4. Multiple Citizens: How to Cultivate Relations

Chapter 4

MULTIPLE CITIZENS

How to Cultivate Relations

In the Square Mile—the financial center of London, where narrow streets, Victorian buildings, and Roman walls collide with glass-and-steel skyscrapers—unusual gardens are springing up. Planted in corrugated steel pipes and granite troughs, vegetation grows at roadside edges and adjacent to construction sites, where it absorbs, exchanges, and filters air pollution. Community groups and residents' associations have developed these air-quality gardens to draw attention to elevated levels of air pollution in central London. The gardens demonstrate how plants sense, absorb, and capture gases and particles from the air while making and remaking urban atmospheres.

As it turns out, environmental sensing occurs through more than just technologies in their usual configuration. Environmental sensors are well established as analog or digital instruments for measuring pollution and other disturbances. But more-than-human organisms also sense and communicate environmental processes. Bioindicators and sentinel organisms, from birds to marine life, detect and respond to changes in their milieus.[1] Such exchanges across organisms and environments demonstrate how sensing involves multiple entities and worlds of experience. More-than-human modes of sensing can also become more or less evident through digital sensors that work with and alongside organismal detection. These practices present yet another way of computing otherwise by reworking relations with other organisms.

In this way, plants perform as sensors and measurement devices that detect environmental changes. Some plants signal the presence of particular pollutants in environments through their leaves and growth patterns. Other plants are especially effective at taking up pollutants by absorbing gaseous substances through their stomata, drawing in heavy metals from the soil through their roots, or channeling and depositing particulates on their leaves. Plants, lichens, and mosses

Figure 4.1. Installation of Dustboxes in air-quality gardens at the Museum of London. Photographs by Citizen Sense.

sense and register air pollution through changes in their structure, distribution, and prevalence. As bioindicators, plants do not typically provide an instantaneous measure of pollution levels but rather signal relative gradients and relationships that become evident within environments over time. In sensing pollution, plants materialize other registers of experience that involve more than one organism responding to stimuli. In other words, plants incorporate, signal, and respond to environmental pollution through relational modes of sensing.[2]

Although vegetal participants are involved in sensing, absorbing, capturing, recycling, and reworking pollutants, within the wider context of "citizen sensing" more-than-human organisms do not typically register as "citizen sensors." In an attempt to expand the usual human-to-machine configuration of citizen sensing,[3] this chapter takes up more-than-human ways of sensing environments to consider how multiple other entities contribute to projects to make more breathable worlds. By focusing on the construction of two air-quality gardens as sites of vegetal and digital pollution sensing, I investigate how citizens and sensing transform through these more-than-human relations and world-making practices.

In constructing these gardens, Citizen Sense worked with several collaborators, including the Museum of London, a landscape architect, and the air-quality team at the City of London Corporation, to develop and test air-pollution gardens that were co-located with air-pollution monitors. We also engaged with museumgoers in a workshop and walk to develop and refine a Phyto-Sensor Toolkit that provided how-to instructions for developing air-quality gardens. In describing the planning, design, construction, and tool-kitting of air-pollution gardens developed in the financial center of London, this chapter documents how plants became evident as sensing organisms that capture and mitigate air pollution, and how these other modes of relational sensing recast environmental experience.

Air-quality gardens sense and transform polluted urban air through vegetation that traps and absorbs pollutants. Such gardens cultivate the bioindicating and mitigating qualities of plants to address the effects of air pollution. In this context, citizen-sensing practices materialize as a composition of air-pollution plants and digital sensors, along with residents, workers, cultural institutions, and local government agencies. The "citizen" operates here less as a universal or individual human agent and more as a project of activating sociopolitical relations across pluralistic registers. Adding to the proliferating list of citizens discussed throughout this study, I suggest these are *multiple citizens*, formed with and through other entities and worlds in the making. Citizens, in other words, form and exist in multiples, as entities involved with many other entities.[4] By investigating these more-than-human sensing relations and collectivities, I consider how exchanges across subjects and worlds make and remake possibilities

Figure 4.2. Dustboxes and Phyto-Sensor Toolkits as part of an air-quality garden workshop at the Museum of London. Photographs by Citizen Sense.

for being and becoming citizens. To engage in this area of inquiry, I consider how more-than-human organisms take up and express changes in their environments. I look especially at how more-than-human air-quality sensing contributes to distinct practices for making and remaking subjects and worlds toward more breathable conditions. And I examine how these affiliations multiply and recast the practices and worlds that could be constitutive of citizenship.

