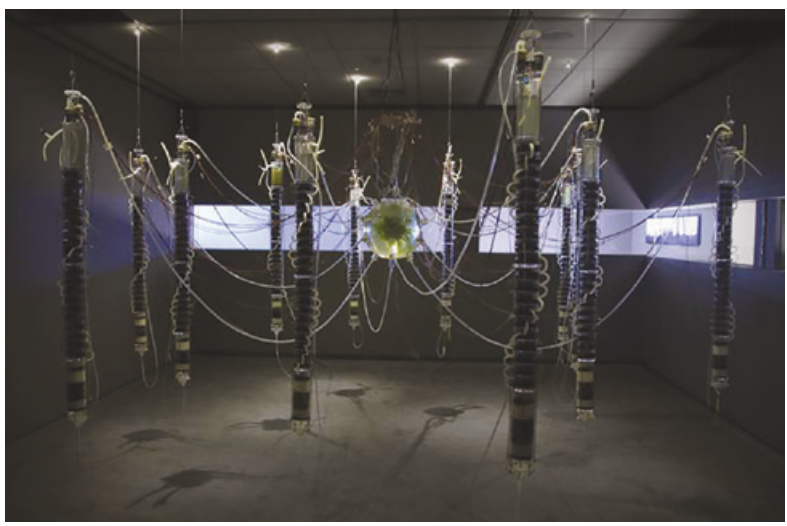

Figure 6.2 Gilberto Esparza, *Plantas autofotosintéticas*, 2015. *Cultivos*, Espacio Fundación Telefónica de Lima, Peru (photograph by the artist).

The exhibited work acquires a certain science fiction aesthetic, with its peculiar, hyperconnected structures suspended in the air as if unanchored by gravity, while the green-tinged central sphere of aquatic plants and microalgae evoke the power of an alien intelligence, controlling its sentinels and feeding vampirically on their nutrients. The defamiliarizing, futuristic effect presents ordinary plants and microorganisms in a very different light, encouraging us to appreciate their potential role in a visionary glimpse of a new world. Other elements in the installation resituate the project squarely in the here and now, however. The waste water for each of the 10 cylinders was drawn from 12 locations around the city in which the exhibition was held, and these were pinpointed on a map. The electricity produced by each of the cylinders was measured to show the relative levels of contamination at each of the sites.

Plantas nómadas and *Plantas autofotosintéticas* are evidently – and deliberately – not solutions that could be rolled out on factory lines to solve the world's environmental problems. They are not motivated by the logic of increasing productivity that has underpinned many commercial robot research and design programmes; instead, they aim to generate a greater balance in the relationship between technology and the environment, and between humans and technology. The idea, in Esparza's words, was to create 'un dispositivo de reflexión y de sensibilización acerca del agua' (a device to encourage reflection on, and raise awareness of, water).[28] In the end, he states simply, the conclusion of the project is that 'no necesitamos tecnología para resolver el tema del agua' (we don't need technology to solve the problem of water). Technology here is simply a medium and could be entirely removed, if we allowed bacteria the time they need to clean water of its pollutants.

The coevolution of nature and technology

The theme of biological time that emerges so clearly in Esparza's work is also central to a number of projects developed by Ivan Henriques. His own prototypes for autonomous biomachines are often fuelled – like Esparza's – by energy derived from microbial fuel cells. This grants them a level of autonomy, allowing them to generate the power to find food sources in order to access the energy needed to search for food again. In Henriques's work, these hybrid machines are sometimes designed for bioremediation purposes, but also, more speculatively, for the human colonization of other planets such as Mars. This departure from the

terran, far from being a humanist bid for technological transcendence, allows him to emphasize our complete reliance as a species on plant life and to speculate about a future coevolution of organic life and human-produced technology that is based on relations of greater equality.

Working with scientists and students from the Vrije Universiteit in Amsterdam and engineers from CEFET in Rio de Janeiro, Henriques developed a prototype for an autonomous robotic machine that would enter into a symbiotic system with its environment.[29] A mobile, transparent, triangular bubble with three tentacle-sensors extending outwards, *Symbiotic Machine* (2014) is designed to float alongside the algal bloom that often develops in Dutch lakes and waterways as a result of fertilizer run-off; among other damaging consequences, the algae block sunlight and starve fish of oxygen. *Symbiotic Machine* can be used to clean rivers and lakes of algae, relying entirely on solar power and energy derived from the algae themselves. It is able to move to capture sunlight and to detect and collect spirogyra algae, from which it harvests energy by hacking into the photosynthesis process. To do this, it needs to break the algae's cell membrane, which it does with a motorized grinder. With the help of photocells – which generate electricity when light falls on them – the electrons of the ground-up algae are captured and the tiny voltages generated are stored in two rechargeable AA batteries. The energy extracted is then used to power the machine to collect more algae.

Caravel (2016) is also designed to clean water, but rather than tapping into the energy produced by photosynthesis, it harvests the electricity produced by the anaerobic respiration of bacteria, using microbial fuel cell technology.[30] It operates as a colony of floating hexagon and trapezoid machines that can drift through contaminated water in need of purification (see Fig. 6.3). It contains plants that are particularly effective in filtering water and also bacteria that feed on the chemicals in polluted water, producing electricity. Like *Symbiotic Machine*, it is fully self-sustaining and uses only natural sources of energy, becoming part of the ecosystem of rivers and lakes.

As in Esparza's *Plantas nómadas*, the intervention of technology in *Caravel* and *Symbiotic Machine* merely optimizes the renewing and recycling properties of plants and algae, without disrupting natural cycles. Henriques's projects are explicitly framed by a series of reflections on temporality and coevolution, which imagine new possible forms of integration between machines and their biological environment. As he suggests,

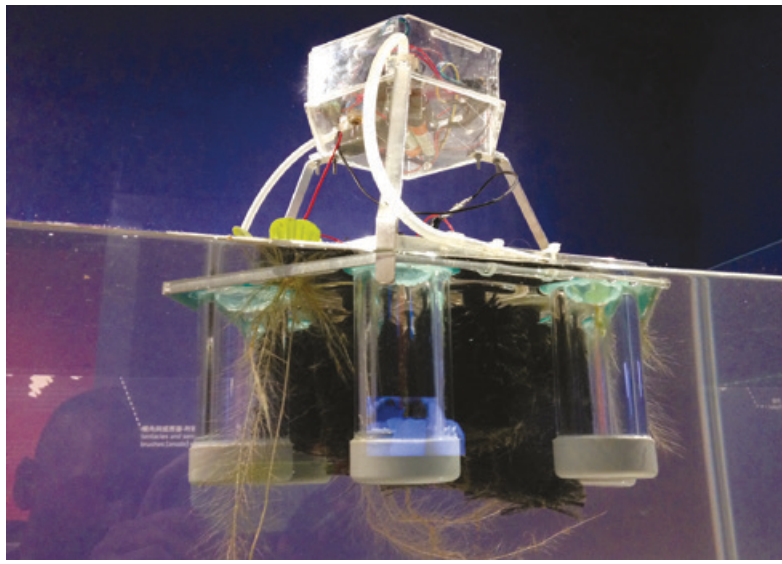

Figure 6.3 Ivan Henriques, *Caravel*, 2016. Digital Art Festival Taipei (photograph by the artist).

> We could invent machines that bring about a balance between nature and technology. Everything comes from nature, all the technologies that we have. But the imbalance comes from the fact that in order to make our designs, we rely on natural resources, and technology is moving at a faster speed than nature can accommodate. If we change our designs, we can find a technology where nature and technology move together.[31]

In searching for this new kind of coupling, in which technology is adapted to the life cycles of living organisms, the projects Henriques undertakes have a broader aim: to return to humans the choices that often seem to have been taken away from us as we are swept up in a tide of technological progress. The Chilean neurobiologist and philosopher Humberto Maturana, a key influence on Henriques's thinking, similarly refuses to indulge in the kind of technological determinism and apocalypticism that is ubiquitous in contemporary culture, which leads us to speak 'as if technology did determine our actions regardless of our desires'.[32] For Maturana,

> the expansion of biotechnology […] has not expanded our understanding of living systems as systems, nor has it expanded our understanding of ourselves as human beings. Quite the contrary.

> The expansion of biotechnology interlaced with the explicit or implicit belief in a reductionist genetic determination, as well as our immersion in a mercantile culture that penetrates all dimensions of our psychic existence, has obscured our view of ourselves as living beings of systemic identity that can become one kind of being or another according to how we live.[33]

Henriques's projects are designed to encourage us in precisely this way to understand that we can choose the directions technology will take, and that one of those possible choices would involve developing technologies to create a world in which all forms of life may successfully coevolve. His work therefore creates a kind of utopian science fiction that counters the apocalyptic visions of Hollywood science fiction films. For this reason, he prefers to present his works as finished products, with less emphasis on artistic process. The effect is most powerful, he believes, if his viewers can imagine his machines as objects that are already part of a world in existence.[34]

The futuristic, sci-fi quality of Henriques's projects reaches a pinnacle in design concepts for seed dispersion and cultivation devices that would allow plants to grow on Mars and other planets, which would be a crucial stage in preparing their atmospheres for human habitation. The research he has carried out for the *Symbiotic Machines for Space Exploration* project (*SyMSE*, 2016–17) has come to fruition in three artworks to date, including *C-DER* (2019, see Fig. 6.4).[35] Like many machines, it takes its inspiration from nature, with its wing shapes modelled on autorotating maple seeds, and it is initially fuelled by solar power. When it lands on another planet, it will start to generate oxygen via the photosynthesis of the algae, plants and lichens it carries inside its biodegradable plastic dome. Some of the plants are then harvested to provide electricity for the drone's mechanical systems; the energy stored can also be used for other terraforming purposes.

For Henriques, the human colonization of other planets is inevitable; 'the real question is, are we going to approach design and technology on other planets in the same way as we have on Earth, or are we going to do something different?'[36] His *SyMSE* project reminds us that we are entirely dependent on plant life for the oxygen we breathe (and indeed the food we eat), and that any future extraterrestrial colonization will need to involve close cooperation with plants. As the plant biologist Stefano Mancuso puts it, 'we can be sure of one thing: whatever destination – near or far – we choose as the next step of our expansion into space, we cannot go there without plants'.[37]

Figure 6.4 Ivan Henriques, *C-DER*, 2019. *Atmospheric Trilogy – Symbiotic Machines for Space Exploration, Orbit ° Space: Speculative Futures*, Bozar Institute, Brussels (photograph by the artist).

Mancuso was himself involved in a feasibility study led by the European Space Agency into the use of plantoids (robots whose design is inspired by plants) for planetary exploration.[38] The little plantoids would be powered via photovoltaic cells on their 'leaves', while their 'roots' would push down into the ground and send back comprehensive data on soil composition. Mancuso explains that their 'underlying thesis was simple: because plants are the pioneer organisms par excellence, by studying their systems of survival and replicating them in a plantoid, we could build a machine with a greater ability to survive in hostile environments'.[39] Mancuso offers many reasons for emerging technologies to mimic the plant world: plants consume very little energy, they are modular in structure with a distributed intelligence, and they behave like colonies. He concludes: 'When you want to design something robust, energetically sustainable, and adaptable to an environment of continuous change, there is nothing better on earth to use as inspiration.'[40]

Henriques's biomachines differ from Mancuso's plantoids in an important respect. They do not merely base their logic on the sensory capacities and the distributed intelligence of the plant world but are instead hybrid organisms that couple human-built technologies with

plants and bacteria. Unlike Mancuso's plantoids, Henriques's hybrid forms do not seek new forms of sustainability through the continued exploitation of fossil fuels, but through collaborations with other life forms. *Caravel* and *SyMSE* do not subscribe to a 'solutionist' agenda; they help us to understand the relationship between machines and living organisms and to imagine a future in which they might work together in a more integrated and balanced manner, for the benefit of whole ecosystems, whether on Earth or on other planets. If Promethean projects like colonizing space and terraforming Mars often conspire, as Val Plumwood maintains, 'to conceal from us our dependency on nature, to overestimate our autonomy and manipulative ability, to claim invincibility so we believe we know no limits',[41] Henriques's projects remind us precisely of our utter reliance on plants and the need to create nurturing environments for them.

This vision is not just needed for a future existence on another planet; it is urgently required to save our own. While Henriques was working on the *SyMSE* project, a dam failed on the River Doce in Brazil near the city of Mariana in Minas Gerais. Sixty million cubic metres of iron waste were released into the river in a 10-metre tsunami of toxic reddish-brown mud, causing unprecedented human and environmental damage. For a solo exhibition in Rio de Janeiro in 2016, *Marte Mariana* (*Mars Mariana*), Henriques created a parallel between the Martian terrain for which his machines were being designed and the barren, red landscapes of Mariana, which were now just as inhospitable to life and would require a similar effort of cultivation to restore to fertility (see Fig. 6.5).[42] While we are busy imagining ways of creating a habitable ecosystem from a lifeless desert on Mars, we are rapidly turning Earth's own flourishing habitats into wastelands where nothing can live.

An early precursor of the works of Esparza and Henriques featured here, Hans Haacke's *Rhine-Water Purification Plant* (1972), also reclaimed polluted water, in this case from the Rhine. The water was brought into the gallery in large glass containers and then reclaimed through a system of pumps and filters before arriving in a transparent tank, where the presence of goldfish confirmed the water's return to a healthy state in which it could support life. A comparison between *Rhine-Water Purification Plant* and works such as the *Plantas autofotosintéticas*, *Caravel* and *Symbiotic Machine* reveals a significant difference, however. Unlike Haacke's purification plant, these bioremediation machines do not focus our attention on the potential of human engineering, but on nature's own self-renewing capacities. Dependent on electricity and fuel, *Rhine-Water Purification Plant* was, as Sven Lütticken points out,

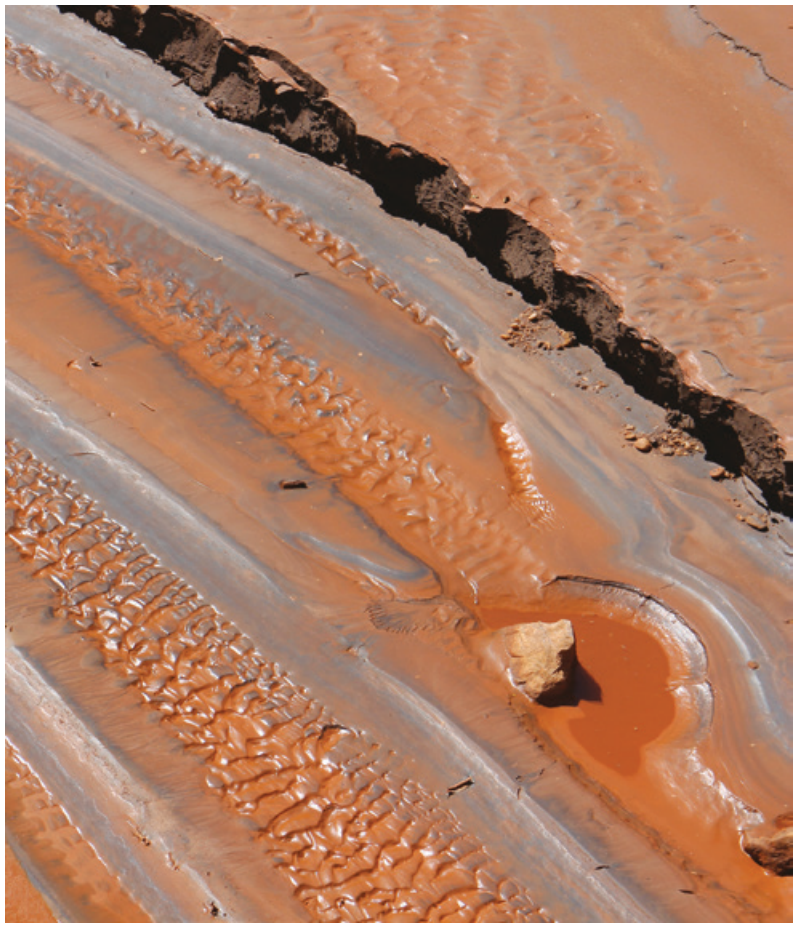

Figure 6.5 Ivan Henriques, *Marte Mariana #1* (aluminium c-print), 2016. *Relandscape/Repaisagem*, Centro Municipal de Arte Hélio Oiticica, Rio de Janeiro (photograph by the artist).

'therefore implicated, however modestly, in a political economy that destroys not only social fabrics but ecologies in order to stabilize itself'.[43] In contrast, these more recent projects are designed to be autonomous systems that do not require ongoing human intervention or any energy sources beyond natural sunlight and the electricity produced through decomposition.

T. J. Demos criticizes *Rhine-Water Purification Plant* for neglecting to involve its human viewers. Demos finds fault in 'its failure to involve the audience more directly within its feedback loop; rather, it relegated

viewers to mere observers of a system that excluded their immediate active participation'. This meant that it did not directly encourage civic involvement on the part of viewers in improving the ecological health of their communities. The work became, for Demos, a mere 'engineering demonstration' that underpinned its 'techno-scientific instrumentalism'.[44] The purpose of the works I have explored here, however, is precisely to dislodge human participants from centre stage, in order to afford us a glimpse of the powerful regenerative capabilities of plants and microorganisms. For this reason, they gesture towards a kind of non-participatory art in which humans are neither the primary actors nor the primary beneficiaries.

Recolonizations

The ephemerality and dematerializing effects of systems art, which focuses on processes that take place over time rather than finished objects, are taken to an extreme in the work of Ana Laura Cantera. What we see in Cantera's work, however, is a more genuinely ecological vision that does not simply attempt to demonstrate the heterogeneous elements that function together to form an ecosystem, but that is much more fully conscious of the ethics and environmental consequences of the artwork's own participation in that system.

Like Gabriela Munguía and Guadalupe Chávez (see Chapter Five), Ana Laura Cantera teaches on the master's course in Electronic Arts at the Universidad Nacional de Tres de Febrero in Buenos Aires, specializing in bioart. She has been closely involved with biohacking groups in the city that work across the borders of art, biology, material sciences, cybernetics and electronics. In 2017, she founded Mycocrea with the biologist Emiliano Gentile, a laboratory that creates sustainable biomaterials and design objects using everyday waste and mycelia (the fine, branching filaments of an underground fungal network).[45] Cantera has developed several projects that form interfaces between robotic devices and plants or mushrooms for the purpose of cultivating or regenerating life, and more broadly to explore a post-anthropocentric framework for the development of artificial intelligence.

Cartografías invisibles (*Invisible Cartographies*, 2018) was developed on a residency programme as part of LAM 360°, a biennial land art festival held in Mongolia.[46] Like Esparza's *Plantas nómadas* and Henriques's *Caravel*, it explores how technologies may be placed at the service of non-human species, but does so with closer (and more playful) reference to the typical anthropomorphism of robot design. With the artist and electronic

technician Demian Ferrari, Cantera designed a 3D-printed robot with belts, axles and rotating feet that were robust enough to cope with the rugged steppes and mountains of the region.[47] As well as a GPS device, the robot – called *Life Guardian* – featured a number of sensors, both on its frame and its 'head', complete with goggle eyes (see Fig. 6.6). It was controlled by a small mushroom, carried at the front in a little transparent plastic dome, which opened and closed like a clam. The mushroom dictated when and how far the robot should move. The sensors captured a range of variables, including temperature, humidity, the composition of gases in the atmosphere, and the colour of the mushroom (an indication of its health). The robot was programmed to move in search of the best conditions to ensure the mushroom's wellbeing, and to stop when it reached a place where all the variables were within preset parameters.