This chapter investigates how practices of sensing environmental pollution generate different articulations of citizens and experience when extended through more-than-human affiliations. Digital sensors might tune humans in to more-than-human sensing. But more-than-human sensing does not simply replicate what a digital device indicates. Instead, these other modes of sensing signal how relations and exchanges within milieus sediment over time. Processes of sensing pollution through organisms rework the boundaries of subjects and environments. What surfaces through these sensing practices is not just measurable levels of pollution but also the ongoing and accumulative effects of pollution in lived environments.

By engaging with organismal contributions to environmental problems, this chapter explores how different approaches to sensing generate multiple citizens and citizenships. Citizens and citizenship in this sense are not sole attributes of human actors. Instead, they are conditions activated through exchanges with other entities and milieus. The "multiple" is as much about multiplying entities as multiplying relations that co-constitute worlds and ways of being and becoming citizens. When multiplied across entities and milieus, citizenship becomes a capacity of differently activated worlds. Such a shift in focus reworks the subjects, practices, and worlds for experiencing and addressing environmental pollution.

Throughout this study, I have discussed how the conditions of being and becoming citizens depend upon the breathability of worlds. As a form of breathability and breathing, sociality can constitute what Ashon Crawley calls an "openness to worlds."[5] Such openness is part of "a critique of the ongoing attempt to interdict the capacity to breathe," which cultivates collective and aesthetic exchanges that come "to constitute community."[6] Crawley works against the racialized and reduced modes of being that form through closed and airless approaches to subjects. Breathability involves exchanges across subjects and worlds, and these exchanges can form and transform subjects and worlds beyond limited modes of being.

Such openness to worlds also requires sociality and exchanges with and across multiple more-than-human entities and milieus. Robin Wall Kimmerer conveys how breathing involves and generates conditions of reciprocity across multiple entities when she writes, "The breath of plants gives life to animals and the breath

of animals gives life to plants. My breath is your breath, your breath is mine."[7] These exchanges are more than physical interactions. They are also constitutive of political subjects and modes of governance, forming what Kimmerer refers to as a "democracy of species."[8] In this way, pollution surfaces not simply as an event to observe and detect because it interrupts or obstructs breath. Instead, it is a problem that activates expanded subjects, relations, practices, and collectives for working and reworking environments.

Citizens form through these processes, exchanges, and struggles, where breathability involves a collective searching toward open air that constitutes political life. This chapter investigates how to tune in to collective respiration with more-than-human entities as a condition of making citizens and worlds. As in earlier chapters, I explore how making breathable worlds gives rise to distinct citizens and citizenships. Still, here I emphasize the more-than-human exchanges that inform political life. Air-quality gardens attempt to improve breathability by decreasing air pollution and remaking urban conditions by engaging with vegetal sensors. They potentially contribute to different ways of constituting citizens and citizenship. The incorporation of more-than-humans into projects of political engagement could expand the breathability of worlds by pluralizing the exchanges with and through which community is constituted. These citizenly reconfigurations could contribute to the right to be in relation with environments and multiple other entities, carrying on from the last chapter. Yet such projects also demonstrate how difficult it is for some citizens to address air pollution, where emissions often continue unchecked, and remedial interventions that require the contributions of multiple organisms become a stopgap measure for making more breathable worlds.

Citizens form in multiples: as a proliferating range of political engagements, as a differential cast of human and more-than-human subjects, and as a plurality of relations and worlds in the making that unfold in conditions of struggle. Focusing on projects to make air-quality gardens in London, I consider how citizen-sensing practices exceed a more typical or scripted enactment of citizenship through devices. Instead, these practices spill over into urban projects that enlist monitoring but work toward other configurations of citizens and worlds. I turn now to examine how citizens multiply by incorporating more-than-humans into projects of sensing air pollution. I then document how the Citizen Sense research group engaged with Londoners and London institutions to build air-quality gardens and test different approaches to sensing with vegetation through a Phyto-Sensor Toolkit. In this discussion, I consider how citizenship materializes across multiple entities through how-to practices that include how to construct air-quality gardens, how to transform citizen sensing through citizen gardening,

how to aerate a Phyto-Sensor Toolkit, and how to multiply citizens in worlds. More-than-human modes of sensing surface here as propositions for how to expand environmental subjects and relations toward more breathable worlds. When constructing an air-quality garden, you might find that relationships across citizens, environments, and multiple organisms can be reworked in more reciprocal and expansive ways by computing otherwise.

SENSING MULTIPLE CITIZENS

Vegetal sensing, which the Phyto-Sensor Toolkit activates, is a method that offers different ways to tune in to environmental processes. Unlike digital sensors, plants do not typically produce real-time measurements of environmental variables, whether temperature, particulate matter, or ultraviolet rays.[9] Vegetal sensing also does not easily translate into the standard taxonomies of human sensing. Instead, such sensing unfolds through distributed and mutual responses, incorporations, and transformations in environments. As one mode of more-than-human sensing, bioindication is a process whereby environmental pollution registers in the bodies, distribution, growth, frequency, and relations of organisms. Organisms express physiological or other observable changes that can also indicate the accumulation or duration of pollution events—or even their possible recovery from pollution. Changes in organisms can signal changes in environments. These more-than-human and multiple modes of organismal sensing show how pollution is a relational event that opens toward ecological configurations of entities, which also become sites of political potential.

Bioindication is one such mode of sensing that demonstrates how environmental subjects materialize as they experience the lived effects of pollution.[10] Here, practices of monitoring and measuring pollution do not rely on instruments, in the usual designation, to document quantitative values of atmospheric pollution. Instead, organisms become gauges by indicating the spread and accumulation of pollution in particular sites, as well as approximate levels of pollutants, through their form and growth patterns.[11] Often referred to as a "qualitative" mode of monitoring environments, bioindication expresses how environmental processes such as pollution transform particular organisms in a nonlinear and yet accumulative way.

Bioindicators are species that express certain qualities of ecosystems, especially in relation to pollution. Biomonitoring can be undertaken by studying organisms in their environments or through transplant studies, where organisms are brought into environments to understand how they react to pollution.[12] Indicators are often compared to an index, which establishes a set of protocols

for reading and describing the environmental condition that the indicator is expressing. The qualitative aspects of bioindication are a unique aspect of this mode of monitoring. Yet they can align with quantitative monitoring if undertaken systematically through the use of indices.[13]

Bioindication highlights how pollution influences the material transformations of organisms in their habitats. It can map onto numerical indices of pollution, and it can also provide a way to understand the possible "health," "vitality," and even "luxuriance" of organisms by providing a more dynamic, ecological, and complex understanding of pollution.[14] Here, pollution is less about a numerical value and more about an ongoing set of transformative effects that can rematerialize and remake environments. Bioindication requires homing in on the effects of exposure over time, not necessarily as an instant measure of air quality but rather as durational materializations of pollution that affect wider ecologies. Different ways of "taking measure" and attending to the expressions of pollution through organisms can reorient attention from isolated variables to experiences and relations. Such a shift in focus can remake the designation of environmental problems (along with collectives and actions) by differently attending to the relations that pollution affects.

World Making and Phytosociological Associations

These vegetal operations, then, establish how to sense is to transform. By making and remaking atmospheres and soil, plants not only process pollution but also contribute to projects of multispecies world making.[15] World-making projects have been discussed not just through pragmatist philosophy but also through the work of feminist technoscience and Indigenous scholars.[16] Writing about world making in her discussion of the Matsutake Worlds Research Group, Anna Tsing notes that "each living thing remakes the world" through "multiple time-making projects" that transform landscapes.[17] These worlds are in the making through the activities of multiple entities as they contribute to forming distinct environmental conditions.[18] Such conditions indicate how organisms are in correspondence with and diverging from numerous other entities, responding to environmental events in different ways and across variable durations.

Vegetal forms of more-than-human sensing can show how these organisms experience pollution and form as distinct environmental subjects and worlds through responses to environmental pollution. Environmental pollution often registers through measurements that exceed acceptable levels or health effects and challenges made to regulators and polluters. Yet pollution also becomes evident through ongoing transformations of organisms and environments. Such modes

Plate 1. Citizen monitoring of gas emissions near fracking infrastructure; pro-fracking signs at vacated home site known to have polluted well water in Dimock, Pennsylvania. Photographs by Citizen Sense.

Plate 2. A Speck particulate-matter monitor with DIY weatherproof housing; pro-fracking sign protesting zoning regulations of fracking industry, Pennsylvania. Photograph above by Citizen Sense; photograph below by anonymous participant; courtesy of Citizen Sense.

Plate 3. Signs alert passersby to air pollution on busy road in London; testing citizen-monitoring technology during a walk in New Cross Gate, South East London. Photographs by Citizen Sense.