Cantera explained that they took the inspiration for the work from 'zombie ants', which are infected by a certain fungus that entirely takes over control of an ant's actions, hijacking its nutrients and compelling it to transport it to a place where the fungus can grow and release spores to infect other ants. In a similar way, the fungus in *Life Guardian* 'hacks into'

Figure 6.6 Ana Laura Cantera and Demian Ferrari, *Life Guardian (Invisible Cartographies)*, 2018. Site-specific installation, 5th Land Art Mongolia Biennial, Khentii Province, Mongolia (photograph by Ana Laura Cantera).

the robot's system, obliging it to carry out its own objectives. Cantera considers this work and others a way of bringing about 'un equilibrio de fuerzas' (a balance between forces)[48] that reverses the usual subjection of organic life to technological control in order to maximize resources for the human consumption of food and fuel. It allows us to rethink technology, not as a hegemonic tool, but as a potential partner in supporting and boosting the growth of living organisms in a way that responds to their own needs and interests, rather than ours.

The first electronic autonomous robots were created by the neurophysiologist and robotician William Grey Walter. For his series *Machina speculatrix* (1948–9), he designed three-wheeled electromechanical devices that looked rather like tortoises and could respond to basic environmental stimuli. Like *Machina speculatrix*, Cantera's *Life Guardian* is constantly connected to its environment by means of complex feedback systems. Its aim is not primarily to be found in 'duplicating the purposiveness of living organisms', however (as Burnham describes Grey Walter's project), but in subjugating technology to the needs of other species.[49] It speaks to the importance of finding new ways of ensuring, as Cantera puts it, 'la convivencia con la naturaleza, el equilibrio' (coexistence with nature, balance).

The post-anthropocentric impetus in Cantera's works is brought sharply into focus if we compare them with Christa Sommerer and Laurent Mignonneau's *Trans Plant* (1994).[50] As participants walked around the *Trans Plant* installation, stopped, and made gestures within a semi-circular space, their actions caused a variety of plants to grow in a virtual jungle that sprang up on the surrounding screens. While the work is clearly designed to promote engagement with the plant world and to celebrate growth and biodiversity, it pays no attention whatsoever to the ecological dynamics that underpin the real-life relationship between humans and plants. Human presence in *Trans Plant* was sufficient to stimulate plant growth: wherever participants walked, for example, grass grew. In her work *Parasitoides* (2012–13), Cantera reverses this relationship, referencing the more general truth that humans are dependent on plants for their growth and not vice versa.[51] The beating of a mechanical heart depends on the condition of plants rooted in soil and enclosed in human-shaped transparent plastic bags (see Fig. 6.7); as the plants run out of oxygen, which they need for respiration, and the temperature of the containers rises, the heart begins to beat more intensely, and the plants push their way out of the stitched seams of the plastic figure, eventually causing it to explode. An imbalance in the plant world thus results in the destruction of the human figures. Cantera

Figure 6.7 Ana Laura Cantera, *Parasitoides*, 2012. Fase 4 Encuentro de arte y tecnología – *Post ecología: Hacia una naturaleza y una cultura sustentable*. Centro Cultural Recoleta, Buenos Aires (photograph by the artist).

problematizes the simplistic and anthropocentric understanding of the relationship between human agency and plant growth that is suggested in Sommerer and Mignonneau's piece.

Cantera created *Flujos en retorno* (Returning Flows, 2013) as a site-specific work to illustrate cycles of energy in nature, allowing us to see the activity of bacteria in generating electricity as they break down matter in soil.[52] She assembled microbial fuel cells in the form of bricks made of mud, organic waste and biodegradable plastic (see Fig. 6.8). As time passed, bacteria present in the soil metabolized the organic matter, transferring electrons to one of the electrodes attached to the brick. An Archimedean screw pumped water to the bricks from the river nearby, allowing the electrical circuit to be completed, but also contributing to the proliferation of the bacteria, along with fungi, lichen and other kinds of vegetation, which in turn caused the disintegration of the bricks and the eventual erasure of the work. The amount of electricity generated by each brick was tiny, but together they produced sufficient energy to power the Archimedean screw, thus creating an autonomous, self-maintaining system.

Figure 6.8 Ana Laura Cantera, *Flujos en retorno*, 2013. Site-specific installation, Visconde de Mauá, Brazil (photograph by the artist).

The work introduces viewers to the potential for bioremediation and alternative energy sources in a natural process that goes on everywhere around us. There is an important difference, however, between *Flujos en retorno* and the use of microbial fuel cells in environmental projects or in the robots designed by Esparza and Henriques discussed above. Cantera's work was deliberately designed not to last, as the piece's feedback mechanisms lock it into an auto-destructive cycle. The greater the voltage generated by the bricks, the more frequent the turns of the Archimedean screw pumping the water up to them; the more water the bricks received, the greater the production of electricity and the greater the proliferation of bacteria and their decomposing activity.[53] Over a period of weeks, the bricks returned to their natural state, and the system became reintegrated with its environment.[54]

Symbolically, the human-engineered element of the piece only speeded up the processes of decomposition and disintegration inherent in nature, drawing attention to them as they gradually overtook and eliminated human efforts to measure and harness the power of nature. As Cantera explains, 'La transformación es entonces protagonista del proyecto' (transformation is therefore the protagonist of the project):[55] it is a transformation wrought by nature that human technology can only

accelerate. *Flujos en retorno* points to microbial activity as a fundamental process that is constitutive of life, which exceeds human control and has no need of humans. Cantera writes:

> Las bacterias, hongos y microorganismos que conviven a diario con nosotros, son sistemas relacionales organizados, autónomos y autosuficientes. Nos constituyen y a su vez nos prescinden. Evolucionan, mutan, nos consumen y hasta pueden matarnos. Sin embargo, no los vemos: actúan de forma independiente y son sumamente fundamentales para la salvaguarda de la biosfera.[56]
>
> (The bacteria, fungi and microorganisms that coexist with us every day are organized, autonomous and self-sufficient relational systems. They constitute us, but they do not need us. They evolve, they mutate, they consume us, and they can even kill us. But we do not see them: they act independently and are absolutely fundamental to the protection of the biosphere.)

A work like *Caravel* has – at least in principle – a practical purpose, that of cleaning waterways of pollutants; the artistic value of the project lies for the main part in its speculative, utopian qualities. *Flujos en retorno* is designed expressly to disintegrate, serving no specific purpose other than to demonstrate the power of energy cycles in nature, to which human engineering both materially and symbolically succumbs. Yeregui observes that many technological works of art claim to deploy dynamics of the non-linear and of uncertainty, but everything is ultimately subjected to 'una lógica de funcionamiento que somete a las formas y a los lenguajes a un conglomerado asible' (an operating logic that subjects forms and languages to a conglomerate that is easily grasped), producing a kind of verticality in which technology always restores order.[57] In contrast, Cantera's work allows space for the unpredictable transformations of living systems, 'escapando a la dictadura de una simulación perfectamente ordenada y pergeñada' (escaping from the dictatorship of a perfectly ordered and plotted simulation).[58]

Cantera's DIY approach, her interest in energy cycles and her use of natural organisms within ephemeral systems are just some of the points of contact between her work and that of Víctor Grippo in the 1970s. Alicia Chillida observes that, in its use of humble materials and basic tools, Grippo's work searched for 'soluciones artesanales, no industriales' (handcrafted solutions, rather than industrial ones) to create 'una *tecnología de la pobreza*' (a *technology of poverty*), emerging as an alternative to – or in the absence of – First-World technologies.[59] The potatoes

in his *Analogías* series degraded over time, needing regular replacement as they perished, their energy gradually used up. It is here that we may appreciate how the design of Cantera's *Flujos en retorno* differs from Grippo's systems. First, Cantera's work is not an analogy for something else, such as political commitment or a collective consciousness, in human society; instead, it deploys technology to make visible the material transformations that maintain ecological equilibrium, on which humans also depend. Second, while Grippo's potatoes simply decay and are removed, in *Flujos en retorno* the energy cycle is completed: through decomposition, energy and nutrients are returned to the soil, ready to be taken up by other organisms.

Esparza, Henriques and Cantera thus sketch out a possible future for technology that is not (only) tied to human interests, but that cooperates with the life cycles and behaviour of other organisms. Their engagement with biological time, which also characterizes the work of Guto Nóbrega and other artists explored in Chapter Five, also points away from a kind of art–science that is committed to the instant and immediate visual appeal of the spectacle. Nóbrega suggests that 'é necessário desenvolver uma cultura de descondicionamento sobre o excesso, a imediaticidade que vimos vivendo nas últimas décadas' (it is necessary to develop a culture of deconditioning towards the excess and the immediacy that we have been living in recent decades), a task that would involve shifting our attention from the acceleration that marks the contemporary world and towards the flows of life in which we all participate.[60] In designing the works explored here, Esparza, Henriques and Cantera are less attracted by the lure of inventing the new, and more interested in recycling and repurposing what already exists. This demonstrates the extent to which they understand their work as always already embedded within natural-technical ecosystems that are bound together through relations of interdependence. It is this attention to interdependence and reciprocity within a consciously ethical and ecological framework that marks a shift in emphasis here from the systems art of the 1960s and 1970s.

II. Curation and care

Other recent works of systems art produced by Latin American artists limit to a greater degree the role of mediating technologies and draw even more attention to the self-sufficiency of the biological processes that create and maintain natural ecosystems. At the same time, they charge humans with a unique ethical responsibility for the care and cultivation

of life. The rather paradoxical version of human exceptionalism that emerges in works by Zerbarini, Fargas and Espinosa exposes points of tension between critical posthumanism – which tends to accord more agency to non-human actors – and environmentalism, which often lends greater importance to human action. My discussions here will be guided by the work of two scholars who have theorized care as an ethical practice with regard to the environment, but whose perspectives have not yet been brought into dialogue, perhaps because they hail from quite different disciplinary backgrounds. The Spanish-Belgian researcher María Puig de la Bellacasa works at the intersection of feminist theory, science and technology studies, and the environmental humanities, while the Brazilian philosopher Leonardo Boff, one of the founders of liberation theology, is an authoritative voice on questions of social and environmental justice in Latin America.

Puig de la Bellacasa argues for an expansion of care – which has been central to feminism's concern with 'devalued agencies and exclusions' – to include more-than-human worlds. She starts from the widely cited definition of care given by Joan Tronto and Bernice Fischer, as '*a species activity that includes everything we do to maintain, contain, and repair our "world" so that we can live in it as well as possible*. That world includes our bodies, ourselves, and our environment, all of which we seek to interweave in a complex, life-sustaining web.'[61] She proposes that we broaden this definition to include not just everything 'we do' to care for 'our' world but everything that 'is done' to care for 'the world', as other species also care, and the world is not only ours. This care should be given so that 'all' – humans and non-humans – can live in the world as well as possible.[62] What is important, she claims, is the interweaving of living things 'that holds together worlds as we know them, that allows their perpetuation and renewal'.[63] Rethinking care in this way helps us to avoid positioning other forms of life as objects of our paternalistic protection, while understanding our own obligations towards them.

For Boff, whose diverse sources include not only Christianity and other religions but the science of evolution and complexity theory, care is not only a practice but also an ontological category, a form of being in the world. The essence of being human is to be found in care, Boff affirms; care is not merely an individual act or one virtue among others, but a mode-of-being-in-the-world on which all relations are founded:

> Significa una forma de ex-istir y de co-existir, de estar presente, de navegar por la realidad y de relacionarse con todas las cosas del mundo. En esa co-existencia y con-vivencia, en esa navegación y en

> ese juego de relaciones, el ser humano va construyendo su propio ser, su auto-conciencia y su propia identidad.[64]
>
> (It means a form of existing and coexisting, of being present, of navigating reality and relating to all the things of the world. In that coexisting and living together, in that navigation and interplay of relations, humans construct their own being, their self-awareness and their own identity.)

Within a relationship of cooperation and reciprocity with nature, Boff argues that humans do bear the greater responsibility for stewardship; he calls for 'una ética del cuidado' (an ethics of care) that would extend to the other species that share our ecological niche, and to the planet as a whole, as well as to the poor and the disadvantaged.[65]

The art of hatching chicks

The Argentine artist Marina Zerbarini, more widely known for her work in electronic art, turned her hand to incubating chicks in a project that sets out the conflict between capitalist modes of production and values of care. It also challenges certain paradigms borrowed from cybernetics that underpinned systems art involving living organisms (such as the concept of interchangeability and replaceability) and the widespread perception of these works – widely repeated by artists and critics in the 1960s and 1970s – as being somehow free of cultural meanings.

Síntesis simbiótica entre un ser vivo y una máquina (*Symbiotic Synthesis Between a Living Being and a Machine*, 2010–13) comprises an artificial incubation system for chicks, in which temperature, humidity and ventilation are carefully controlled over a period of 21 days to permit the chicks to grow and hatch.[66] In the face of the apocalyptic view of machines held by many, Zerbarini explains, she wanted to create an 'alternative perspective' and to show how technology may be used to nurture and protect. Her incubator provides a care that is deliberately small-scale, high-quality, and designed for the greatest wellbeing of the chicks, contrasting with the commercial chicken industry, which is focused on high quantities and economies of scale. These contrasts are clearly brought out in the video documenting the work.[67]

Zerbarini's piece bears similarities to *Chickens Hatching* (1969), one of the first works for which Haacke constructed a system involving live organisms. Both works construct a system of incubators used to hatch chickens from eggs. In *Chickens Hatching*, Haacke intended to exploit the

contradictions that would emerge from the framing within a museum of a 'real-time' system that is 'totally immune' to the additional (cultural) meanings invested in it by that framing.[68] In seeking to contrast the 'apolitical' nature of biological systems with the cultural and ideological determination of human social systems, however,[69] Haacke ignored the extent to which the control of biological systems is deeply entrenched in the broader dynamics of factory production. To Haacke, 'The chickens in the museum, naturally, are still the same kind of chickens that would also have been born from these eggs on a chicken farm; and if they are sent to a farm at the end of the exhibition, they are indistinguishable from all other chickens there.'[70] Zerbarini's work, in contrast, distinguishes precisely between these kinds of chicken. Haacke aimed to create a system in which the viewer was 'relegated to the role of witness to a process that would evolve without him';[71] Zerbarini's system highlights the role of the artist as carer, and, by extension, the duty of care that falls on all designers and operators of systems for the artificial cultivation and germination of life.

Síntesis simbiótica is based on a relational ethics of care that responds to the vulnerability or dependency of other beings. An ethics of care differs from a rights-based approach, such as the rights of nature now enshrined in the constitutions of Ecuador and Bolivia. Care emerges here as a value, but also, importantly, as a practice, something that is repeated with attention to the needs of the other. The ethical and practical dimensions of care are heightened by the development of the work within the domestic space of the artist's home, together with the honest account given in the video and website documentation of the several failures experienced in hatching the chicks, until the correct conditions were devised. In the context of the commercial production of eggs, where technologies are often deployed solely to maximize profits, *Síntesis simbiótica* reconnects scientific and technical knowledge with practices of care. It demonstrates the extent to which care may be understood, as Puig de la Bellacasa suggests, 'as a politics of knowledge at the heart of technoscientific, naturecultural worlds'.[72] For Boff, acknowledging the central importance of care does not mean rejecting all intervention in the world; it means 'renunciar a la sed de poder que reduce todo a objetos desconectados de la subjetividad humana' (renouncing the thirst for power that reduces everything to objects disconnected from human subjectivity) and, crucially, 'organizar el trabajo en sintonía con la naturaleza, sus ritmos y sus indicaciones' (organizing work in tune with nature, its rhythms and cues).[73]

The ethics of planetary care

For his ongoing *Proyecto Biosfera* (*Biosphere Project*, 2006–), Joaquín Fargas creates transparent acrylic spheres of different sizes, containing water, plants and microorganisms: entire ecosystems taken from ponds or other natural habitats (see Fig. 6.9). These have been placed in museums and galleries in different countries around the world, but around 700 of them have also been given to individuals, including journalists, business executives and intellectuals. The spheres are hermetically sealed, requiring only light and warmth to continue growing for perhaps a year or two, before decomposition gradually sets in. Exhibited on simple stands or hanging from gallery ceilings, the spheres are silent and unmoving. The only visible evidence of the activity going on inside is the presence of tiny droplets of water that have condensed on the inside of the globe. As in Haacke's *Grass Grows* (1969), the entirely commonplace existence and growth of a very ordinary set of plants acquires an enchanting dimension when it is framed within a gallery. The relatively small size of the spheres accentuates their fragility: planet-shaped, they point towards the vulnerability of the Earth's biosphere as a whole, in need of protection against human activity. Although – like

Figure 6.9 Joaquín Fargas, *Proyecto Biosfera*, 2014. *Horizontes de Deseo*, MAR Museo de Arte Contemporáneo, Mar del Plata, Argentina (photograph by the artist).

Haacke's *Condensation Cube* (1965) – the sealed nature of the globes suggests a closed system, in reality they are fully dependent on external elements such as light and heat. To receive one of these spheres is to assume the responsibility for caring for it: to a much greater degree than Haacke's spectators, we understand the extent to which we are ourselves implicated in guaranteeing the appropriate conditions for the survival of these living systems.

More recent presentations of the *Proyecto Biosfera* have accentuated the planetary vision evoked by the use of globes, creating specific visual analogies that engage with the first images of the planet photographed from space. In the 2020 exhibition held in the Ruskin Gallery (Cambridge, UK), a documentary video made by Nicolás Muñoz juxtaposed shots of the globes with images of the Earth as seen from space, together with the famous statement made by Bill Anders, NASA astronaut, on the Apollo 8 flight in 1968: 'We came to explore the moon and what we discovered was the Earth.' The beauty and fragility of the planet on view in those images and others of the 1970s did not lead to an intensification of space programmes so much as to a 'return to earth', Robert T. Tally suggests, inspiring a new utopianism and a new environmental awareness.[74] As Anders would go on to say, quoted in the video, 'rather than a massive giant, [the Earth] should be thought of as the fragile Christmas-tree ball, which we should handle with care'. In the video, Fargas expresses this delicacy in a reverent gesture, holding a tiny *Biosfera* globe up to the light between his thumb and forefinger.

Near the globes, a sequence of images uploaded onto a desktop computer allowed the gallery-goer to zoom in (courtesy of Google Maps) from outer space to the United Kingdom, to Cambridge and the Ruskin Gallery, and then right into one of the Biosphere globes, to the microcellular structures of its leaves, and finally suddenly back again to the galaxy-studded universe. The visualization recalls the famous *Powers of Ten* film, made by Charles and Ray Eames in 1977 (from an earlier sketch in 1968), in which images repeatedly expand out, by a factor of 10 each time, from two people sitting on a picnic blanket to the furthest reaches of the universe, and then inward to show subatomic structures.[75] Fargas's innovation – based on scientific knowledge that was not available in the 1970s – is to create a loop, in which scrolling forwards, deep into microscopic structures, takes us without warning out again to the universe, demonstrating the visual resemblance that unites structures at very small and very large scales in the cosmos, from the web-like cellular architecture of leaves to the interconnecting filaments of galaxies and gases that form the cosmic web.

At first sight, the planetary vision that emerges from *Proyecto Biosfera*, like that of the first photographs of the Earth taken from space, might be charged with flattening out difference in favour of a deceptive image of homogeneity and unity. The small size of most of the *Biosfera* globes might also reinforce our assumed position of transcendence with respect to the world we live in. Does Fargas's work thus bolster the prevailing narrative Boff critiques, according to which we think we are '*sobre* as coisas e não *junto* e *com* as coisas' (*above* things and not *together with* things), imagining ourselves to be 'fora da natureza e acima dela' (outside and above nature)?[76] The shifting scale of Fargas's work complicates, however, what might otherwise be a lofty vision of dominion over the planet. Containing just a few plants each, his globes are not totalities but parts of a whole; their scattering in homes and galleries across the world reminds us that what we have in our care or in our field of vision is a tiny fragment of the life our planet sustains. In a similar way, the Google Maps visualization reveals the interconnections that structure the cosmos and (literally) locates us within these, encouraging us to grasp something of our membership, in Boff's words, of 'uma comunidade maior, planétaria e cósmica' (a greater planetary and cosmic community).[77] Reflecting on those first images of the Earth taken from space, Boff considers that their impact lies in their revelation of our mutual belonging to the Earth as an organic unity, to the extent that

> [n]unca mais sairá da consciência humana a convicção de que somos terra […] e de que o nosso destino está indissociavelmente ligado ao destino da Terra e do cosmos onde se insere a Terra.[78]
>
> (The conviction will never again leave human consciousness that we are earth […] and that our destiny is indissolubly bound to the destiny of the Earth and to the cosmos in which the Earth is held.)

While the hermetically sealed plexiglass globes do not perhaps speak to us of our integration with other species, their framing in this way draws attention to living organisms that might otherwise go unnoticed, setting them aside as something deserving of our greater care and causing us to consider their needs. The containers also prevent us from putting the plants to any purpose of our own, other than contemplation: they exist on their own terms, simply for the purpose of life.

We might contrast Fargas's *Proyecto Biosfera* with Eduardo Kac's *The Eighth Day* (2001), a work that is similar in structure, consisting of a plexiglass dome containing an ecosystem for viewers to observe. It

brings together plants, amoebae, fish and mice that have been genetically modified to produce green fluorescent protein, like Alba, the *GFP Bunny* (2000). *The Eighth Day* inserts itself as a coda at the end of the seven Judaeo-Christian days of creation, signifying the moment at which humans will take over the act of creation, using sophisticated technology to produce new transgenic flora and fauna. By contrast, in Fargas's biospheres, all the spectacle and the miracle of creation is to be found in unadorned nature, and our role as humans is not to intervene in it via techniques of advanced bioengineering but simply to pursue an ethics of care. Likewise, Fargas's work also differs from Zerbarini's *Calor, vapor, humedad: Turner en el siglo XXI* (Heat, Steam, Humidity: Turner in the 21st Century, 2006), in which human participants may control an environment contained within a transparent dome by increasing heat and humidity, creating – as Natalia Matewecki points out – a metaphor for the effects of human action on the planet.[79] While Zerbarini's piece increases our awareness of how technology may be used to regulate the biosphere and its sensitivity to human control, Fargas restricts human participation to the simple act of setting the globe in a place where it will receive enough light but not too much heat. The *Proyecto Biosfera* thus carves out a paradoxical role for human carers: the fragility of the little globes expresses the need for care, but the limits Fargas places on interaction helps us to understand our role as a very simple one (and yet, it would appear, very difficult to put in practice): that of ensuring the basic conditions needed for growth that are already given by the Earth's biosphere.

Cultivating life amid political violence

Questions of care within artistic practice are also taken up by the Colombian artist Lina Espinosa and given an additional significance within the context of the political violence that has ravaged the country for many decades. Espinosa's work has brought her into contact with communities in different regions of Colombia whose lives and livelihoods have been made vulnerable through violence or the contamination produced by mining. In 2009, she held workshops with residents of the Tolima department of Colombia, inviting them to intervene in printed maps of the network of rivers in the department to create more affective cartographies that represented their concerns about their region. A number of them chose to emphasize the vulnerability of the environment to the impact of mining, especially on waterways and different species.[80] She also worked with fishermen in the Santa Marta bay area on the Caribbean coast in 2013 in order to

highlight their perceptions of the risks of coal mining and mass tourism to the marine environment and to their own trade.[81] In multiple projects inspired by maps, Espinosa explains that what she looks for in a map is exactly what a conventional map cannot show: she is not interested in cartographic precision, but what a map might convey of the complexity of life in a certain territory or its existence within a personal or social imaginary.[82]

It is against this broader interest underlying many of Espinosa's artistic projects that her collaborations with scientists are best understood. During a bioart residency at the School of Visual Arts in New York in the summer of 2013, she worked with microbiologists to produce *Bacteria Maps*, digital prints of fluorescent bacteria drawings.[83] She used a genetically engineered strain of *E. coli* bacteria frequently used by biophysicists in experiments, to which a gene for bioluminescence is added, extracted from light-producing marine organisms, to render visible processes that would otherwise be difficult to see. In a Petri dish filled with agar stained with a dark blue pigment, she inserted bacteria that had been modified in this way to produce luminescence. After cultivation for several weeks, the bacteria grew to trace in delicate glowing dots the lines of a world map, and maps of Manhattan, South America and Colombia. As the maps are 'drawn' while the bacteria are still invisible, both the artist's visual memory and a certain element of chance come into play; the presence of the accidental is also enhanced by the uneven growth of the bacteria and the unplanned invasion of other bacteria into the Petri dish.

Using living organisms in this manner allowed Espinosa to express, with reference to the rigour and precision of cartographic science, something of 'la naturaleza cambiante de la vida' (the changeable nature of life) that fills the spaces between the lines of a map: its essential instability, its mutability, its vulnerability to so many different factors.[84] The sophistication of science and its control over nature – to the point of being able to modify the genome of bacteria, some of the tiniest living organisms with which we can interact – are thus juxtaposed in these maps with what cannot be fully controlled, what escapes regulation. A companion piece, developed using similar techniques back in Bogotá, expresses more clearly the local resonances Espinosa wishes to give her work. In another Petri dish, she traced with bacteria the number 7,488,526, which corresponded to the number of people who had been victims of violence in the conflict in Colombia to that date (June 2015), according to official estimates. The piece makes reference to the multiplication associated with bacterial growth – the number was

clearly destined to rise – but also contrasts the marvellous achievements of science in genetic engineering with an utter failure to prevent the violence affecting so many.

Espinosa's aim in the *Dibujos habitables* (*Inhabitable Drawings*) (2015–18) was to 'crear una imagen que sea la antítesis de la guerra' (create an image that was the antithesis of the war) and to 'generar una obra que albergue y fomente la vida' (generate a work that harbours and promotes life).[85] It took her several months, with the advice of biologists, to find a marine plant pliable enough to survive being carefully entwined around a wire structure in a glass tank filled with water (see Fig. 6.10). It was a process of negotiation: even once established, parts of the plants in the living 'drawings' evade control, escaping towards the light or a better food source. Espinosa then created the conditions for a sustainable ecosystem, providing nutrients and the first companion species, such as tiny ghost shrimps. The idea was emphatically not to create an aquarium: spectators are not dazzled by colourful tropical fish, but have to search for the life within, to detect the small but incontrovertible proofs of an

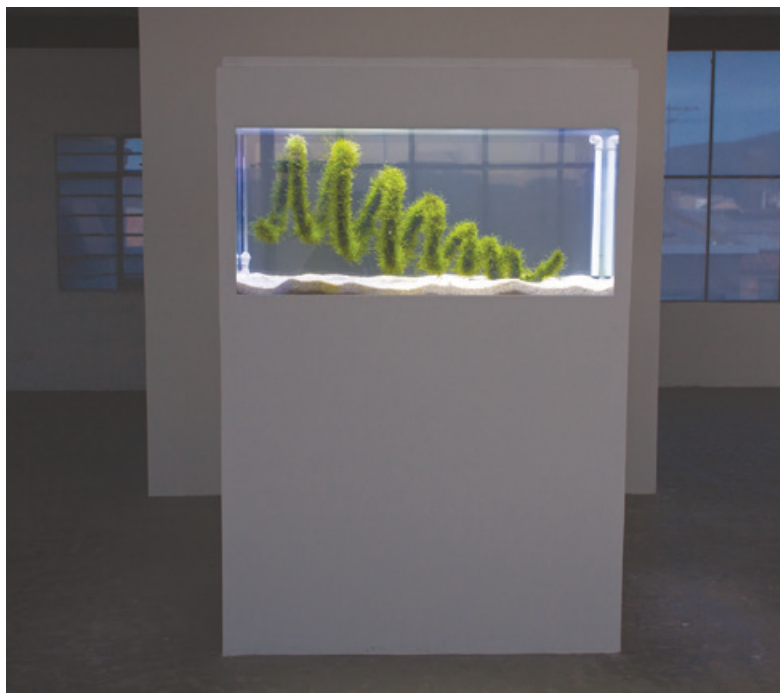

Figure 6.10 Lina Espinosa, *Dibujo habitable*, 2015. FLORA ars+natura, Bogotá (photograph by Gonzalo Benavides).

ecosystem at work. Everything appears delicate and fragile, from the slender fronds of the plant, moving minimally in the water, to the minute, diaphanous forms of the ghost shrimps gliding almost imperceptibly between them. The work speaks of the need to find another way of seeing the apparently insignificant, to create liveable spaces, structures in which life may flourish, and to seek to forge and maintain a fragile equilibrium in the context of the enormous legacies of decades-long violence.

The *Dibujos habitables*, like the *Bacteria Maps*, had to be securely destroyed after their exhibition. The use of bacteria – especially genetically modified ones – is permitted only if strict protocols are followed, and in the case of *Dibujos habitables* Espinosa herself decided that releasing a potentially invasive non-native plant species into the environment might have devastating effects.[86] In this way, her work and its aftermath point to the unresolvably complex nature of conservation, in which some species must be sacrificed in order to preserve others, confounding any simplistic application of moral principles based on the sanctity of life. Puig de la Bellacasa observes, in a similar vein, 'In some contexts, care is inseparable from killing: like in weeding one's garden to make possible more fertile growth.'[87]

Espinosa's *Bacteria Maps* and *Dibujos habitables* draw on scientific techniques and forms of visualization – the cultivation of bacteria, gene manipulation, microscopy and the design of microbial ecosystems – in order to create a more poetic evocation of what escapes our knowledge and control. While scientific advances in biotechnology in particular have enabled an unprecedented power to intervene even in the genomes of individuals, in contrast – Espinosa writes – we appear to have very little control over the relationship between the environment and industrial production, or over the consequences of social conflict; 'vivir en comunidad es cada vez más difícil' (living in community is increasingly difficult).[88] She explains that one of the motivations behind the *Dibujos habitables* project was to reflect on 'la dificultad para lograr una convivencia más imaginativa, equitativa, solidaria y sostenible entre nosotros' (the difficulty of reaching a more imaginative, equitable, caring and sustainable form of coexistence between ourselves), a vision we are afforded by the poised tranquillity of the thriving microscopic community she has fostered. Espinosa's work brings together questions of social and environmental justice in ways that echo the ways these are co-articulated in Boff's writing. Like Boff, she posits the coextension of the social and natural worlds, opening the notion of community beyond the human and expressing the political and environmental urgency of developing new practices of care.

The asymmetries of care

The utopian gesture of these works by Zerbarini, Fargas and Espinosa is to imagine, by framing living organisms in art, ways in which humans may use scientific knowledge and technology in order to cultivate and sustain the natural world. This is a knowledge that is inseparable from practices of care, which in turn stem from an understanding of the interdependence and proximity that characterize our relations with other things and beings; Boff reminds us that 'Conhecer não é apenas uma forma de dominar a realidade. Conhecer é entrar em comunhão com as coisas' (to know is not simply a form of dominating reality. To know is to enter into communion with things).[89]

In contrast to many of the other works discussed in this book, which emphasize the agency and autonomy of other species – diminishing human exceptionalism – or focus on the symbiotic relationships that bind different species together in ecosystems, these works also reserve an important role for humans in creating the conditions for the conservation of life. In Fargas's *Proyecto Biosfera* and Espinosa's *Dibujos habitables*, this role is both vital and limited, removing any sense of the human power to manipulate nature and replacing it with a more ethical response that simply but crucially allows room for the world-makings of other species. The use of enclosed glass tanks and plexiglass containers in these works, which eliminate the possibility of direct human contact, points to the essential inequality that governs our relationship with other species, which requires their ways of building communities to be provided with special protection.

For Karen Barad it is the 'power imbalances' that characterize our entanglement with other life forms that give rise to the need for an ethical approach to such connections.[90] To argue (as critical posthumanists and new materialists do) for an agency that is distributed across humans and non-humans is not to diminish our responsibility, but to increase our awareness of the need for care, in order to maintain the health of the complex ecologies in which we and others take part. Puig de la Bellacasa poses a series of acute questions that articulate this paradox:

> How do we actively engage with the lived experiences of forms of nonhuman *bios* whose existences are today increasingly incorporated in the cultural world of human *techne*? How do we acknowledge 'their' agency, and our involvement with it, without denying the asymmetrical power historically developed by human agencies in *bios*? How do we engage with accountable forms of

> ethico-political caring that respond to alterity without nurturing purist separations between humans and nonhumans? How do we engage with the care of Earth and its beings without idealizing nature nor diminishing human response-ability by seeing it as either inevitably destructive or mere paternalistic stewardship?[91]

Her suggestion is that we do so by acknowledging the extent to which 'humans exist only in a web of living covulnerabilities'.[92] The 'co-' represents an interdependency, and the capacity for coevolution and co-creation, but it does not dissolve the boundaries between humans and non-humans. Although care is reciprocal and emerges from relations of interdependency, the 'obligations of care' remain 'asymmetrical', placing a greater obligation on humans to allow all kinds of life to flourish.[93]

Timothy Clark sees contemporary ecocriticism as caught within a contradiction, 'keen to stress nonhuman or material agency and critical of destructive delusions of human control, yet also deeply aware of the urgency of more decisive human action to help avert environmental collapse'.[94] The theories of care developed by both Boff and Puig de la Bellacasa, founded on interdependence and reciprocity, may indicate a way to hold these conflicting paradigms in a productive tension. Boff's understanding of care remains principally identified with the quintessentially human, and with notions of stewardship, in a way that Puig de la Bellacasa's does not. Although both scholars emphasize interdependence and mutual belonging, Puig de la Bellacasa draws greater attention to the care that is exercised by other species, especially within the living webs of soil communities, which demonstrates the extent to which 'humans are not the only ones caring for the earth and its beings'.[95] In the next chapter I will turn to how artists have explored these broader practices of care, focusing on the opportunities created by invertebrates for other species to collaborate and co-create with them in biosocial and biosemiotic worlds.

Notes

1. See Burnham, 'Systems esthetics'; Glusberg, *Arte de Sistemas*.
2. Briante, 'Grippo no deja que duerma la conciencia'.
3. Glusberg, *Benedit: Phitotron*, n.p.
4. Polgovsky Ezcurra, 'The future of control'.
5. Puig de la Bellacasa, *Matters of Care*, 156.
6. See Du, Li and Gu, 'A state of the art review on microbial fuel cells'; Franks and Nevin, 'Microbial fuel cells, a current review'.
7. Del Dottore et al., 'Toward growing robots'.

8. Hernández García, Niño Bernal and Hernández-García, *Ecopolítica de los paisajes artificiales*, 37.
9. Gudynas, *Derechos de la naturaleza*, 71.
10. Svampa and Viale, *Maldesarrollo*, 365.
11. Yeregui, 'Prácticas co-creativas', 3.
12. For more on the 'logic of plant life' summarized here, see Chapter Four.
13. Cuevas, 'En el borde de la ficción', 20.
14. See Esparza, *Cultivos*, 266–7.
15. The project has been exhibited in a number of countries since 2010, including Spain, Belgium and various locations within Mexico.
16. The video can be viewed at https://www.youtube.com/watch?v=137KANbB1FA. A second part, showing *Plantas nómadas* at work at the same location, is available at https://www.youtube.com/watch?v=kQwYEWaEHTs&t=539s. Accessed 27 October 2020.
17. Designed by Ariel Guzik, the sound system comprises an acoustic box made from acrylic, a crystal tube held in place with silicon springs and a mobile phone vibrator. See https://www.plantasnomadas.com. Accessed 27 October 2020.
18. Conversation with the author, 17 August 2019.
19. See https://www.plantasnomadas.com, where the process of development is meticulously documented. Accessed 27 October 2020.
20. See, for example, Philamore et al., 'Toward energetically autonomous foraging soft robots'.
21. Conversation with the author, 17 August 2019.
22. See https://www.plantasnomadas.com/pdfs/2010_plantas_nomadas_gilberto_esparza.pdf. Accessed 27 October 2020.
23. Hauser, 'Hard scrap, soft politics, and wet machines', 343; emphasis in original.
24. Hauser, 'Hard scrap, soft politics, and wet machines', 343.
25. Conversation with the author, 17 August 2019.
26. *Plantas autofotosintéticas* was first shown as part of the *Cultivos* exhibition, held in the Espacio Fundación Telefónica de Lima, Peru, between 30 August 2014 and 22 February 2015. A video explaining how the system works is available at https://www.youtube.com/watch?v=PVK1aiIj6p8. Accessed 27 October 2020.
27. Conversation with the author, 17 August 2019.
28. See the short documentary film about the work directed by Matic Zavodnik, available to view at https://vimeo.com/167715023. Accessed 27 October 2020.
29. The *Symbiotic Machine* was developed with the assistance of Raoul Frese and Vincent Friebe from the Vrije Universiteit's LaserLaB, the applied physicist Michiel van Overbeek and Leydervan Xavier from the Centro Federal de Educação Tecnológica Celso Suckow da Fonseca in Rio de Janeiro (CEFET/RJ). It was exhibited at the Glass House in Amstelpark, Amsterdam between 9 March and 27 April 2014. A video documenting the different stages of the machine's design and construction may be viewed at https://vimeo.com/88759818. Accessed 27 October 2020.
30. Henriques created the project with the collaboration of scientists of LabMET, in the Faculty of Bioscience Engineering at the University of Ghent. It was exhibited at the Digital Art Festival, Taipei, between 11 and 20 November 2016.
31. Conversation with the author, 29 March 2019.
32. Maturana, 'Metadesign', 179.
33. Maturana, 'Metadesign', 187.
34. Conversation with the author, 29 March 2019.
35. *C-DER* was shown in the *Atmospheric Trilogy – Symbiotic Machines for Space Exploration* installation, part of the *Orbit ° Space: Speculative Futures* exhibition held between 26 and 28 April 2019 at the Bozar Institute, Brussels. The *SyMSE* project has been developed in collaboration with the Vrije Universiteit in Amsterdam, the European Space Agency, the Willem de Kooning Academy, CEFET/RJ and the Center for Microbial Ecology and Technology (CMET) at Ghent University.
36. Conversation with the author, 29 March 2019.
37. Mancuso, *The Revolutionary Genius of Plants*, 191.
38. The team's final report, entitled *Bio-inspiration from Plants' Roots*, is available to read at https://pdfs.semanticscholar.org/4fc4/467457bd772a62c736b72dbffb2a4aabb7ab.pdf. Accessed 28 October 2020.
39. Mancuso, *The Revolutionary Genius of Plants*, 182.