Plate 4. Installation of Dustbox in the Beech Street regulatory air-quality monitor. This monitor, sited at the edge of a traffic tunnel and near the Barbican Tube Station, regularly registers high levels of nitrogen oxides and particulate matter. Photograph by Citizen Sense.

of environmental sensing highlight how entities and environmental affiliations are affected by and transform through pollution. While in some ways bioindication might become legible through correspondence to an index that provides a systematic way of observing pollution, in other ways it gives rise to more open-ended engagements of incorporating and responding to environmental change. These open-ended or open-air instrumentalisms signal the distributed capacity of organisms and environments to generate different propositions for being together.

As I have discussed throughout *Citizens of Worlds*, environmental sensing—and the practices and entities involved in monitoring—can make environmental struggles matter in distinct ways. Measuring air quality with regulatory monitors is one way to sense environments. Attending to pollution as it accumulates in organisms, bodies, and ecologies is another way to tune in to environments. These different modes of sensing generate distinct forms of evidence and relevance. They also show how various entities and collectives work through and are individuated by pollution. As Gilbert Simondon has developed the concept, individuation refers to how entities are in-formed in relation to each other and their milieus.[19] Subjects, relations, and milieus all have the potential to transform and are not pregiven, although they can be in-formed by sedimentations and inheritances. Here, a "human" is not a fixed entity and can shift in relation to different relations and milieus.[20] So too might a "citizen" be encountered as an entity that changes through the collectives and worlds that affect it and to which it contributes.

In this way, subjects—including political subjects—are bound up with multiple other organisms and environments. Research focusing on the symbiotic characteristics of organisms suggests that even the notion of an organism as an individual is fraught with problems. Scott Gilbert, Jan Sapp, and Alfred Tauber have suggested through their work on symbiosis not only that "we have never been individuals" but also that "we are all lichens."[21] Indicator species such as lichens, plants, and many other organisms can provide a way to rethink environmental change through relational distributions of subjects. Such an approach can generate a less anthropocentric rendering of a changing planet, while connecting environmental subjects to earthly conditions that influence them.[22] Indeed, if lichens such as *Umbilicaria* are present, Kimmerer notes, "you know you're breathing the purest air. Atmospheric contaminants like sulfur dioxide and ozone will kill it outright. Pay attention when it departs."[23] The disappearance of bioindicating organisms can signal the contamination of the atmosphere that affects multiple other organisms and relations, which in turn could also be negatively affected by pollution.

Such a remaking of subjects through environmental affiliations has consequences for how to constitute political subjects and engagements. This distributed and multiple rendering of a subject is far from the universal and static figure that propagates through conventional humanism. A subject necessarily includes all that sustains it. Bioindication is not just an organism signaling the presence of pollution. It also expresses broader environmental engagements that influence earthly inhabitations. Organisms can draw attention to conditions of what Tsing calls the "more-than-human sociality" that informs environmental processes.[24] For instance, a forest encompasses the bioindicating characteristics of individual organisms, and materializes and sustains the more-than-human social worlds that are made through these organisms.

More-than-human sociality aligns with the "community approach" to bioindicator-based monitoring, "where indicator values are not assigned to single species or communities, but to groups of species with similar ecological requirements."[25] Rather than monitoring individual entities or variables, these more collective approaches can document how ecological relationships are expressive of environmental pollution and change. The shared "phytosociological associations" and "multidimensional relationships"[26] of indicator organisms are an area that has hitherto been somewhat under-studied, however. While scientific texts might chalk this omission up to the lack of a systematic methodology for evaluating community indicators, fledgling methods have been developed that, for instance, indicate air pollution through phytosociological relationships such as epiphytic organisms that grow on trees. Acidity and toxicity, the availability of light and water, and the abundance of nitrogen affect these organismal relationships. Similar to the *Umbilicaria* lichen, the presence or absence of epiphytes signals broader processes at work in the composition and decomposition of environments.

In other words, bioindication as an expression of ecological communities can be a way to get a sense of the health of environments, since "the replacement of a community by another one can be considered a clear indicator of environmental change."[27] Christelle Gramaglia and Delaine Sampaio da Silva suggest that "sentinel organisms" can signal conditions of pollution while at the same time demonstrating how an ecosystem such as a river operates as a "collective entity."[28] These more-than-human modes of sensing involve other communicative exchanges, as well as distinct expressions of sentience, intelligence, and "meaning" that require connections to numerous ecological operations.[29] Rather than designating how a stable nature might be sensed, or bioindicated, by other organisms, more-than-human sensing is instead expressive of multiple environmental inhabitations and relations.[30]

Vegetal sensing draws attention to how environmental subjects take account of and form distinct experiences of their worlds.[31] Connections across organisms and environments are continually remade through the accumulation and dissipation of pollutants. More-than-human sensing signals relationships across organisms, the composition of ecological communities, and the effects of their inhabitations. Such modes of sensing serve as provocations for how to characterize, engage with, and act on environmental problems. If "practice imposes upon its participants certain risks and challenges that create the value of their activity,"[32] as Stengers suggests, then more-than-human modes of sensing indicate how risks and challenges cascade across pollution, bodies, environments, and relations. Practices of vegetal sensing recast how pollution becomes evident as well as how it might be acted upon. By incorporating multiple entities into practices of citizen sensing, it could be possible to rework conditions of political possibility while generating alternative strategies for making more breathable atmospheres.

The Political Work of Multiple Citizens

Air-quality gardens draw attention to how more-than-human relations contribute to breathable worlds. Vegetal sensing offers other practices for inhabiting environments and for constituting citizenship. These are multiply constituted modes of citizenship that, drawing on Tsing, attempt to "make common cause with other living beings" by engaging with more-than-humans as "political work."[33] Such political work involves reciprocity and exchange—of sensing, breathing, making, and remaking. Possibilities for more expansive environmental politics surface through tuning in to the world-making projects of other organisms. Air-quality gardens can be spaces for cultivating and pluralizing sensing subjects. They work and rework environmental pollution toward other earthly inhabitations.

Multiple citizens take shape through the "collective potential" generated by these different affiliations, exchanges, and ways of parsing environments.[34] Sensing processes and relations give rise to multiple citizens and citizenships that remake environmental struggle and politics. Here, an environmental citizen is not the familiar figure of a responsible consumer–subject amenable to behavior change but rather an opening into other practices and relations of more-than-human sociality and political engagement.

However, the multiplications of citizens and citizenship do not signal a mere concatenation of actors. Instead, they are sites of struggle. Struggle here is not merely or necessarily a political contest that takes the form of "debate." Instead, it forms through environments at saturation points, species loss, disconnection from land, and contaminated ecologies. The struggles that shape the political