40. Mancuso, *The Revolutionary Genius of Plants*, 174.
41. Plumwood, *Environmental Culture*, 35.
42. *Marte Mariana* was exhibited as part of the *Relandscape/Repaisagem* solo show held at the Centro Municipal de Arte Hélio Oiticica, Rio de Janeiro, Brazil, between 3 August and 22 October 2016.
43. Lütticken, 'Abstract habitats', 114.
44. Demos, *Decolonizing Nature*, 48.
45. See https://www.mycocrea.com. Accessed 28 October 2020.
46. The festival took place in Khentii Province, between 30 July and 8 August 2018.
47. The work may be viewed in action at https://www.youtube.com/watch?v=yK95aQvYHnI. Accessed 28 October 2020.
48. Conversation with the author, 23 April 2019.
49. Burnham, *Beyond Modern Sculpture*, 332.
50. The work may be viewed in action at https://www.youtube.com/watch?v=gduXrdsQG-w. Accessed 28 October 2020.
51. The work was first 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, between 11 and 14 October 2012.
52. The project was developed during the *Residência NUVEM – Estación Rural de Arte e Tecnología*, held in Rio de Janeiro in July 2013.
53. Cantera, 'Co-creaciones híbridas', 128.
54. Cantera, 'Co-creaciones híbridas', 71.
55. Cantera, 'Co-creaciones híbridas', 71.
56. Cantera, 'Co-creaciones híbridas', 72.
57. Yeregui, 'Prácticas co-creativas', 5.
58. Yeregui, 'Diálogos a-sublimes', 168.
59. Chillida, 'Transformación', 24; emphasis in original.
60. Correspondence with the author, 5 June 2020.
61. Fisher and Tronto, 'Toward a feminist theory of caring', 40; emphasis in original.
62. Puig de la Bellacasa, *Matters of Care*, 62, 161.
63. Puig de la Bellacasa, *Matters of Care*, 161.
64. Boff, *El cuidado esencial*, 32, 74–5.
65. Boff, *El cuidado esencial*, 108.
66. The work was first presented in the Espacio Fundación Telefónica in Buenos Aires in January and February 2011, although no chicks hatched at the end of the period of incubation. Further experimentation was required before a successful attempt in 2013.
67. The video documenting the artwork may be viewed at https://www.youtube.com/watch?v=CGkRKEBF4Ds. Further documentation is available at https://www.marina-zerbarini.com.ar/simbiosis/index.html. Accessed 28 October 2020.
68. Haacke, 'Provisional remarks (1971)', 121.
69. Haacke, 'Provisional remarks (1971)', 123.
70. Haacke, 'Provisional remarks (1971)', 121.
71. Haacke, 'Provisional remarks (1971)', 121.
72. Puig de la Bellacasa, *Matters of Care*, 15.
73. Boff, *El cuidado esencial*, 84.
74. Tally, 'Beyond the flaming walls of the world', 196–7.
75. The film may be viewed at https://www.youtube.com/watch?v=0fKBhvDjuy0. Accessed 28 October 2020.
76. Boff, *Ecologia*, 101.
77. Boff, *Ecologia*, 16.
78. Boff, *Ecologia*, 30.
79. Matewecki, 'El discurso de la biología en el arte argentino contemporáneo', 48.
80. Some of the maps produced for the project, called *Zonas vulnerables Tolima*, were shown at the Biblioteca Darío Echandía in Ibagué, Colombia, in October 2009.
81. Photographs of this work were displayed as part of the *Impacto mínimo* exhibition in the Museo Bolivariano de Arte Contemporáneo in Santa Marta from 20 March to 4 May 2013. Some of them may be viewed at https://www.linaespinosa.com/exposicin-impacto-mnimo. Accessed 28 October 2020.
82. Conversation with the author, 14 February 2019.

83. These were first shown as part of the *Semi-Living* exhibition at the School of Visual Arts, New York, on 20 June 2013. Images of the works may be seen at https://www.linaespinosa.com/bacteria-maps. Accessed 28 October 2020. To produce this work, Espinosa worked with biologist Sebastian Cocioba, bioartist Suzanne Anker and photographer Raul Gómez Valverde.
84. Conversation with the author, 14 February 2019.
85. Conversation with the author, 14 February 2019. The *Dibujos habitables* were exhibited at the FLORA ars+natura Gallery in Bogotá between 5 October and 12 November 2015. Images of the exhibition may be viewed at https://www.linaespinosa.com/exposicin-dibujo-habitable-i. Accessed 28 October 2020.
86. Conversation with the author, 14 February 2019.
87. Puig de la Bellacasa, *Matters of Care*, 164.
88. Espinosa, 'Dibujo habitable'.
89. Boff, *Ecologia*, 29.
90. Dolphijn and Van der Tuin, '"Matter feels, converses, suffers, desires, yearns and remembers": Interview with Karen Barad', 55.
91. Puig de la Bellacasa, *Matters of Care*, 144.
92. Puig de la Bellacasa, *Matters of Care*, 145.
93. Puig de la Bellacasa, *Matters of Care*, 156.
94. Clark, *Ecocriticism on the Edge*, 165.
95. Puig de la Bellacasa, *Matters of Care*, 161.

7
Sensory worlds and the pluriverse

Ants and other social insects have frequently become paragons of ideal behaviour in human societies. Since the nineteenth century in particular, models based on the organization of insect societies have helped to naturalize social hierarchies in the human world, as well as methods of rational management and the capitalist division of labour. For the Victorians, ants represented the epitome of industrial efficiency; in our own age, as one variety of capitalism has yielded to another, they are more likely to be considered exemplars of flexible problem-solving. Tomás Saraceno (Argentina) and Kuai Shen (Ecuador), both currently resident in Germany, have developed projects that explore the sensory worlds, creative intelligence and social organization of spiders and ants (respectively). In these projects, spiders and ants become models of cooperation, problem-solving, self-organization and creativity. These traits are, of course, the skills increasingly prized by neoliberal capitalism. However, the emphasis here is not on increasing productivity through 'flexible' working practices, but on creating multispecies communities based on mutualism and the sustainable use of resources. In their work, in contrast to that of many earlier artists, writers and scholars, the social behaviour of invertebrates becomes a paradigm for the pursuit of life in a post-capitalist and post-anthropocentric era, pointing to the possibility of reorganizing human social life around relationships of kinship and collaboration rather than capitalist production.

Like many scientists and social theorists before them, Saraceno and Kuai Shen construct analogies between the natural world and human society in order to make points of a moral or ethical nature. But their works also lead us beyond analogy, as analogy depends on a separation of the two things being compared. Here, (animal) nature and (human) culture are not to be understood as opposed. The cultural is always

biocultural and the social is always biosocial; ecologies are always thoroughly cultural and political as well as biological. Andreas Weber observes a turn in recent biology towards a recognition that meaning and expressiveness are 'not just epiphenomena' but 'deeply rooted in the heart of nature'.[1] His proposition that '[w]e need to understand life as a not only material, but deeply sense-creating phenomenon'[2] becomes the cornerstone of the projects developed by Saraceno and Kuai Shen. The analogies suggested by these works are therefore deliberately unstable conceits that point us towards the inseparability of nature and culture. This may be interpreted as a decolonial move, as it undermines the binaries that underpinned the colonial separation of nature and culture and promotes an understanding that is more relational and biocentric.

This chapter also explores how studying multispecies communities in art projects may help us think through the politics of the 'pluriverse' as a decolonial project. The understanding of sensory worlds that Saraceno and Kuai Shen promote in their projects is closely linked – I will show – to the idea of the 'pluriverse' as theorized by Arturo Escobar, Walter Mignolo and Enrique Dussel as well as Mario Blaser and Marisol de la Cadena. Quoting Subcomandante Marcos, the Zapatista leader, Blaser and de la Cadena are inspired by the exhortation to construct 'un mundo donde quepan muchos mundos' (a world in which many worlds fit) as a way of disarming the threat to other worlds that characterizes the Anthropocene.[3] For Escobar, the concept of the pluriverse is founded in the 'ontological struggles' over territory being advanced by 'indigenous, Afrodescendant, peasant, and poor urban communities' in Latin America and other regions of the world.[4] Yet there is an (often implicit) assumption in his work, and in that of other scholars working on political ontology in Latin America, that the concept of the pluriverse reaches beyond human world-makings to address the need to accommodate the world-makings of other species. Indeed, dividing human world-makings from other kinds would be nonsensical within the post-anthropocentric framework they adopt. The resistance of indigenous and other groups to extractivist practices and the reduction of the natural world to resources and commodities is rooted in an understanding of the complex and co-constituting relations that different forms of being – humans, animals, rivers, forests, mountains – maintain with each other as subjects dwelling in multiple but interconnected worlds. My reading of these works will therefore bring out possible points of contact between decolonial theory, post-anthropocentrism and environmentalism.

I. Spider/webs: from connection to coevolution

Spiderwebs have become the principal subject and medium of many works by Saraceno since 2009. He has worked closely with arachnologists and engineers to capture and model the structure and operation of spiderwebs and to study social behaviour in different species of spider. Saraceno provides stunning evidence of spider intelligence in webcraft, producing dramatic, large-scale sculptures that map with scientific precision the extraordinarily complex architecture of webs woven by black widow spiders.[5] Some philosophers and art critics have read Saraceno's vast web reconstructions as a metaphor for the multiple connections of contemporary networked society. Angharad Closs Stephens and Vicki Squire, for example, reflect on ways in which the topology of *14 Billions (Working Title)* (2010) helps us to think about citizenship 'as constituted through a range of connections rather than in terms of a single unified whole'.[6]

Much more convincing is Sasha Engelmann's proposal that these webs do not work as metaphors but establish 'structural homologies' with other forms of matter at different scales; more importantly, they provide the opportunity to construct 'visceral, tactile knowledge' through the painstaking simulation of spider webcraft.[7] Exhibition texts create associations between the form of spiderwebs and the underlying structure of the universe, highlighting the increasing use among astrophysicists of the spiderweb as a figure to describe the filaments linking galaxies and clusters.[8] These connections suggest the extent to which, Engelmann argues, '*14 Billions* is not a discrete object, but is part of an ecology of images circulating in the sociotechnical space of the art studio and more widely in astrophysics, computing, culture, and biology'.[9] Although Saraceno's spiderweb reconstructions are exhibited in a completed state, they bear witness to an extraordinary work of mapping and assembly that Engelmann describes in detail, during which time 'the web exerted its own expressive force on humans'.[10] Even exploring the huge webs as a gallery visitor gave some sense of this experience, although it was perhaps more evocative in this case of the fly's entanglement than the spider's artistry. Visitors could crawl under or step over the knotted black cables, the openness of the structures inviting exploration. The taut black lines extending across the brightly lit white walls and floor of the gallery produced a sense of spatial disorientation that affected the explorer's ability to judge distance and direction. With cables stretching out at all

levels and in different directions, it was difficult to avoid colliding with them; touching them sent vibrations through the whole.

Jussi Parikka argues that Saraceno's work is best understood as the creation of 'dynamic' sculptures and models that are not merely 'representational schemas' or reflections of theoretical concepts but 'a more complex *working with*' objects of research, as well as 'the staging and producing of working objects'.[11] Indeed, I will suggest, Saraceno's work with dynamic models, and particularly with real spiderwebs, allows us to perceive the insufficiency of dominant images and conceptions of the network, which are used to evoke the increasing forms of economic, cultural and technological connectedness experienced in the twenty-first century. Networks only describe the topological arrangement of the different entities they connect: they express a relationship, but do not tell us what kind of relationship it is or how it evolves over time. Moreover, Escobar objects that many network approaches 'still take for granted the existence of independent objects or actors prior to the networking'. In place of network thinking, the concept of the pluriverse rests on the recognition that 'life is interrelation and interdependence through and through, always and from the beginning'.[12] Similarly, Tim Ingold argues that the 'web of life' is 'not a network of connected points, but a meshwork of interwoven lines'.[13] This takes us from an understanding of the world as 'an assemblage of bits and pieces' and towards one of 'a tangle of threads and pathways', along which actions emerge through an interplay of forces.[14] By emphasizing the dimension of time and the work of collaboration, I will suggest, Saraceno's work with real webs helps us think not only about connectedness, but about coevolutionary dynamics: the interdependent relationships that both create and emerge from that connectedness over time. They move us from a simple survey of connections – however complex the resulting network might be – to a deeper understanding of the forms of collaboration and co-creativity that bind us to other species and to our environment.

Co-creativity: the interweaving of sensory worlds

The vast majority of spider species are solitary, and may display aggression towards other members of their own species or even engage in acts of cannibalism. A small percentage of species have been described as 'social' or 'semi-social', meaning that they may cooperate in catching prey, sharing food, building nests and caring for each other's young. Saraceno's *Hybrid Webs*, which have been exhibited worldwide since 2012, frame

collaborative webs created by different species of spider in open carbon fibre structures suspended from the ceiling. Both scientific knowledge of the species' particular weaving habits and aesthetic judgement are used by the human curators in the development of the webs, to decide when to rotate the frames, when to introduce other spiders and when to exhibit the webs as complete.[15] In this way, the combined weavings of the spiders also become human–spider co-creations, demonstrating the potential for multispecies sociality and aesthetic co-production between humans and non-humans.

Saraceno curated hybrid webs of significant dimensions for a solo exhibition at the Museo de Arte Moderno in Buenos Aires in 2017–18.[16] Working with a team of arachnologists, he collected spiders of the *Parawixia bistriata* species from the Chaco region, in northern Argentina, who would create the giant work *Instrumento Musical Cuasi-Social IC 342 construido por 7000 Parawixia bistriata* (*Quasi-Social Musical Instrument IC 342 Built by 7000 Parawixia Bistriata*). The spiders had spun their webs for several months in the gallery before the exhibition's opening and had since been released back into their previous habitat. Woven between frames hung in an entirely black gallery, their huge webs were picked out by spotlights, giving them a ghostly, silvery brilliance as they shimmered against the black background of the gallery walls. The sheer beauty of the exhibition made visitors feel they were entering a fairytale realm, in which the forgotten and the mundane had been magically transformed into the fabulous landscapes of a new kingdom.

Interestingly, *Instrumento Musical Cuasi-Social IC 342* not only testified to, and produced, cross-species encounters between humans and spiders. It also demonstrated the risks of such interactions. Over time, the webs became laden with dust, the remains of flies and the occasional dead spider, held by the stickiness of the silk threads. Their geometrical perfection deteriorated, with frayed filaments hanging loose and radial lines collapsing into each other, producing holes. The fraying webs bore witness to the unintended impact of humans in accelerating the decay of the webs, as visitors introduced more dust into the gallery and caused turbulence through their movements. The exhibition also pointed to the *missed* encounters between humans and non-humans: what remains invisible because it takes place outside the diurnal rhythms of human life and institutional norms, for example. Museum staff explained that the spiders were nocturnal weavers, and that they had considered opening the gallery overnight for visitors to see them in action, but that (unsurprisingly) this move would have been unpopular among the gallery attendants.

Other spider-related works by Saraceno give us greater insight into the sensory world of spiders, and turn their human observers more deliberately into co-participants in interspecies performances. In *Arachno Concert*, dust particles move around a black exhibition space, set in motion by two sources of vibrations: first, those caused by a spider in its web, captured by piezo microphones and amplified through a loudspeaker, and, second, the movements of the exhibition's human visitors.[17] Cameras track the movements of the dust particles, caught in the beam of a projector, and their collisions are translated into low-frequency sounds, amplified by the same speaker. The result, as Saraceno describes it, is 'like a jam session between the spider, the dust, and the humans moving around the space'.[18] Techniques of amplification, magnification and projection introduce us into a new sensory world, in which we are able to see movements and hear sounds that are normally imperceptible to humans.

The *Arachno Concert* and other, similar performances are intended to open up to us the particular sensory worlds of the spider, and how these extend beyond their bodies to the webs they spin and repair. The findings of arachnologists have indicated that webs do not simply capture prey, but also act as a highly developed information system for the spider. With poor vision, spiders create a 'view' of the world around them with the aid of sensitive vibration sensors on each leg, which allow them to detect the type of prey caught and any compromise to web integrity.[19] Researchers have found the engineering of webs to be analogous to the construction of a musical instrument, proposing that 'silk fibers are "tuned" to a resonant frequency that can be accessed through spider "plucking" behavior, which enables them to locate both prey and structural damage'.[20] Saraceno deploys the term 'spider/web' to express the 'living material assemblage' that brings together both the web and the spider that builds it, as the web is fully part of the spider's sensory and cognitive systems.[21]

Saraceno's 'spider/webs' are thus excellent examples of the concepts of 'embodied mind' and 'cognition as enaction' developed by the Chilean biologist and philosopher Francisco Varela. For Varela, the mind is not separate from the body, and we do not acquire knowledge or understanding by registering true representations of an external world. Instead, 'the world is not something that is given to us but something we engage in by moving, touching, breathing, and eating'.[22] This means that reality is 'perceiver-dependent, not because the perceiver "constructs" it as he or she pleases, but because what *counts* as a relevant world is inseparable from the structure of the perceiver'.[23] Varela calls this a 'post-Cartesian' knowledge that is 'built

from small domains composed of microworlds and microidentities'.[24] Exploring the extended cognition of spider/webs also becomes a way of reflecting on the extent to which the perception and intelligence of all living organisms, including humans, are thoroughly embedded in their environment to the point of being inseparable from it. This understanding of the connections that constitute the world we inhabit is much richer than that of a network. Ingold explains, 'The lines of the spider's web, for example, quite unlike those of the communications network, do not connect points or join things up. Secreted from the body of the spider as it moves, they are the lines along which it acts and perceives.'[25] In similar ways, our own cognition is both embodied and ecological: the atmosphere, our habitat and the other species that compose it alongside us are fully part of our perceptual and cognitive apparatus, as they are for all living organisms.

Varela's work – like that of his mentor Humberto Maturana – was deeply inspired by the Estonian biologist Jakob von Uexküll, whose ideas Saraceno frequently cites in exhibition texts. Uexküll's insights have been highly influential in the fields of ethology, theoretical biology, biosemiotics and cybernetics, and his early twentieth-century work on subjective environments (*Umwelten*) has also attracted the interest of a number of philosophers, including Martin Heidegger, Georges Canguilhem, Maurice Merleau-Ponty, Giorgio Agamben, Gilles Deleuze and Félix Guattari. Taking a neo-Kantian approach to animal perception, Uexküll insisted that every living organism inhabits a unique perceptual world to which it is bound, remaining 'permanently enclosed' in that space, as if it were a 'soap bubble'.[26] He rejected as a comforting 'illusion' the 'widely held conviction that there must be one and only one space and time for all living beings'.[27] The task of biology, as Uexküll saw it, was to 'abandon our fond belief in an absolute, material world, with its eternal natural laws' – a claim of universality he attributed to physics – and to acknowledge the subjectivity with which living beings relate to, and shape, their individual milieus.[28]

For Uexküll, these different sensory worlds are, nevertheless, intricately connected. He uses the metaphor of melody and counterpoint to describe the close relationships between the animal and its environment and between different living organisms, which contribute to the vast composition that is Nature.[29] He gives as an example the relationship between the spiderweb and the fly. The web is spun so finely that it eludes the crude visual perception of the fly, which is caught unawares. This leads Uexküll to argue that the web is 'configured in a fly-like way' or that 'the fly-likeness of the spider means that it has taken up certain motifs of the fly melody in its bodily composition'.[30] Parikka notes that

Uexküll's use of the metaphor of music introduces a sense of becoming over time that distances us from approaches to insects as machines, suggesting instead that '[a]nimals create worlds as an unfolding not unlike the temporality of music'.[31] Rather than different machines with specific functions that combine to form a system, Uexküll understands the relationship between a species and its environment (including other species) as a coevolutionary one that unfolds over time. Living organisms are bound together in the 'mutual relations' that Uexküll finds to be marked by processes of 'inter-adjustment'.[32]

A temporal framing of this kind is created in a series of *Arachnid Orchestra* performances organized in the context of Saraceno's exhibitions, in which human musicians have performed alongside and in acoustic dialogue with spiders, whose web vibrations are picked up by sensitive piezo microphones. The vibrations, motifs and melodies that give duration to this performance of interspecies co-creativity also act as musical metaphors for the progressive collaborative 'composition' of species through multiple relations with other species and their biophysical milieu. At the same time, the highly visible presence of microphones, cameras, amplifiers and speakers in these performances remind us that we can only approach the sensory world of the spider through the mediation of technology. They encourage us to recognize the incommensurability of different sensory worlds in a way that problematizes (as Uexküll's work does) the notion of a unified cosmos, while calling us to recognize the extent to which these worlds are bound together and coevolve over time.