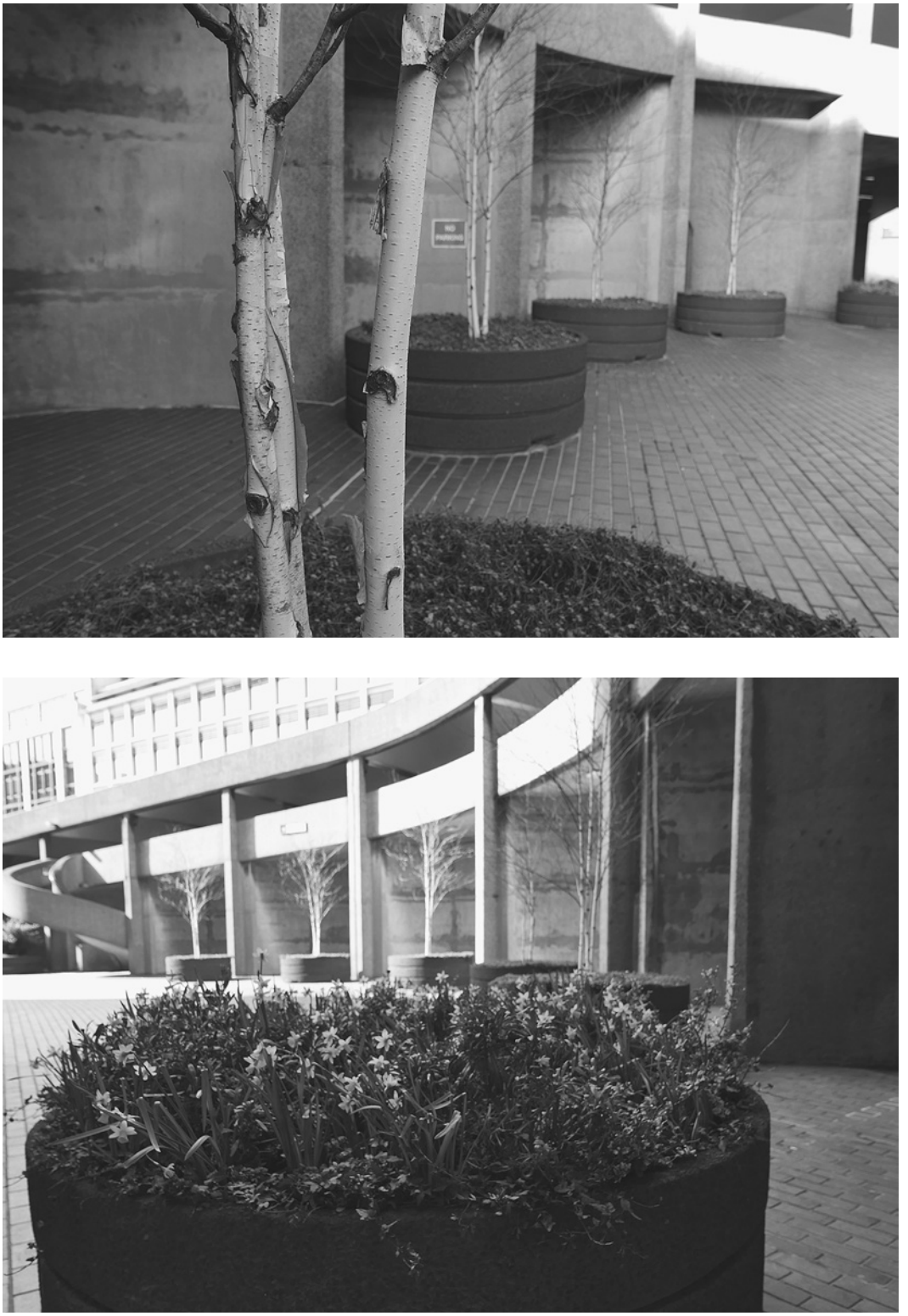


Figure 4.3. Air-quality garden installations at the Barbican in the City of London. Photographs by Citizen Sense.

capacities and designations of subjects are multiple. Yet this plurality might also move toward "more different ways of being in relation," as Berlant suggests in the first epigraph to this book's Introduction. In this way, citizenship is always in process and "produced out of a political, rhetorical, and economic struggle over who will count as 'the people.'"[35] These struggles extend not just to who counts as the people as a collection of humans but also to the possibilities for being in relation with other entities and environments that might make for less destructive worlds. The demos that materializes here necessarily extends to the incorporation of more-than-humans and environmental relations as part of what makes these worlds breathable. Such pluralizations become sites of possibility by transforming the conditions and relations that could be activated through citizens of worlds.

In this regard, Kim TallBear points to the need to "indigenize" fields such as science studies and animal studies, which produce human subjects detached from environments and organisms and separate the organisms they study from their milieus. Drawing on American Indian metaphysics, TallBear seeks to "extend the range of nonhuman beings with which we can be in relation," which in turn would inform the ecologies we inhabit and the environmental subjects we become.[36] Here, TallBear points to how practices for indigenizing environmental subjects can transform social and political engagements by attending to earthly relations. Subjects are not pre-constituted as free-floating cognizers of worlds. Instead, worlds inform and co-constitute subjects. Or as Jennifer Wenzel writes regarding Frantz Fanon's *Wretched of the Earth*, "decolonization demands . . . a shift in the valuation and disposition of nature,"[37] not as an external entity against which to define humans but as a reworking of humans and more-than-humans toward less extractive and more reciprocal relations.

In this inquiry into how citizens of worlds form and are sustained, multiple modes of citizenship and "membership" materialize. Writing about historical restrictions to Indigenous citizenship, Leanne Betasamosake Simpson explains how nationhood is remade and differently lived within Indigenous worlds, less as a territory of violence and hierarchy and more as a web of relations. Indigenous nations are in relation with plant nations, animal nations, and many other more-than-human nations. A nation is an "ecology of relationships" that distinctly constitutes power and governance.[38] Citizens and citizenship are then reconstituted through connections to multiple other entities and milieus, which are formative of political subjects. Human citizens form in relation to councils of plants, animals, and atmospheres, among countless other collectives. They make contributions along with vegetal citizens and plant nations, which form other possibilities for collective affiliation and environmental inhabitation.[39]

Such formations of environmental citizenship are an attempt to rework political subjects through multiple relations. Plants, among many other organisms, open into other inhabitations and durations.[40] They draw attention to environmental attachments and formations of subjects through the signaling, incorporation, and transformation of pollution. The next section describes how Citizen Sense engaged with collaborators to construct and test air-quality gardens. On one level, this initiative could be seen as an idiosyncratic gardening project. On another, through its attention to how multiple organisms respond to air pollution, it offers an invitation to cultivate practices for working with more-than-human citizen sensors toward more breathable worlds.

CULTIVATING MORE-THAN-HUMAN WORLDS

Sensors would initially seem to activate and format citizens as collectors of data. Yet such a diagram of action is never so straightforward. As described in the previous chapter, communities in South East London often mobilized data to support and extend sustained efforts toward environmental and social justice. But practices for tuning in to urban environments were not linear expositions of evidence. Instead, they were formed through ongoing experiences that often drew on data in more provisional ways. Citizens proposed multiple actions that they formulated in advance of, contemporaneous with, and based on evidence from air-quality monitoring. These proposals included responding to findings about the important role of vegetation and green spaces in mitigating air pollution by improving green infrastructure, planting trees, and protecting green space. Indeed, some of the lowest levels of air pollution in this citizen-monitoring network were found in an enclosed garden on a pedestrian street. While citizens' proposals did not take the direct form of air-quality gardens, they did advocate for tree planting and green-space preservation. These proposals demonstrated how citizen sensing becomes involved with more-than-humans when attempting to cultivate more breathable worlds.

While we were in the process of finalizing our collaborative monitoring in South East London, in June 2017 the Museum of London wrote to Citizen Sense to ask if we would like to contribute to a project to develop air-quality gardens and test our sensors at the museum.[41] Working along with the City of London Corporation and supported by funding from the Mayor of London Low Emission Neighbourhood scheme, we helped develop the gardens as part of a broader initiative to investigate and implement projects for improving air quality. Related London-wide initiatives included transportation experiments (as discussed in the

previous chapter with Deptford Folk's successfully funded pilot project), no-idling campaigns, and green-infrastructure installations.

There has been considerable debate about green infrastructure within air-quality research communities. Some air-quality researchers see a focus on vegetation as distracting from the key problem of removing emissions at the source. In contrast, others suggest that a wide range of approaches should be explored to improve air quality. Here, the question of practicability also arises: citizens might be less well placed to redesign transportation infrastructure, for instance, than to plant air-quality gardens. The difficulty of shifting to less fossil-fuel-intensive transportation proves intractable across all levels of governance, both in the UK and farther afield. Citizens take up projects such as air-quality gardens because other efforts to address air pollution have failed or because they feel this is an intervention that is within reach. Practices for addressing air pollution become informed by these more or less feasible struggles to transform cities toward more breathable worlds. Thus the relative feasibility of political engagement directly impacts organisms not just through biodiversity collapse and extinction but also through the distinct types of work in which more-than-humans become enrolled as they process and transform the residues of fossil fuels and the pollutants from extractive economies.[42]

With the air-quality garden installation, the Museum of London was interested in developing a demonstrator project to facilitate collective research into air quality. We considered how the garden could include plant installations, air-quality monitoring, and public engagement and events. Citizen Sense contributed to these aspects of the project by providing suggestions for air-quality plants that would bioindicate and mitigate air pollution, installing Dustbox sensors in gardens and other nearby locations, hosting a workshop and walk with museum-goers to investigate air-quality vegetation and gardens, and developing an openly available Phyto-Sensor Toolkit for the wider development of air-quality gardens. In addition to our contribution to the gardens, Grow Elephant, a London-based landscape architecture firm that had developed temporary community gardens and garden clubs within South East London, built two garden planter structures and installed the air-quality plants. After a relatively rapid development process in the summer of 2017, the air-quality demonstrator gardens opened at the museum in September as part of its *City Now City Future* exhibition, with one garden at the entrance to the museum and one situated at a walkway intersection.

I describe in more detail the process of how we constructed these air-quality gardens below. Yet it is important to note that this project did not materialize as a singular endeavor. Instead, the Museum of London's air-quality garden exploration

Figure 4.4. City in Bloom and air-quality garden initiatives developed through the City of London with local residents. Photographs by Citizen Sense.

took place within a broader context of multiple other community air-quality initiatives underway in the City of London. These initiatives tended to draw on participants from demographics that were very different from South East London or rural Pennsylvania. Residents in the City of London are primarily (although not exclusively) from more privileged economic backgrounds and work in (or have retired from) higher-paying professions. But similar to South East London and rural Pennsylvania, there was considerable variation in the types of participants engaged in environmental monitoring.