In the coexistence of different 'dwelling worlds' (Uexküll) that are 'perceiver-dependent' (Varela) we may also detect the principles that underlie the relational ontologies and the concept of the pluriverse as theorized by Mignolo, Escobar and other decolonial thinkers in or from Latin America. Escobar builds explicitly on the work of Varela, showing how his understanding of the indivisibility of mind, body and world undermines the tradition of Western rationalism, in which 'the world out there preexists our interactions'.[33] The 'one-world world', founded on such notions of objectivity, 'has arrogated for itself the right to be "the" world, subjecting all other worlds to its own terms or, worse, to nonexistence'.[34] Escobar explains that in one-world metaphysics there is a single reality that is perceived differently by multiple cultures and subjective viewpoints.[35] The pluriverse is composed instead of 'una multiplicidad de mundos mutuamente entrelazados y co-constituidos pero diferentes' (a multiplicity of worlds that are mutually entwined and co-constituted, but different).[36] In his work with spiders, Saraceno focuses our attention in

a similar way on the coexistence of sensory worlds that undermines 'the belief in the existence of one and only one world' (Uexküll).[37] Thinking about the coevolution of the fly and the spiderweb helps us to grasp the extent to which, in the relational ontologies described by Escobar, '*nothing preexists the relations that constitute it*'.[38]

Understanding different worlds as fundamentally incommensurable but nevertheless co-constituted is key to composing 'a world in which many worlds fit'. Pluriversal politics cannot ignore the fact that some world-makings undo the worlds of others. This is why Blaser and de la Cadena voice suspicion of discourses of commonality and the commons, as notions of 'the common good' require the destruction of what cannot be recognized from the perspective of dominant worlds. They invite a kind of politics that 'might not start from, nor resolve in[,] ontologically homogeneous grounds'. As a counter-discourse to the commons, they propose the 'uncommons as the heterogeneous grounds where negotiations take place toward a commons that would be a continuous achievement'.[39]

Recent works by Saraceno that focus on the cohabitation of humans and spiders, discussed below, create some sense of the 'heterogeneous grounds' on which negotiations between different world-makings take place. They do so by giving voice to divergent and often incompatible perspectives, such as the scientific, the spiritual, the material and the mythical. I will suggest, however, that these projects – often utopian in their register – place greater emphasis on the possibilities for communication and collaboration than on irreducible ontological difference. In this way, they can be read as an expression of desire for the commons that Blaser and de la Cadena hold as the final objective, but which does not always keep fully in view the 'uncommons' that is the starting point of negotiations between different worlds.

Synanthropic futures and the ethics of entanglement

The year 2019 saw the launch of www.arachnophilia.net, an archive and forum for an interdisciplinary network of collaborators whose interests connect with Saraceno's research into spider behaviour and spider/web architecture, biomaterials and biotremology (the study of the vibrations created and felt by the spider in its web). As stated on the website, Arachnophilia 'seeks to weave a relationship between scientific, philosophical, cultural images and stories that describe the synanthropic and entangled relations that have existed between humans and spiders over thousands of years'.[40] The term *synanthropic* describes

species that live in close proximity to humans and benefit from the kind of environments humans create. Houses, gardens, shopping malls, waste dumps and other urban habitats provide spiders with protection from extreme temperatures and web-destroying predators. But the projects featured on the website also ask us to reconsider our own dependence on spiders and other invertebrates, which are disappearing at an increasing rate. This has major consequences for the ecosystems in which they participate, resulting in decreasing pollination rates, a decline in the decomposition of organic material (essential for all life cycles), and reduced food sources for other animals.

How we, as humans, might live with spiders in a way that is more attuned to their modes of existence becomes the most important theme of many of Saraceno's spider exhibits, and of the research exhaustively compiled for the website www.arachnophilia.net. The studies featured there emphasize the extent to which spiders coexist synanthropically with humans in domestic and industrial environments, having coevolved with humans over thousands of years.[41] This relationship, while it might seem inconsequential or even distasteful or irksome to us, is crucial to the maintenance of the ecosystems we rely on. Saraceno's *Spider/Web Pavilion 7* (2019), created for the 58th Venice Biennale, emphasizes the contemporary ecological importance of spiders and confronts us with an anomaly: 'While invertebrates make up more than 95% of animal species, most countries lack ethical guidelines and regulations regarding their nonhuman rights'.[42]

A large hybrid web dominates the entrance to *Spider/Web Pavilion 7*, of a similar kind to those developed for Saraceno's exhibitions worldwide. But the concept of interspecies communication and collaboration is taken further here, as *Spider/Web Pavilion 7* engages playfully with the idea of the oracle, drawing on spiders' real and mythical skills of divination. Spiders and other animals have been known to 'predict' weather events and even extreme natural phenomena such as earthquakes; observing their behaviour patterns closely might even improve our own forecasting of such events. Some communities, including the Mambila and other groups in Nigeria and Cameroon, practise spider divination to determine a course of action in a context of uncertainty, such as illness.[43] *Spider/Web Pavilion 7* therefore places scientific approaches to spider behaviour alongside ones grounded in the supernatural, which do not share a common ontological plane.

Thirty-three 'Arachnomancy cards' were displayed in the Pavilion, with designs reminiscent of tarot cards. These cards also form the basis of the Arachnomancy app, released in conjunction with *Spider/Web*

Pavilion 7. Touching a card in the app reveals its face, featuring a fine black-and-white line drawing and a title.[44] Before you can ask the oracle for a reading, you are asked to take a photograph of a spider/web nearby. Your image and its geolocation – uploaded, classified and stored in the Arachnophilia archive – contributes to 'a collective endeavour of mapping against extinction'. Once you have submitted your image, the reverse of the card is revealed. On each card is inscribed a short poetic text and some details of the species of spider depicted and the kind of web it weaves.

Most of the cards' illustrations are of webs; strikingly, they are almost always woven in or around plants or trees or the corners of a room, as if to demonstrate – as Ingold suggests – that 'the web is not an entity. That is to say, it is not a closed-in, self-contained object that is set over against other objects with which it may then be juxtaposed or conjoined.' Instead, it is a 'tissue of strands' that attaches to twigs, which are attached to roots, and all the other threads that link it to the wider environment.[45] The texts on the cards similarly emphasize coexistence and collaborative composition. They call our attention to 'sym(bio)poetics', 'interspecies togetherness', 'synanthropic futures', and 'entangled dependency'. They counsel us to take greater note of the natural world around us, to attune ourselves to the musical 'scores' of other organisms, and to consider our 'own score, and for which creature it is composed'.

Many of the texts explicitly undermine the premises of the 'one-world world' (OWW) that is the object of Escobar's critique, as it is for many decolonial thinkers. Escobar explains:

> The notion of the OWW signals the predominant idea in the West that we all live within a single world, made up of one underlying reality (one nature) and many cultures. This imperialistic notion supposes the West's ability to arrogate for itself the right to be 'the world', and to subject all other worlds to its rules, to diminish them to secondary status or to nonexistence, often figuratively and materially.[46]

The concept of the pluriverse challenges the notion of a single world in which we all live but interpret differently according to our particular cultural lens. It is founded instead on a relational ontology, in which multiple worlds coexist and, as Ingold states, 'beings do not simply occupy the world, they *inhabit* it, and in so doing – in threading their own paths through the meshwork – they contribute to its ever-evolving weave'.[47] In a similar way, one of Saraceno's Arachnomancy cards asks: 'What does it mean to be with worlds instead of being in them?'

After reading your chosen card, you are invited to type your question for the oracle, and then to cover your eyes and ears, and to 'feel the future', as your phone vibrates to a specific rhythm, taken from biotremological recordings held in the Arachnophilia archive. Biotremology is an important strand of the Spider/Web Research Group established by Saraceno and his collaborators, and a bioacoustic experimental research programme is currently exploring how and why spiders produce and capture vibrations.[48] In the context of the Arachnomancy app, however, the vibrations remain ludically opaque, reminding us that we have no skills to interpret their meaning. When they finish, you read: 'The Oracle has spoken […]. Spider/webs weave worlds of vibration in tune to the astral scores. Sense new threads of connectivity, or else face the eternal silence of extinction.' You are directed to www.arachnophilia.net, 'a living archive of coexistences', or to consult the oracle again. You can also share your reading by email with friends, or invite them to join Arachnophilia.

The operation of the app thus emphasizes community over communication, as the prophetic vibrations of the spider oracle are even more enigmatic to us than those of an ancient-world priestess. But appointing spiderwebs as oracles allows Saraceno to explore in a more poetic key the idea of 'a messenger between perceptual worlds', establishing a channel of communication between species that are rarely aware of each other's existence or ways of life.[49] Such communication may, in some cases, be biologically possible. Arachnophilia.net cites an article published in 1880 in *Nature* on 'The influence of a tuning-fork on the garden spider', an early experiment using a vibration source to induce a behavioural response in spiders.[50] The web may perhaps act as a medium for two-way communication between spiders and humans. Notwithstanding the potential scientific basis for such communication, the Arachnomancy project uses scientific accounts in a manner that leaves room for other ways of explaining relations. Many of the Arachnomancy cards retell narratives of fossil fuel extraction and climate change in a mythical key, as in the card entitled 'Lost Secret': 'Liquefied animals are burned to propel us toward unforeseen futures. They take over the sky after being cast out from the depths of the earth.' Ultimately – and this is potentially a weakness in Saraceno's projects – the scientific and the spiritual are represented as complementary discourses that are really just different ways of describing the same kind of relations. Ontological difference is passed over in the search for common ground. In a similar way, in the utopian imaginary of these projects, interspecies communication and collaboration succeed in bridging the divergence between different sensory worlds.

This is partly, of course, explained by the performative and speculative nature of these works, which recognize that the images we show and the stories we tell have a powerful effect on how we perceive and relate to other species. As a text on the Arachnophilia site explains,

> [o]ver thousands of years of cohabitation, spider/webs have figured differently in the collective human imaginary – sometimes as tricksters or oracles, but seldom as companion species whose futures are interconnected with our own. Our images and representations matter: they condition our affective relations to other species, influencing what we value – what we depend upon and consider worth caring for. If we rewrite our images of spider/webs as kin, what new forms of interspecies relations and practices of care might emerge?[51]

Saraceno's webs are therefore not just about interconnection, but what it means, practically and ethically, to live, evolve and create with and alongside other species. *Spider/Web Pavilion 7* and the Arachnomancy app call us to become more responsive to species that live alongside us, and whose worlds coevolve with our own, which in turn is a means to becoming more aware of the impact of human action and the need to minimize harm.[52] More broadly, however, his spider/web projects instil in us a greater understanding of the multiple, co-constituting worlds that make up the pluriverse, and lead us to consider the insights that a relational ontology might afford as we seek to negotiate it, without subsuming it within a single world.

II. Myrmecology and multispecies communities

If most spiders are solitary, ants engage in intensely collaborative practices that extend to many of the other species with which they create and transform habitats. Ants have been the focus of Kuai Shen's research and artistic work for many years. The communities of leaf-cutter ants he has nurtured cohabit with him in his studio, located in an erstwhile factory in an old industrial zone of Cologne. Like Saraceno, Kuai Shen works with piezo microphones and amplifiers to allow us to enter the sensorium of the ant. To a greater extent than Saraceno, however, he uses these technologies to draw attention to the biosemiotic basis of all life. He also emphasizes the ways in which ants make worlds that create opportunities for the world-makings of other species, drawing more direct comparisons and contrasts with human societies. While non-Western ontologies are

occasionally referenced in Saraceno's work within a broader critique of the Anthropocene, some of Kuai Shen's projects create a explicit dialogue between the social organization of ants and the communitarian social structures and cultural practices of traditional Andean societies. My analysis of his work will draw out the risks and possibilities of such comparisons, within a broader discussion of the value of biosemiotic approaches and 'arguments from nature' for decolonial thought.

A world in which many worlds fit

In *Thermotaxis* (2017), a thermal camera monitors a dome-shaped mound of pine needles, the top section of a nest of red wood ants (*Formica rufa*) extracted from woodlands near Vilnius, Lithuania, where the exhibition was held.[53] The mound seems empty and lifeless, but the camera picks up the heat created by insects, spiders, fungi, microorganisms, and other organic material the ants have gathered for their nest.[54] Data from the thermal images is then transformed into sound, combining distant, rumbling shudders with high-pitched whistles and the occasional whiplash effect or chime of a bell.[55] The sound is based on a digital musical score composed by Kuai Shen and activated by the variable intensity of the heat registered by the camera. He explains that it was intended to evoke 'atmospheric sensations of being immersed in hibernation'; it certainly creates an unhomely, remote soundscape.[56] Yet the sounds testify to the heat produced by multispecies collaboration, suggested musically by the presence of several distinct sounds interwoven to form a single track.

The exhibition text points to the importance of the red wood ant in the regulation of ecosystems, listing its roles in controlling outbreaks of pests, contributing to the nutrient heterogeneity of soil, aiding seed dispersal and creating the conditions for microbial communities to thrive. In these roles, ants are continually involved in 'transforming the availability and accessibility of resources to others', and building 'the foundations of a complex forest life' by facilitating relationships between multiple species.[57] Kuai Shen explains that the red wood ant hosts at least 49 living organisms, of which 12 depend on them for their survival; during the winter, the ants cluster together to produce heat, which is increased by the presence of other insect companions and microbial cohabitants. Kuai Shen contrasts the extraordinary success of ants as a colonizing species with that of humans. Unlike the rapid growth of human urbanization, ant expansion transforms natural spaces but at the same time offers 'opportunities for cooperation, reconstruction and cohabitation'.[58]

Biosemiotics and the social organization of ants

In Kuai Shen's *0h!m1gas* (2010), a series of interlocking plexiglass chambers houses a community of *Attini* leaf-cutter ants, a supply of leaves and the fungus they are cultivating (see Fig. 7.1).[59] This biological system is complemented by a technological one, composed of piezoelectric amplifiers, vinyl records, turntables, video cameras linked to motion-tracking software, and display screens. Kuai Shen describes the work as a 'biomimetic stridulation environment'. Leaf-cutter ants stridulate by raising and lowering a segment of their body, so that a ridged part of their abdomen is rubbed against a scraper, producing vibrations. Stridulation sends out an alarm signal (for example, if an ant is trapped), but it is also used to recruit nestmates to particularly lush leaf-cutting sites.[60] In *0h!m1gas*, the vibrations created by stridulating ants – not normally audible to humans – are picked up by sensors and converted into data that drives a stepper motor operating one of the turntables. The other turntable is driven by a different set of data generated by the movement of the ants, captured by video cameras. The jerky, unpredictable movements of the turntables produce bursts of sound that recall the screeching, warping and hissing effects created by DJs using scratching techniques.

Figure 7.1 Kuai Shen, *0h!m1gas*, 2012. Manifesta 9, Waterschei Mine, Genk, Belgium (photograph by Kristof Vrancken).

Kuai Shen explains that the work was inspired by the structural and functional resemblance between the ant's stridulatory organ and the vinyl turntable as an artefact of music production.[61] When amplified, the sound of ants stridulating is rather like the sound generated by the baby scratch, the chirp scratch or the tear scratch in turntablism, which denote different effects created by rubbing the needle against the grooves of a vinyl record. Both ant stridulation and scratching are, Kuai Shen proposes, evidence of emergence: both have developed into complex forms of social and cultural expression through being 'experienced, explored, intertwined, and remixed'.[62] Ants largely communicate through pheromones, but stridulation is an additional form of expression that is used to modulate or amplify other signals. Building an exhibition around stridulation allows Kuai Shen to emphasize the complexity of ant semiotics, expanding our awareness of the existence of sign systems beyond the human.

Charlotte Sleigh's strongly historicized exploration of myrmecology shows how changing cultural contexts in the late nineteenth and twentieth centuries framed how ants were used to model aspects of human life, becoming, successively, 'psychological, sociological, and informational entities'. Moral readings of ant behaviour have cast them either as a social ideal or as 'an anathema that humanity should avoid at all costs'.[63] For the late Victorians, ants were 'laudable models' of hard work and social responsibility, while in the early decades of the twentieth century they came to symbolize the 'unthinking mass' in which individualism would be entirely lost.[64] Ants have more recently been at the centre of protracted debates over the nature of (animal) instinct and (human) intelligence. If ants were formerly understood to work like tiny robots, fulfilling their programmed functions, more recent research has repeatedly highlighted their ability to learn, to alter their behaviour and to collaborate in order to solve non-linear problems. Following in Sleigh's historicist vein, Parikka's seminal work on insects and media technologies traces more recent deployments of insect models in the fields of cybernetics and artificial intelligence, as well as in cultural and media theory. Like Sleigh, he finds that 'insect bodies contract and transduce more abstract social and political concerns', becoming 'an overdetermined, floating signifier' for different, contradictory ways of thinking about bodies and collective life.[65]

Kuai Shen's own work – in projects such as *Thermotaxis* and *0h!m1gas* – certainly presents ant society as complex and intelligent, but it rejects the co-option of ant social organization for the purposes of presenting capitalism or economic rationalism as somehow more natural.

Eben Kirksey finds that the analogies drawn by biologists between ant and human labour have usually been 'grounded in economic models of rationality and scarcity'.[66] These assume that ants, like humans, are rational economic actors who pursue their own good. Kuai Shen's own understanding of ant communities strongly differs. While he also uses social organization in ants as an exemplar for human society to follow, the connection he makes is of a very different kind. He suggests that 'las hormigas tienen algo que decirnos, que nosotros no sabemos, para cuidar la naturaleza' (ants have something to tell us, that we don't know, about how to look after nature).[67] For Kuai Shen, ants 'succeed as eco-engineers because they create opportunities for other creatures'.[68] Leaf-cutters like the ones exhibited in *0h!m1gas* are often called 'agricultural' ants, as they developed farming techniques 50–60 million years before humans did.[69] These ants do not feed directly on plants or other insects, but instead bring fresh vegetation back to their nests to feed a fungus, which converts it into edible food for them. This interdependence between ants and their fungus has been called 'one of the most successful symbioses of all time'.[70]

Kuai Shen's intention in *0h!m1gas* is not only to contest a series of historical analogies based on the dynamics of social organization in ants. It is also, importantly, to question the perceived boundaries between nature and culture. The extent to which ants transform the landscapes they inhabit and cultivate, together with the complexity of ant semiotics, suggests that their way of being in the world is cultural as well as natural. The explicit parallels between stridulation and turntablism in *0h!m1gas* ask us to consider both as cultural practices that have emerged from social interactions within a specific environment. The work also enlarges our understanding of what media may mean, beyond the exclusively human, rather like the manner in which Parikka expands his definition of media to include 'a contraction of forces of the world into specific resonating milieus'.[71] Kuai Shen's embedding of human media technologies – the vinyl turntable – within a broader study of non-human semiotics and sonification responds to the 'urgent need' Parikka identifies 'for a cartography of potential forces of inhuman kinds that question evolutionary trees and exhibit alternative logics of thought, organization, and sensation'.[72]

Technozoosemiotics and 'mutual aid'

Like Saraceno, Kuai Shen has synthesized ant and human creativity in live, improvised acts of interspecies music-making. The sounds of ant stridulations are combined with instruments played by humans to form

hybrid electro-acoustic performances. In one of these, *Plectrum*, ant 'songs' are acoustically amplified and interwoven with the pluckings of an electric guitar, producing a kind of duet.[73] Like *0h!m1gas*, the performance is based on a physiological and acoustic analogy between the ant's scraper and the guitar plectrum. In 2012, Kuai Shen produced an album based on field recordings made in the Otonga Reserve in Ecuador with the title *Stridulation Amplified: Compositions with the Stridulatory Organ of Atta cephalotes*. Some of the tracks combine modified stridulation sounds into an electronic composition, while others are original recordings of the acoustic vibrations generated by the ants in situ; all of them, however, bear traces of some kind of the human–ant encounters that generated the recordings. In one, Kuai Shen inadvertently left a microphone on while other people were using the lab in which he was recording: we hear the ants' stridulations accompanied by the sounds of human activity in the same environment. Playfully, Kuai Shen suggests that the pieces recorded for *Stridulation Amplified* might be played back for the ants to 'feel and enjoy'.[74] Although this idea was initially a metaphorical one, he discovered that the piezoelectric sensors used to record the ants' vibrations could also be used as a loudspeaker, to retransmit acoustic sound as a series of vibrations that would be sensed by the ants.[75]

The zoologist and artist Louis Bec coined the term *technozoosemiotics* to refer to the use of technology to create interfaces between the sign systems of different species. Situated 'at the cross-roads of semiotics, ethology, the cognitive sciences, technology, computer science and artistic activity', the aim of technozoosemiotics, as conceived by Bec, is to develop forms of interspecific communication to enhance the potential for 'exchange and assistance among all parts of the alive'. These could even succeed in 'laying the foundation for a new ecosystemic, geopolitical, geocultural and economic approach'.[76] In a similar manner, Kuai Shen considers that his own hybrid systems bring together technology and biology in a way that allows him to 'promote and consolidate environments that breed life'.[77] As 'an unknown territory we need to explore', interspecies communication allows us to 'experience the perceptions and sensorial apparatuses of complex societies that can inspire us'.[78]

What inspires Kuai Shen most about the complex societies ants create is their commitment to mutualism and how this might change our thinking about the ways in which we compose our own worlds. He identifies the Russian geographer and activist Peter Kropotkin as '[p]erhaps the first advocate of mutualism regarding the ethologies of

inter-species relation'.[79] Kropotkin's *Mutual Aid: A factor of evolution* (1902) presents the case for considering 'Mutual Aid and Mutual Support' as 'a feature of the greatest importance for the maintenance of life, the preservation of each species, and its further evolution'.[80] Although he does not dispute the existence of interspecies warfare in what Darwin described as 'the struggle for life', Kropotkin finds – on the basis of his own extensive observations of animals in their habitats – that cooperation is 'far more important' than contest.[81] Kropotkin is careful to distinguish between Darwin's own work – in which he explored evidence for cooperation as well as competition – and the 'narrow' interpretations of it peddled by his followers.[82] These have led to a widespread conception of the animal kingdom as 'a world of perpetual struggle among half-starved individuals, thirsting for one another's blood'.[83] Instead, Kropotkin emphasized that, among animals belonging to the same species, or even to the same society, 'Sociability is as much a law of nature as mutual struggle'.[84]

Kropotkin's emphasis on cooperation over competition is prescient of more recent turns in evolutionary biology. His zoological observations and conclusions became the foundation of a broader anarcho-communist philosophy, which advocated the abolition of the state and capitalism in favour of the many examples of common ownership and cooperation that he found at work in 'primitive' tribes, early European societies, and villages far removed from the Tsarist government, vestiges of which persisted in the labour union movements of his time. He draws continual parallels between insect or animal cooperation and human societies that are not organized around capitalist principles of private ownership. His work thus presents the commons not as some quaint, premodern form of social organization that was bound to die out as the state and the market gained power, but as a vital dynamic that is fully in consonance with the flourishing of biological and social life throughout the history of evolution.

Ant communities and Andean collectives

Kuai Shen's exhibition *Yupana emergente: Biológicas ancestrales y cosmovision andina reanimada por hormigas* (Ancestral Biologics and Andean Cosmovision Reanimated by Ants, 2014) can in many ways be seen as a continuation of Kropotkin's project.[85] The exhibition was the result of a collaboration with the German artist Katharina Klemm and the Colombian media artist Gabriel Vanegas.[86] It connects the social organization of ant colonies with that of traditional indigenous

communities via a series of visual analogies. In the centre of the gallery space, glass ant enclosures sit on top of a number of truncated pyramids. Inside, Acromyrmex leaf-cutter ants cultivate their fungal garden by feeding it with fresh vegetation and removing waste. They collect leaves from an enclosure in which a *yupana* has also been placed. The *yupana* cannot be accurately translated into English, given the absence of equivalent instruments in the West and insufficient knowledge about its historical use. It takes the form of a table comprising a series of boxes; it is understood to have been used by pre-Incan cultures to count and to archive stories in conjunction with the *quipu* (or *khipu*, a recording device made from knotted cords), while some local archaeological findings even suggest that it was also used to calculate when solstices and equinoxes would fall. During the Incan Empire, both the *yupana* and the *quipu* became sophisticated systems for counting and collecting taxes.[87]

The pyramids are linked in a straight line with narrow white bands, allowing the ants to move between one part of their community and another (see Fig. 7.2). The path thus created duplicates another series of straight white lines traced on the floor, emanating from the pyramids and leading out to the gallery walls. These resemble *ceques*, a series of ritual pathways that led outward from Cusco to the rest of the Incan Empire, linking *huacas*, which were places of ceremonial or religious significance

Figure 7.2 Kuai Shen with Gabriel Vanegas and Katharina Klemm, *Yupana emergente*, 2014. Centro de Arte Contemporáneo in Quito, Ecuador (photograph by the artist).

located along the way. In the exhibition, these lines therefore identify the ant pyramids with ancient *huacas*, a resemblance strengthened by the presence of photographs of stone-built altars at sacred sites, in the form of small pyramids. To these two series of lines, a third is added, with the display of a large *quipu* on one of the gallery walls. These knotted strings were used in the Andean region to keep records, including calendrical and astronomical data that would have been indispensable to an agricultural society. The exhibition text reinforces the parallel between ant organization and instruments of Andean culture, referring to the foraging columns of army ants, which emanate outwards from the nest, creating a pattern that is echoed in the *quipu*.

The visual connections created between the biosocial life of ants and ancient Andean societies are complemented by a series of images and texts on the gallery walls that draw attention to the importance of *yupanas*, *quipus* and other technologies in Andean culture. The exhibition thus performs a media archaeology of some of the most important technologies and social practices of Andean society, demonstrating the extent to which they are rooted in biosocial forms of organization also found in other species. Further associations are made, for example, between the division of labour in *Acromyrmex* ant communities and in Andean societies: exhibition texts compare the organization of ants into castes, to perform different tasks for the benefit of the whole community, with the function of *ayllus* (which pre-date the Incan Empire), self-sustaining collectives in which kin members worked on behalf of the community. It is also suggested that we think of the leaf-bearing ants as *chasquis*, the messengers who carried messages and gifts across the Incan Empire.

Images of the *chakana*, or Southern Cross, remind visitors of the Andean cosmovision that was violently supplanted by the cross of the Catholic Church, as a strategy of colonization. *Yupana emergente* clearly has a decolonizing aim, reanimating traditional forms of social organization – some of which are still in evidence in indigenous communities today – by using living organisms to trace their lines and figures. One gallery text reads: 'Si nos abrimos a otras formas de percepción e interrelación, nos daremos cuenta que el mundo en el que vivimos no es una ley natural, sino el resultado de una imposición económica, política y social' (if we open ourselves up to other forms of perception and interrelation, we will realize that the world we live in is not a natural law, but the result of a social, political and economic imposition). We are encouraged to reflect on the importance of the ancestral knowledge and practices that were all but lost with the invasion

of the Spanish and the subsumption of the Americas to colonial capitalist enterprise, and to question whether other forms of social organization and common ownership, closer to the kinds of cooperation Kropotkin found everywhere in the animal world, might serve as better models for contemporary communities.

Arguments from nature in decolonial thought

There is, of course, a sinister colonialist ring to the depiction of 'primitive' societies as closer to nature, still able to enjoy a relationship lost by the developed world in its embrace of modernity. Linda Tuhiwai Smith reminds us that '[i]n the nineteenth century the scientific drive assumed that there were universal models of human society and human nature, and that societies deemed to be more primitive could contribute to science by showing the most simple, most fundamental systems of social organization'.[88] Through the analogies it creates with ant organization, Kuai Shen's *Yupana emergente* might be seen to encourage us to view indigenous Andean society as more natural, and therefore more universal, or even more primitive.

However, three crucial differences mark the replacement of this colonial vision with a more decolonial one. The first is that Andean social organization, like that of ants, is not presented as 'simple' but as complex, flexible and adaptable. There is also no attempt to elevate Andean philosophy to the status of a hegemonic discourse; instead, the intention is to pluralize knowledge. This is very much in line with the anti-universalist approach to environmentalism taken by many Latin American thinkers, for whom, as Leff states, it is '[e]sa idea de lo Uno, del dios único que organiza al mundo en una unidad, en un *uni*verso, es lo que está entrando en crisis' (that idea of the one, of the one God who organizes the world into a unity, into a *uni*verse, is that which is being thrown into crisis).[89]

The second difference lies in the emphasis on knowledge and practice, which counters the underlying racism of colonial representations of indigenous people as closer to the natural world. Escobar argues that the ontological struggles of indigenous, Afrodescendant and other peoples in Latin America over land designated for development are producing 'among the most insightful knowledges for the cultural and ecological transitions seen as necessary to face the crisis'. This is because these knowledges are 'profoundly attuned to the self-organizing dynamics of the Earth'.[90] There are no traces of essentialism or primitivism here: it is not that indigenous people are *themselves* 'closer to the Earth' but that the forms of knowledge and practice that many communities

have developed, founded on relational ontologies, are more valuable in thinking our way to a possible future world beyond the deep social inequalities and ecological damage bequeathed by colonialism and capitalism.

And finally, a 'return to nature' is not represented here as a nostalgic escape to some past plenitude but as a model of the society of the future, in which we will all need to find more creative and less destructive ways of cohabiting with other species. A 'return of the communal' is increasingly in evidence in indigenous and popular struggles in Ecuador and a number of nearby countries, where it is a crucial way of envisioning a post-capitalist, post-liberal society, in which capitalism and liberalism will no longer be the hegemonic forms of economic and social organization.[91] Appeals to traditional forms of knowledge are not necessarily nostalgic: referring to Afrodescendant communities in Colombia, Escobar claims: 'Far from an intransigent attachment to the past, ancestrality stems from a living memory that orients itself to the ability to envision a different future – a sort of "futurality" that imagines, and struggles for, the conditions that will allow them to persevere as a distinct world.'[92]

'Arguments from nature' have, of course, been roundly rejected by feminists and opponents of slavery and racism, given their deployment throughout history in order to naturalize many forms of social inequality. In Kuai Shen's *Yupana emergente* and other exhibitions, they play a more liberatory role in stripping Western capitalist modernity of its claim to represent the natural (Darwinian) order of things, in which nature is reduced to a resource for which humans compete. Weber describes how the workings of Darwinist natural selection have been adopted to explain the dynamics of a free market economy: 'In perennial rivalry, fit species (powerful corporations) exploit niches (markets) and multiply their survival rate (profit margins), whereas weaker (less efficient) ones go extinct (bankrupt).' He explains, however, that '[t]his metaphysics of economics and nature […] is far more revealing about our society's opinion about itself than it is an objective account of the biological world'.[93] Weber's own use of metaphors from nature avoids biological reductionism and determinism: as he states, if we look to nature for models of a commons economy, 'Natural principles may impose certain necessary parameters to life, but those principles are nondeterministic and allow for significant zones of creativity and autonomy.'[94] A number of decolonial thinkers, of whom Escobar is perhaps the most prominent, draw extensively on the work of biologists and ecophilosophers in their discussions of relational ontologies in the social world, licensed to do so in part by their critique of the Western divide between nature and culture.

Most importantly, of course, culture is not here reduced to nature; the two are interwoven in what Eduardo Gudynas would call 'social-ecological assemblages'[95] that demonstrate how the social organization of human and non-human species has evolved within a specific landscape, and in 'dialogue' with the affordances and constraints of that environment, shaping it and being shaped in turn. Divisions between nature and culture are eroded in the work of both Saraceno and Kuai Shen through an emphasis on the semiotic in invertebrate cultures. Wendy Wheeler affirms that it is 'increasingly well understood that numbers of other species have rudimentary forms of culture', leading to the view that 'culture is semiotic, biosemiotic, evolutionary and natural'.[96] This is not to say, she is clear, that culture can be reduced to nature, but that 'both natural and cultural life evolve layer upon layer'.[97]

From biocentrism to posthumanist curation and spectatorship

The 'social-ecological assemblages' Gudynas describes arise from the interdependence of humans and non-humans as conceived in the biocentric perspectives developed by many Andean and Amazonian communities.[98] These constitute 'radical attempts to question modernity', exposing its limits and exploring alternatives to its instrumental values.[99] Although these projects differ, what they hold in common 'is a value shift from utilitarian anthropocentrism to multiplicity and biocentrism'.[100] With *Yupana emergente*, Kuai Shen engages directly with cultures that have been built on such principles. In contrast, the intensely poetic discourse produced by Saraceno's studio team has taken on increasingly mystical overtones but floats free from any particular cosmovision. Repeated exhortations to perceive the interconnections between all things, human and non-human, material and spiritual, are expressed in a language that resonates in a very general way with contemporary ecological thought, new materialism, practices of mindfulness (which originated in Buddhist thought but have since disseminated much more widely), and holistic New Age spirituality. However, both artists clearly promote a biocentric perspective, adopting an ethical approach that stems from a belief in the value inherent in all living things, and opposing the human-centred approaches to nature that characterize Western modernity.

Staging the aesthetic creativity of other species and their social intelligence goes a good way towards contesting the utilitarian management of nature and ascribing an inherent value to non-human life. While invertebrate creativity is certainly displayed here for the aesthetic enjoyment of human viewers, the spectatorial distance that is

preserved in a gallery space – and reinforced in Kuai Shen's case by glass containers – helps us to understand that this beauty and this complexity emerge from the ways in which these creatures connect with and compose their own world rather than existing for our pleasure or contemplation. As Weber puts it, 'The beauty of living things stems from the fact that they are embodied solutions of individual-existence-in-connection.'[101] The need to use techniques of amplification and magnification to tap into the sensory worlds of invertebrates is also key to the presentation of their creativity as part of the intrinsic value of nature: the extraordinary feats of communication and composition we witness in exhibitions by Saraceno and Kuai Shen would pass us by in daily life, as our senses are not attuned to them. These are not species that we would seek to preserve on the basis of their aesthetic value to humans, but for the crucial roles they play within complex ecologies (in which we are also implicated), and for the inherent value of their perceptual intelligence and skill in crafting.

This is one of the ways in which these projects move beyond humanist notions of ethics and of spectatorship. Entanglement in and of itself does not necessarily undermine a humanist ethics, as the idea – profoundly challenging as it may be – that what is good for other species is good for us might simply retain the fundamental objective of ameliorating human society. By choosing to work with invertebrates, Saraceno and Kuai Shen challenge the common categories we use to sort other living beings into ones that are worth preserving and ones that do not need our protection, which are often based on the degree to which we perceive them as similar to us or on their aesthetic or economic value to human society. Through their projects, both artists enjoin us to become more conscious of the activity of invertebrates in our localities, and to appreciate their significance for more-than-human communities.

As yet, no nation has devised laws or ethical codes of practice for working with insects. Kuai Shen reflects explicitly on the questions of care raised by the practice of curating live ant exhibitions in the absence of such legislation. Moving ant communities from one place to another in order to exhibit them exposes them to risk; reflecting on his responsibility towards them becomes an important part of Kuai Shen's research. He was surprised that, during the *Manifesta* exhibition of *0h!m1gas*, only three of its many visitors expressed concern about where the ants had been taken from, why he was 'imprisoning' them, and whether the community was really growing.[102] His artistic practice involves a continual reflection on the need to care, daily, for the ants from whom he hopes to learn, and of care as an important part of that learning itself. Performing with ants 'requires continuity and nurturing relations' and a specific

concern for their 'ecological needs'; Kuai Shen maintains that all artistic performances that involve other living beings demand a similar attention to the ethical implications of such intervention.[103] A commitment to care in relation to his invertebrate co-creators has shaped a decision to work more often in the future in their natural habitat rather than transporting them to his own. To work with ant communities directly in the Amazon forest is to subject himself to a degree of physical risk and discomfort that he considers to form part of his broader responsibility as an artist.[104] It is a gesture towards the kind of reciprocity that is an essential part of our responsibility to other species.

The emphasis on biosemiotics in projects by Saraceno and Kuai Shen – demonstrating the extent to which other species build a culture that relies, like ours, on signs and their interpretation – opens up not only an ethical perspective but also a decolonial one. The understanding we gain of the biosocial and biocultural world-makings of other species challenges the divisions on which Western modernity has been founded, and specifically the separations between culture and nature, and humans and non-humans. The artistic and curatorial practices developed by Saraceno and Kuai Shen also contest the notion that our knowledge of other species and the natural world is independent of our relationship with it, a conception rooted in rationalist Western modernity and underpinned by the objectifying processes of science. In contrast, Escobar observes, the relational ontologies of many Andean and Amazonian communities are 'built on the basis of the interconnectedness and interdependencies of everything that exists, including all kinds of entities (human and not), on the continuity between knowing, doing, and being and between the biophysical, human, and spiritual worlds'.[105] The relationship these artists forge between knowledge and care will be addressed in the Conclusion as part of a broader discussion of changing notions of participation in contemporary art–science projects.

Notes

1. Weber, *Biopoetics*, 6; among the works cited by Weber as growing evidence of this approach are Hoffmeyer, *Signs of Meaning in the Universe*, Deacon, *Incomplete Nature*, and Kull, 'Evolution, choice, and scaffolding'.
2. Weber, *Biopoetics*, 3.
3. Blaser and de la Cadena, 'Introduction', loc. 88, 144.
4. Escobar, 'Thinking-feeling with the Earth', 20.
5. See, for example, *Galaxies Forming along Filaments, like Droplets along the Strands of a Spider*'s *Web*, first exhibited at the Venice Biennale in 2009, and *14 Billions (Working Title)*, exhibited at Bonniers Konsthall, Stockholm, between 25 February and 20 June 2010.
6. Closs Stephens and Squire, 'Politics through a web', 9.
7. Engelmann, 'Of spiders and simulations', 309–10.

8. The analogy has become popular since the publication in 2006 of images captured by the Hubble Space Telescope, which showed the morphology of radio galaxy MRC 1138–262 to be 'reminiscent' of a spiderweb. Miley et al., 'The spiderweb galaxy', L29. Studies published two years later provided evidence to support the theory that the missing (hitherto undetectable) 50 per cent of baryonic matter in the universe makes up a dense gas forming 'an enormous spider web of tendrils' linking galaxies and clusters. Werner et al., 'Detection of hot gas in the filament connecting the clusters of galaxies Abell 222 and Abell 223'; also see Thompson, 'Piece of missing cosmic matter found'.
9. Engelmann, 'Of spiders and simulations', 315.
10. Engelmann, 'Of spiders and simulations', 315.
11. Parikka, 'A recursive web of models', 327, 321.
12. Escobar, *Designs for the Pluriverse*, 101.
13. Ingold, *Being Alive*, 63.
14. Ingold, *Being Alive*, 92, 64.
15. See Engelmann, 'Social spiders and hybrid webs at Studio Tomás Saraceno'.
16. The exhibition, entitled *Cómo atrapar el universo en una telaraña* (*How to Entangle the Universe in a Spider Web*), was shown in the Museo de Arte Moderno in Buenos Aires from 7 April 2017 to January 2018. Images of the exhibition may be viewed at https://www.estherschipper.com/exhibitions/473-how-to-entangle-the-universe-in-a-spider-tomas-saraceno and https://www.museomoderno.org/en/exposiciones/tomas-saraceno-how-entangle-universe-spider-web. Accessed 28 October 2020.
17. *Arachno Concert: With Arachne (Nephila senegalensis), Cosmic Dust (Porus* [sic] *Chondrite), and the Breathing Ensemble* formed part of the *Aerosolar Journeys* exhibition, held at the Wilhem-Hack Museum in Ludwigshafen am Rhein (11 February to 30 April 2017) and subsequently at the Museum Haus Konstruktiv in Zurich (1 June to 3 September 2017). The same design principles were used in *The Cosmic Dust Spider Web Orchestra* element of the exhibition held at the Museo de Arte Moderno de Buenos Aires, *Cómo atrapar el universo en una telaraña* (*How to Entangle the Universe in a Spider Web*).
18. Schaschl and Saraceno, 'Everything starts as a cloud of cosmic dust: A conversation between Sabine Schaschl and the artist', 98.
19. Mortimer, Soler et al., 'Tuning the instrument'.
20. Mortimer, Gordon et al., 'The speed of sound in silk'.
21. See http://arachnophilia.net/scanning-the-web. Accessed 29 October 2020.
22. Varela, *Ethical Know-How*, 8.
23. Varela, *Ethical Know-How*, 13.
24. Varela, *Ethical Know-How*, 18.
25. Ingold, *Being Alive*, 85.
26. Uexküll, *A Foray into the Worlds of Animals and Humans*, 69.
27. Uexküll, *A Foray into the Worlds of Animals and Humans*, 54.
28. Uexküll, *Theoretical Biology*, 89.
29. Uexküll, *A Foray into the Worlds of Animals and Humans*, 172.
30. Uexküll, *A Foray into the Worlds of Animals and Humans*, 158, 190–1; also see 158–60.
31. Parikka, *Insect Media*, 68.
32. Uexküll, *Theoretical Biology*, 166.
33. Escobar, *Designs for the Pluriverse*, 83.
34. Escobar, *Designs for the Pluriverse*, 67.
35. Escobar, *Sentipensar con la tierra*, 145.
36. Escobar, *Sentipensar con la tierra*, 146.
37. Uexküll, *A Foray into the Worlds of Animals and Humans*, 54.
38. Escobar, *Designs for the Pluriverse*, 101; emphasis in original.
39. Blaser and de la Cadena, 'Introduction', 18, 19.
40. See http://arachnophilia.net/about-us/. Accessed 29 October 2020.
41. See http://arachnophilia.net/mapping-against-extinction/. Accessed 29 October 2020.
42. The 58th Biennale was held between 11 May and 24 November 2019. See https://studiotomassaraceno.org/spiderweb-pavilion-7/. Accessed 29 October 2020.
43. See Gufler, 'Yamba spider divination'.
44. Images of the cards may be viewed at https://studiotomassaraceno.org/arachnomancy-cards/ and the app is available to download for iOS or Android (see http://arachnophilia.net/arachnomancy). Accessed 30 October 2020.

45. Ingold, *Being Alive*, 91.
46. Escobar, *Designs for the Pluriverse*, 86.
47. Ingold, *Being Alive*, 71.
48. See http://arachnophilia.net/sonifying-the-web. Accessed 30 October 2020.
49. See https://studiotomassaraceno.org/spiderweb-pavilion-7/. Accessed 30 October 2020.
50. Boys, 'The influence of a tuning-fork on the garden spider'. See http://arachnophilia.net/mapping-against-extinction.
51. See http://arachnophilia.net/entanglements. Accessed 30 October 2020.
52. Bennett, *The Enchantment of Modern Life*, 157.
53. The work was shown as part of the *Citynature: Vilnius and Beyond* exhibition, held in the National Art Gallery in Vilnius, Lithuania, between 3 February and 19 March 2017.
54. Originally, Kuai Shen had intended to remove part of the nest with the ants hibernating in it. Later, he realized that it was likely that the ants had moved further below ground, as the mound was moved late in winter that year. The upper part of the mound was clearly still living, however, with its resident organisms such as spiders, mites, fungi and bacteria. In order to minimize disruption to the ant community, Kuai Shen did not return to extract more of the mound.
55. A recorded sample of the sound produced may be heard at http://kuaishen.tv/thermotaxis.html. Accessed 30 October 2020.
56. Auson, 'Tactical ant media', 691.
57. See http://kuaishen.tv/thermotaxis.html. Accessed 30 October 2020.
58. See http://kuaishen.tv/thermotaxis.html.
59. The title *0h!m1gas* is pronounced like the Spanish word for ants, *hormigas*. The work was first shown as part of Manifesta 9, the European Biennial of Contemporary Arts, held at Waterschei Mine, Genk, Belgium, between 2 June and 30 September 2012. A video documenting the exhibition may be viewed at http://kuaishen.tv/0hm1gas/0hm1gas_movie_all.html. Accessed 18 May 2020.
60. Roces and Hölldobler, 'Use of stridulation in foraging leaf-cutting ants'.
61. Kuai Shen, '0h!M1gas'. Amplified sounds of ant stridulation recorded by Kuai Shen can be heard at http://kuaishen.tv/stridulations.mp3. Accessed 10 November 2020.
62. Kuai Shen, '0h!M1gas'.
63. Sleigh, *Six Legs Better*, 11.
64. Sleigh, *Six Legs Better*, 17.
65. Parikka, *Insect Media*, 43.
66. Kirksey, *Emergent Ecologies*, 28.
67. Conversation with the author, 21 March 2019.
68. Kuai Shen, '0h!M1gas'.
69. Hölldobler and Wilson, *The Leafcutter Ants*, loc. 296.
70. Hölldobler and Wilson, *The Leafcutter Ants*, loc. 203.
71. Parikka, *Insect Media*, xiv.
72. Parikka, *Insect Media*, xix.
73. See http://kuaishen.tv/plectrum.html. Accessed 10 November 2020. The first *Plectrum* performance was given in Cologne on 13 September 2014, with musicians Markus Muschenich and João Martins. Performances have also taken place in Dresden (2015) and Lugano (2016).
74. See http://kuaishen.tv/stridulation-amplified.html. Accessed 10 November 2020. As far as is known, this is not scientifically possible, as ants do not hear in the same way as we do: they sense the stridulations of other ants through their legs.
75. Correspondence with the author, 15 July 2019.
76. See https://v2.nl/archive/articles/squids-elements-of-technozoosemiotics. Accessed 31 October 2020. The essay was originally published in Bec, 'Squids, elements of technozoosemiotics'.
77. See http://kuaishen.tv/0hm1gas/0hm1gas_movie_all.html. Accessed 10 November 2020.
78. Kuai Shen, '0h!M1gas'.
79. Kuai Shen, '0h!M1gas'.
80. Kropotkin, *Mutual Aid*, 2.
81. Kropotkin, *Mutual Aid*, 11.

82. Kropotkin points to Darwin's acknowledgement in *The Descent of Man* that the pursuit of mutual welfare within animal societies creates the best conditions for survival. Communities that cooperate, Darwin writes, 'would flourish best, and rear the greatest number of offspring'. Kropotkin, 9; Darwin, *The Descent of Man, and Selection in Relation to Sex*, 1:82.
83. Kropotkin, *Mutual Aid*, 10.
84. Kropotkin, *Mutual Aid*, 11.
85. *Yupana emergente* was first exhibited at the Centro de Arte Contemporáneo in Quito from 13 December 2014 to 8 February 2015. See http://kuaishen.tv/yupanaemergente.html. Accessed 31 October 2020.
86. Katharina Klemm and Gabriel Vanegas lead an intercultural project based in Santa Rosa de Cabal, Colombia, which brings together farmers, indigenous and Afrodescendant groups, academics, scientists and local inhabitants to exchange knowledge and develop projects in teams. See https://www.minkalab.org. Accessed 31 October 2020.
87. See, for example, Moscovich, *El khipu y la yupana*.
88. Smith, *Decolonizing Methodologies*, 86.
89. Leff, *Discursos sustentables*, 84; emphasis in original.
90. Escobar, 'Thinking-feeling with the Earth', 24.
91. Escobar, *Designs for the Pluriverse*, 176–7; Escobar, 'Latin America at a crossroads', 11–12.
92. Escobar, 'Thinking-feeling with the Earth', 19.
93. Weber, *Enlivenment*, 24.
94. Weber, *Enlivenment*, 40.
95. Gudynas, 'Deep ecologies in the highlands and rainforests', 4.
96. Wheeler, *Expecting the Earth*, 65.
97. Wheeler, *Expecting the Earth*, 65.
98. Gudynas, 'Deep ecologies in the highlands and rainforests', 4.
99. Gudynas, 'Deep ecologies in the highlands and rainforests', 5.
100. Gudynas, 'Deep ecologies in the highlands and rainforests', 5. Gudynas acknowledges that biocentric perspectives are not shared by all indigenous societies: Gudynas, *Derechos de la naturaleza*, 110.
101. Weber, *Enlivenment*, 38.
102. Conversation with the author, 21 March 2019.
103. Auson, 'Tactical ant media', 685, 689.
104. Conversation with the author, 21 March 2019.
105. Escobar, 'Afterword', 396.

Conclusion

Art, science and the decolonization of knowledge

Developed at the intersections between multiple disciplines (art, philosophy, architecture, engineering, physics, chemistry, biology, astronomy and others), the projects explored in this book may be viewed as 'limit cases' that give us special insight into what aims or means – if any – could be regarded as specific to those different branches of knowledge and practice. Many of them demand that we suspend or revise more common distinctions between art and science. What separates the collection of atmospheric data by the global Aerocene community from a citizen science project? How do the prototypes designed by Ivan Henriques for terraforming Mars differ from the very similar research being undertaken by NASA? On what grounds would we classify the gene-editing techniques used by Lina Espinosa as 'art' but not the use of CRISPR by amateur biohackers? It is abundantly clear that artists and scientists share many experimental methods and modes of presentation. There is also considerable overlap between many art–science projects and citizen science projects in their pedagogical aims and their attempts to create opportunities for hands-on, do-it-yourself experimentation. Although – as I suggested in the Introduction – art may circulate in spheres that are less restricted than those of laboratory science, scientists are also increasingly stepping out of the confines of academic and commercial laboratories in order to engage with the general public in a wide variety of performances, exhibitions and workshops.

As we have seen, some differences certainly emerge in art's greater interest in making sensory the abstract knowledge gained through science. But this is far from a fully accurate distinction, given the heavy reliance of many branches of science on modes of visualization that we might regard as artistic, with certain choices made for expressive or persuasive purposes. Conversely, while the art–science projects described in this book clearly aim to stimulate a sensory and affective response in their viewers and participants, their impact is not confined to such a response: they also expand and interrogate what we know about the planet's

living and non-living systems, even if an underlying didactic purpose is offset by spectacular, enchanting, playful or intimate performances. It is in this particular conjunction of the cognitive, the creative and the affective, I would suggest, that we may locate both the specificity of art in these works and their significant contribution to decolonizing science and nature. The art–science projects explored in this book construct an expanded conception of knowledge, in which cognition is a thoroughly sensory and embodied affair, reflecting the fact that our knowledge of the world is not a knowledge of something outside or beyond us, but of something in which we are always already entangled.

An understanding of the important roles played by subjectivity, affect and the aesthetic in the construction of knowledge is perhaps particularly relevant in the case of environmental knowledge. Beyond a grasp of biology and ecology, Enrique Leff argues, environmental knowledge also involves the formation of new subjectivities and the reinvention of individual and collective identities.[1] Creating this kind of knowledge, he insists, implies 'una desconstrucción del conocimiento disciplinario, simplificador, unitario' (a deconstruction of unitary, simplified, disciplinary knowledge).[2] Reconnecting with the natural world also involves the emotions, Eduardo Gudynas proposes, and for this reason he considers there should be no shame in defending the rights of nature from affective or aesthetic perspectives.[3] In a similar vein, Arturo Escobar draws on the term 'sentipensar' (feeling-thinking), used by activists in several parts of Latin America, 'to suggest a way of knowing that does not separate thinking from feeling, reason from emotion, knowledge from caring'.[4] Using imagery that reminds us of the auditory techniques developed by many of the artists in this book, Leonardo Boff affirms: 'Cuidar de las cosas implica tener intimidad con ellas, sentirlas dentro, acogerlas, respetarlas, darles sosiego y reposo. Cuidar es entrar en sintonía con las cosas, auscultar su ritmo y estar en armonía con ellas' (Caring for things means to be intimate with them, to feel them inside, to receive them, respect them, soothe them and give them rest. To care is to tune into things, to sound out their rhythm and to be in harmony with them).[5]

The art–science projects I have studied consciously create a space of encounter for multiple forms of knowledge and practice that transcend boundaries between the artistic and the analytical, the academic and the activist; between 'hard' and 'soft' sciences, the pure and the applied, the research-led and the practice-led. In his discussion of art projects that decolonize nature, T. J. Demos finds that

> some of the most ambitious artistic engagements […] are those that enact an intersectionalist politics of aesthetics, where art no

> longer prioritizes the gallery-enclosed experience of aesthetic contemplation alone, but rather emerges in close proximity to field research, creative pedagogies, political mobilization, and civil society partnerships and solidarities, whereby interdisciplinary collaboration mirrors the very complex relations of political ecology.[6]

This understanding of art as a privileged locus for transdisciplinary exchange, or simply as a part of an ecosystem that brings together scientific research, politics, civil society, technologies, other organisms and landscapes, is everywhere to be found in the Latin American projects explored in this book.

Their investment in the transdisciplinary construction of knowledge responds to a perceived need to resituate the rationalist, abstract knowledge generated by science within social, cultural and ecological contexts. Bruno Latour argues that good science is not now to be found in the precise, abstracted forms of laboratory knowledge:

> The truth of what scientists say no longer comes from their breaking away from society, conventions, mediations, connections […]. [S]cientists begin to speak in truth because they plunge even more deeply into the secular world of words, signs, passions, materials, and mediations, and extend themselves ever further in intimate connections with the nonhumans they have learned to bring to bear on their discussions.[7]

For this reason, he states, 'The more connected a science the sturdier it is'.[8] The transdisciplinary thrust of these art–science projects is not simply a bid to produce a more truthful knowledge or one that is more thoroughly embedded in the social, cultural and environmental worlds. It also stems from a recognition that knowledge is always a world-making project, never merely a world-representing one. As María Puig de la Bellacasa maintains, knowledge is an act of 'redoing worlds'.[9] In an interdependent world, to care or not to care for someone or something 'inevitably does and undoes relation'.[10] Quite literally, the exhibition of live organisms by Kuai Shen, Tomás Saraceno, Ana Laura Cantera, Guto Nóbrega and others removes them from some of the relations they have forged within their habitat in order to create – it is hoped – new relations with human viewers and listeners. In the gallery environment, they become fully dependent on human carers to supply them with what they need to survive. This staging of the need for care acknowledges the fact that knowing emerges from, and calls

for, care for or about something or someone. To link knowing with caring may, for Puig de la Bellacasa, 'reaffect objectified worlds, restage things in ways that generate possibility for other ways of relating and living'.[11] Projects by Kuai Shen, Saraceno, BIOS Ex MachinA and many others presented here ask us to consider how the particular kinds of knowledge pursued by modern Western science make and unmake worlds, and to question whether our world-makings allow room for the world-makings of other cultures or other species. Such questions take on vital importance in times that are 'deeply antiecological, and in many ways anticollective'.[12]

The aim of many of the art–science projects discussed in this book is to bring Western science together with alternative forms of knowledge in a way that suggests the possibility of new approaches and aggregates. The biocentrism Gudynas advocates 'no reniega de las ciencias contemporáneas, sino que las contextualiza y orienta de otra manera' (does not reject contemporary science, but contextualizes it and directs it in a different way).[13] In a similar way, Boaventura de Sousa Santos contends that 'the ecology of knowledges, while forging credibility for nonscientific knowledge, does not imply discrediting scientific knowledge. It simply implies its counter-hegemonic use'.[14] This might involve 'exploring the internal plurality of science, that is, alternative scientific practices that have been made visible by feminist and postcolonial epistemologies', as well as 'promoting the interaction and interdependence between scientific and nonscientific knowledges'.[15] Works by BIOS Ex MachinA and by Lina Mazenett and David Quiroga, among other artists, clearly promote this kind of interaction, without erasing the conflicts that emerge from it.

The task of (re)connecting science with other practices, from which it has been rigorously excluded in Western modernity, may be easier in the case of environmental knowledge than in other fields, but it remains a challenging negotiation. There is a risk that the representation of indigenous practices might feed a Romantic nostalgia for a lost, pristine nature now ruined by Western technoscience; similarly, indigenous communities may be elevated to the status of guardians of nature in a way that does nothing to tackle the social and economic injustices that characterize conflict over land use in Latin America and other regions of the world. In a context in which policy rarely responds adequately to the empirically based predictions of climate science, it may sometimes be politically exigent to insist on the value of expert knowledge, and at other times imperative to point to its limitations. For Josie Gill, a challenge the decolonization movement faces is the need to make the case for alternative forms of knowledge while distancing itself from 'the

deliberate and misleading denial of scientific fact' in a political sphere in which governments so often disregard the findings of science.[16]

Science and technology beyond humanism

An important way in which these projects 'decolonize' science and technology is in their use of both in ways that do not conform to humanist narratives, in which humanity's destiny is to progress towards an increasing control of nature. Some of them do retain a certain humanist narrative of redemption-by-technology that nonetheless aspires to create a less anthropocentric world. Works by Joaquín Fargas and Saraceno in particular share Félix Guattari's optimism in the potential of 'new techno-scientific means' to solve the major ecological problems that dominate contemporary times.[17] This does not mean in their case an uncritical belief in technology, but a desire to use technology to reconnect us with other spheres of experience and to galvanize us into taking clear action to reverse the damage we have caused to ecosystems. Their work thus counters the 'increasing deterioration of human relations with the socius, the psyche and "nature"' that, for Guattari, is the result of a 'fatalistic passivity' instilled in us by structuralism and postmodernism, which have 'accustomed us to a vision of the world drained of the significance of human interventions'.[18] Of all the artists in this book, Fargas is the most explicit in his belief in the power of human technology to solve the problems we have created. For Saraceno, although the design of new technologies will create new possible ways of living that will minimize our impact on the biosphere, the route to overcoming environmental challenges paradoxically lies in a renewed understanding of our dependence on the elements. His development of new forms of fossil-free flight and airborne living do not primarily express the human capacity to tame nature through technology but return us to an experience of exposure and vulnerability. His projects trace forms of interdependence that bind humans and non-humans together, suggesting new possibilities for a future life-in-common.

A number of the inventions created by artists featured in this book demonstrate a key function of art identified by Critical Art Ensemble, namely the creation of 'proof-of-concept models for postnatural assemblages that can serve conservationist efforts'.[19] In many works, however, what might initially seem to be a 'proof-of-concept model', while resting on sound science, actually holds a more complex relationship with plausibility. The potentially 'useful' art of

bioremediation in projects by Gilberto Esparza and Ivan Henriques, for example, turns out to have very little use in the real world, as the scale at which they operate is deliberately minuscule when measured against the severe contamination that characterizes many regions of the world. Many of the projects engage, in a similarly paradoxical way, with the idea of art as utility. They often subordinate aesthetic design to the communication of scientific ideas or to the exigencies of sustainability, while interrogating the very basis on which we might decide whether a particular design is 'useful' or not. Writing on bioart, Daniel López del Rincón finds that a lack of scientific utility may be understood not as a failing, but as a positive feature that brings into focus issues that would otherwise have remained out of view.[20] In a sense, the utility of art in these cases is precisely to show us that the world is not made for our use. We could also understand many of the works presented here as examples of 'the creative practice of speculative realism', in which art – as Demos submits – becomes a way of exploring 'what a "world-without-us" would be like, or what "zoe-egalitarianism" would mean and "becoming-Earth" entail'.[21] Technology in these projects is most often used to bring into focus the performativity of matter or the extraordinary natural capacity of organisms to communicate and collaborate successfully with other species, to regenerate themselves and their environment, and to adapt and evolve faced with adverse conditions.

Capitalism and the commons

Gudynas argues that a biocentric perspective is not 'una postura primitivista y anti-tecnológica' (a primitivist, anti-technological position); what is being proposed here is not a return to the caves but an advance towards a new future.[22] That future is not anti-technological, but it is generally anti-capitalist. Several projects analysed here contest the principles of biocapitalism by using biotechnologies to create opportunities for communication and collaboration rather than commodification. As Rosi Braidotti observes, cognitive capitalism profits from 'the scientific and economic understanding of all that lives', extracting value from 'the informational power of living matter itself, its vital, immanent qualities and self-organizing capacity'.[23] Science yields the knowledge and the techniques that make possible the patenting of genes or the coupling of living organisms to cybernetic systems to create new forms of robotics and computing devices. In this context, works by Henriques, Interspecifics and BIOS Ex MachinA in particular demonstrate

with clarity how such art projects of this kind may 'inspire, work with or subtend informational and scientific practices',[24] putting such research to alternative uses beyond commercial applications.

Many of these works may be read as deeply critical of capitalism, either explicitly or implicitly (in their active search for alternatives), and particularly in its extractive modes, its reckless subjection of ecological health to economic growth and development, and its commodification and privatization of knowledge. Their creators echo many Latin American political and social ecologists in their understanding of environmental problems not primarily as ecological in nature, but as rooted in the social, political and economic order ushered in by modernity. Leff states, uncompromisingly, that 'para que otro mundo sea posible, la producción del mundo tiene que basarse en otros principios. No sólo necesitamos un cambio de paradigma, sino que es preciso fundar *otra economía*' (for another world to be possible, the world's production must be based on other principles. We need not only a change of paradigm, but also to establish *a new economy*).[25] That new economy, as envisioned in the projects of many of the artists featured here, would be based on the commons. For Maristella Svampa, 'The concept of the common appears today as key in the search for an emancipatory paradigm in the new grammar of social movements in the global North, where struggle is defined against policies of adjustment and privatization (neoliberalism), as well as in countries of the South, where struggles confront developmentalist neoextractivism.'[26] Svampa attests to a rising interest in the commons from different disciplinary perspectives; many of the key concerns she lists – such as the protection of water, the defence of seeds, climate change, the digital and creative commons – are prominent in the projects discussed in this book.

Commoning practices can be understood as highly contestational in the neoliberal context. For Raquel Gutiérrez Aguilar, the politics of the common 'confronts and dissolves' liberal politics by derailing, complicating or slowing down projects that seek to expand capital accumulation.[27] The reappropriative and collective practices of the commons 'allow us to discern a dynamic and logic of life production and reproduction beyond capital and, therefore, beyond the state'.[28] The natural world depicted in many of these projects is organized around principles of cooperation and symbiosis rather than competition for resources, and this paradigm is extended to the social and cultural worlds with which it is intimately connected. The commoning practices of the artists themselves contribute to the development of alternative forms of community and sociability, as well as to kinds of knowledge that

do not conform to the principles or practices of the 'knowledge economy'. These knowledges are copyright-free, global in their circulation but often place-based in their development; they are transdisciplinary and often intercultural.

Many of the projects gathered in this book nevertheless emphasize the processes of construction and negotiation through which a commons and a common world must come into being. They point to the potential gains of cooperation with other species and of dialogue with other forms of knowledge without smoothing over the conflicts and compromises that necessarily arise from these. Rather than performing some sort of utopian reconciliation, many of these artists work – as Latour and Isabelle Stengers do – with a notion of cosmopolitics that contests the very idea of a unified cosmos. Latour declares: 'A common world is not something we come to recognize, as though it had always been here (and we had not until now noticed it). A common world, if there is going to be one, is something we will have to build, tooth and nail, together.'[29] Similarly, Gutiérrez Aguilar calls us to 'pensar *lo común* ya no únicamente como algo dado que se comparte sino, ante todo, como algo que se produce, reproduce y reactualiza continua y constantemente' (think of *the common* not only as something given that is shared but, above all, as something that is produced, reproduced and renewed, constantly and continually).[30] A commitment on the part of these artists to the commons and to constructing a common world leads to a distinctive set of strategies, as I outline below, that engage critically with mainstream theories and practices of participation and dematerialization in art. These strategies become a means of challenging humanist and anthropocentric perspectives, while pursuing a cosmopolitical agenda.

New modes of participatory art

A surge of participatory art projects across the world since the 1990s has emphasized the power of art to intervene in the social sphere. Many of these projects, Claire Bishop observes, attempt to circumvent the modes of artistic production and consumption that have prevailed under capitalism.[31] Rather than creating a discrete object that may be bought and sold in the art market, the artist stages an event or initiates an open-ended process that enlists the participation of others. The social relations that are forged or reconfigured as a result, or a new consciousness that is generated, are often more important than the aesthetic quality of any object or performance produced. While the search for artistic

strategies that would circumvent the commodification of art and the instrumentalization of nature is certainly shared by the artists featured in this book, they are less interested in rehumanizing a 'society of the spectacle' (Guy Debord) by replacing the passive spectatorship of a commodified life with authentic, lived experiences. Their emphasis is placed instead on the agency of other living organisms, whose complex forms of communication and social behaviour we are really only beginning to understand.

Indeed, these projects often complicate and even retreat from participatory modes of spectatorship. Rafael Lozano-Hemmer's *Flatsun* is based on a form of interaction that represents a delusional belief in the power of human agency. His *Vicious Circular Breathing* points to the dangers inherent in sharing spaces with others, creating a work in which participation may result in illness rather than social benefits. Many of the projects I have explored locate themselves in a world in which we have simply participated too much, and with insufficient restraint, to the detriment of other species and their natural habitats. Hence the emphasis on creating autonomous, self-sustaining systems in works such as Esparza's *Plantas nómadas* or Fargas's *Biosferas*, which require humans to exercise care precisely by stepping out of the way. These works are balanced by another series of projects – including Henriques's *Jurema Action Plant* – that do seek to create forms of interaction between human participants and other species, but the outcomes of such interactions are subject to the unpredictability of complex organic systems and are generally programmed for the benefit of other species rather than our own. The urgent need to develop technologies that draw on sustainable sources of energy and serve the natural cycles of ecosystems gives rise to a non-interventionist art of care-at-a-distance, in which we withdraw from, or willingly place constraints on, participation in order to let nature flourish. This does not lead, as we have seen, to a rejection of technology, but to a redirection of its means and ends.

On the other hand, many of these projects do actively encourage the participation of members of the public in workshops, events and forums, in which knowledge and skills are freely shared. They emerge from an ideological commitment to public education and engagement that often steps in to fill the gap left by the state, and indeed to actively construct alternative concepts of citizenship and knowledge. These are based on principles of open access, transdisciplinarity, the building of social relations through the common use of resources, the importance of amateurism, and engaging with local ecosystems and practices, even as

part of a transnational community. These principles are key to commons-based approaches of all kinds.

Only some of the art–science projects discussed here are conceived primarily as community projects, although many of them are developed within a collective, and a good number of them are extended in hands-on workshops open to the general public. Those run by Interspecifics, Colectivo Electrobiota, Kuai Shen, Esparza and others are designed to introduce members of the community to a greater knowledge of the natural world but also to equip them with the hands-on skills to explore it themselves, through cultivating plants or building basic electronic and mechanical systems. These projects are sometimes carried out under the aegis of educational institutions (schools and universities), but are just as likely to be informal, local affairs conducted in run-down premises in less affluent neighbourhoods. With access to far higher levels of funding for development, Saraceno's Arachnomancy app and the online Aerocene forum create the kind of global internet-based communities that are familiar to all users of mainstream social media technologies, but they too encourage members to seek out real spiderwebs and to construct and launch their own fuel-free sculptures.

Revising dematerialization and conceptualism in Latin America

The deployment in these projects of dematerializing strategies that emphasize the ephemeral, immaterial or intangible, creating encounters and performances of all kinds, is motivated not simply by a desire to challenge notions of the art object or to question authorship and originality, but by an ideological and ethical commitment to construct a different relationship with the more-than-human world. Luis Camnitzer observes that dematerialization in Latin America 'follows a prior set of ideological concerns', identifying this as a defining characteristic of conceptualism in Latin America.[32] Writing principally with reference to artworks of the 1960s and 1970s, he finds that dematerialization was, on the one hand, 'a form of applied economics' that allowed art to be produced inexpensively; on the other, it 'proved effective in addressing a primary concern of Latin American artists: the search to invent formats for sharing power: in art, with the viewer; in politics, with the citizens'.[33] Both concerns continue to motivate the use of dematerializing techniques in contemporary Latin American art–science projects. The difference,

perhaps, is that the sharing of power is now envisioned in the context of a more-than-human world.

Indeed, the question of power often comes to the fore in the way that these projects situate science within broader themes of epistemology and ethics, and in their construction of new relationships with the public. Jean-Marc Lévy-Leblond argues that in the recent surge of activities related to the public communication and understanding of science, we have failed to realize that what is missing is not simply access to knowledge, but access to power. It is not that the majority of citizens do not approve of or support science as they used to because they do not understand it, he suggests, but because they want decisions made about scientific research and technological development to be subject to a properly democratic process.[34] It is perhaps partly the heritage of a distinctive form of conceptualism in Latin America that thrusts questions of participation in power to the fore in this new wave of art–science projects. Camnitzer maintains that '[c]onceptualism in Latin America introduced the idea of art as a public domain', with questions of ownership a major concern.[35] He identifies 'empowerment' as 'the intention of much of the political/activist production of conceptualist art in Latin America', arguing that '[e]mpowerment can really only be achieved by exploring the fringes of what is known, by helping expand knowledge, and by keeping any flow of information bidirectional and multidirectional'.[36] The particular modes of participation and performance adopted by many of these artists and collectives are often designed precisely to achieve these objectives.

What counts as dematerialization in art is, of course, a question that only gains in complexity as it is explored. As Douglas Kahn points out, the American artist Robert Barry did not consider his work on electromagnetism to be an exploration of dematerialization; his aim was simply to engage with matter in the form of energy, and in states that elude human perception.[37] A more scientific understanding of the interchangeability between different states of matter and energy complicates any simple division between them, and becomes an important focus for many of the works discussed here, which make visible or audible – or give sculptural expression to – the bioelectrical, electromagnetic and other signals that animate everything that is. Projects by Ivan Henriques, Ariel Guzik, Paul Rosero Contreras, Guto Nóbrega, Gilberto Esparza, Colectivo Electrobiota, Interspecifics and others try to capture or generate moments at which one form of energy, matter or signal is converted into another. This brings us again to an interest in forces and forms of expression beyond the human. Signal, Anna Munster affirms, is 'fundamentally beyond, before and above the

human'.[38] As an energetic phenomenon, it resists circumscription and conscription, as 'its force and matter persist outside our attempts to encode and decode it'.[39]

Many of these projects, from *Jurema Action Plant* to *Cordiox*, dramatize the multiple, heterogeneous, fluctuating, unstable, entangled nature of signals that shape and traverse everything on the planet and beyond it. They do not consider signals primarily as a form of communication but as a transmaterial becoming, in which we are enmeshed with all other kinds of matter. If conceptualism tended to diminish the importance of the physicality of works in order to promote their intellectual aspects, these works promote a kind of thinking *through* matter, as a way of expanding our understanding of the embodied nature of knowledge, and as a bid to construct new forms of relation in a more-than-human world. This is a world in which – as works by Claudia Müller and Michelle-Marie Letelier remind us – human and non-human histories are intimately bound together and continually shaped by the enormous power of non-linear geophysical phenomena such as gravity and the dynamics of planetary winds and tides.

It is this theory of 'radical relationality' (Escobar)[40] that demands a thoroughly transdisciplinary approach to science, one that recognizes the ontological, political, affective and embodied dimensions of knowledge as a world-making practice. In the context of the Anthropocene, Latour contends, 'The idea of a science that emerges from the dispassionate study of external phenomena is now much more difficult to sustain.'[41] Equally, Gudynas affirms, while the insights of science have never been more important in helping us understand complex environments and how they change, 'La clave está en re-crear una nueva ciencia al servicio de toda la vida' (the key is in re-creating a new science at the service of all life).[42] These art–science projects, part of a new wave evident in many regions of the world, are perhaps uniquely positioned to promote the transdisciplinary, creative, intercultural, decolonial, commons-based knowledge we need to negotiate a path to a less anthropocentric era.

Notes

1. Leff, *Discursos sustentables*, 18.
2. Leff, *Discursos sustentables*, 220.
3. Gudynas, *Derechos de la naturaleza*, 308.
4. Escobar, *Pluriversal Politics*, xxxv.
5. Boff, *El cuidado esencial*, 78.
6. Demos, *Decolonizing Nature*, 13.
7. Latour, *Pandora's Hope*, 109.
8. Latour, *Pandora's Hope*, 109.
9. Puig de la Bellacasa, *Matters of Care*, 30.

10. Puig de la Bellacasa, *Matters of Care*, 70.
11. Puig de la Bellacasa, *Matters of Care*, 65.
12. Puig de la Bellacasa, *Matters of Care*, 165.
13. Gudynas, *Derechos de la naturaleza*, 296.
14. De Sousa Santos, 'Beyond abyssal thinking', 69–70.
15. De Sousa Santos, 'Beyond abyssal thinking', 69–70.
16. Gill, 'Decolonizing literature and science', 285.
17. Guattari, *The Three Ecologies*, 31.
18. Guattari, *The Three Ecologies*, 41.
19. Critical Art Ensemble, *Aesthetics, Necropolitics and Environmental Struggle*, 119.
20. López del Rincón, *Bioarte*, loc. 6935.
21. Demos, *Decolonizing Nature*, 20.
22. Gudynas, *Derechos de la naturaleza*, 71.
23. Braidotti, 'A theoretical framework for the critical posthumanities', 41.
24. Braidotti, 'A theoretical framework for the critical posthumanities', 42.
25. Leff, *Discursos sustentables*, 92; emphasis in original.
26. Svampa, 'Commodities consensus', 76.
27. Gutiérrez-Aguilar, 'Beyond the "capacity to veto"', 260.
28. Gutiérrez-Aguilar, 'Beyond the "capacity to veto"', 263.
29. Latour, 'Whose cosmos, which cosmopolitics?', 455.
30. Gutiérrez Aguilar, *Horizontes comunitario-populares*, 75; emphasis in original.
31. Bishop, *Artificial Hells*, 2.
32. Camnitzer, *Conceptualism in Latin American Art*, 4.
33. Camnitzer, *Conceptualism in Latin American Art*, 159.
34. Lévy-Leblond, '(Re)mettre la science en culture', 8.
35. Camnitzer, *Conceptualism in Latin American Art*, 156.
36. Camnitzer, *Conceptualism in Latin American Art*, 262.
37. Kahn, *Earth Sound Earth Signal*, 224.
38. Munster, 'Transmateriality', 153.
39. Munster, 'Transmateriality', 154.
40. Escobar, *Pluriversal Politics*, xiii.
41. Davis, 'Diplomacy in the face of Gaia', 44.
42. Gudynas and Evia, *La praxis por la vida*, 35.

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MODERN AMERICAS

'Joanna Page presents a deeply researched account of contemporary art-science projects in Latin America and their role in the formation of a post-anthropocentric imaginary. Her approach to boundary-breaking practices situates them at the crux of current discussions on the decolonization of both the sciences and the arts.'
– **Mara Polgovsky Ezcurra**, *Birkbeck College*

Projects that bring the 'hard' sciences into art are increasingly being exhibited in galleries and museums across the world. In a surge of publications on the subject, few focus on regions beyond Europe and the Anglophone world. *Decolonizing Science in Latin American Art* assembles a new corpus of art-science projects by Latin American artists, ranging from big-budget collaborations with NASA and MIT to homegrown experiments in artists' kitchens.

While they draw on recent scientific research, these art projects also 'decolonize' science. If increasing knowledge of the natural world has often gone hand-in-hand with our objectification and exploitation of it, the artists studied here emphasize the subjectivity and intelligence of other species, staging new forms of collaboration and co-creativity beyond the human. They design technologies that work with organic processes to promote the health of ecosystems, and seek alternatives to the logics of extractivism and monoculture farming that have caused extensive ecological damage in Latin America.

Decolonizing Science in Latin American Art interrogates how artistic practices may communicate, extend, supplement, and challenge scientific ideas. It also highlights important contributions by Latin American thinkers to themes of global significance, including the Anthropocene, climate change and environmental justice.

Joanna Page is Reader in Latin American Literature and Visual Culture at the University of Cambridge. Her most recent books are *Posthumanism and the Graphic Novel in Latin America* (co-authored with Edward King) and *Geopolitics, Culture, and the Scientific Imaginary in Latin America* (co-edited with María del Pilar Blanco).

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