Residents at the Barbican and Golden Lane Estates had also developed several air-quality gardens in the area. Through a "City in Bloom" initiative, residents compiled a working pamphlet on "Why Plants Can Help Improve Air Quality" to share scientific research on the topic. Based on their research and garden projects, they also compiled *The Clean Air Gardens*. This self-published book includes suggestions for air-quality plants and documents nineteen gardens that they installed throughout the Square Mile.[43]

One of these temporary or "pop-up" gardens at Moor Lane involved a collaboration with landscape architecture students who had recently set up their own design firm, xmpl. The residents and designers obtained donations from construction companies developing transport infrastructure and office complexes to create a unique intervention to address air pollution.[44] Because construction companies at times want to be seen as "good citizens" while undertaking highly disruptive projects, residents and community groups in this area of intensive urban development successfully obtained donations and small amounts of funding to "green" the area. Greening initiatives can often exist in this blurry zone of political engagement. They attempt to make more livable environments, while working within prevailing conditions of urban development to make situated interventions.

Community groups in the area also organized and ran bird walks, bat walks, and tree walks to survey species and introduce people to different ways of looking at and listening for multiple organisms in the Square Mile. They were involved in citizen-science initiatives through the City Nature Challenge, where they surveyed and recorded organisms in the area using iNaturalist to determine relative levels of biodiversity. One local resident led an extensive survey of vegetation in the area to develop a herbarium of plant pressings for the Natural History Museum archive. She located her collection of over two hundred plants on a Google map to document the urban habitat in which the species grew. London plants, as one Barbican resident noted, are never just randomly placed but instead always carry stories about how they came to occupy particular areas. Fireweed is a plant that is well known for spreading in former bomb sites, where it occupies the ruins of once-cratered urban landscapes. Urban ragwort had seemingly been transplanted from Italian volcanoes to the Oxford botanical garden,

Figure 4.5. Construction on the perimeter of the Barbican; internal gardens at the Barbican in the City of London. Photographs by Citizen Sense.

where it traveled up train lines into UK cities. This citizens' herbarium formed a record of flora in an area where green spaces were often transformed or crowded out under constant pressure from development.

Along with these monitoring practices, a group of Barbican residents had set up a diffusion-tube air-quality study to document nitrogen dioxide levels in this central area of London. The Barbican Estate experiences poor air quality because of its location within a dense urban area that suffered from traffic congestion, hard surfaces, and few green spaces or parks. In 2015 they worked with Mapping for Change, a research agency based at University College London, to analyze monitoring data and document the study in a report.[45] They found that pollution levels were especially high on the edges of the estate that adjoined busy roads. However, they also found that nitrogen dioxide levels could be elevated even in garden courtyards when high winds circulated from particular directions.

These monitoring efforts informed a wide range of activities to address, mitigate, and raise awareness about the problem of air pollution, some of which were undertaken in collaboration with the City of London.[46] For instance, the diffusion-tube monitoring study further reinforced the clean-air gardens initiative as a concrete strategy for addressing air pollution. It was in this context of local air-quality monitoring projects, biodiversity surveys, and installing clean-air gardens that Citizen Sense undertook a practice-based investigation into how two air-quality demonstrator gardens could activate expanded relations with more-than-human sensing and work toward more breathable worlds.

How to Construct Air-Quality Gardens

The process of setting up two air-quality gardens at the Museum of London involved much more than locating plants within planters. The demonstrator gardens drew on local initiatives, from monitoring to gardening, while communicating with and connecting to more dispersed publics about projects for addressing air pollution. The demonstrator gardens did not operate as community gardens in the traditional sense of a sustained cultivation space. Nor were they a project for providing food or contributing to (or reforming) disadvantaged communities through gardening, a topic that researchers have discussed as having complex social and political implications.[47] While residents were involved in looking after the nineteen clean-air gardens they installed, Grow Elephant supervised the demonstrator plots during their temporary installation. In this way, the gardens provided a test site for people to learn about air-quality plants, assess how to develop their own gardens, and consider strategies for mitigating air pollution. The gardens also provided a space to study the possible effects of air pollution on plants, while comparing pollution levels from the Dustbox particulate-matter sensor.

While the Phyto-Sensor Toolkit began with the demonstration gardens, it also encompassed a workshop and walk, a physical and online toolkit, and a broader investigation of practices for working with more-than-human sensors.[48] *Phyto-sensor* is a term that the Citizen Sense research group uses to describe the vegetal entities and processes that sense and respond to environmental pollution. The gardens, events, and toolkit explored how plants continually sense and change environments. Because the sensing, bioindicating, and mitigating characteristics of plants are not always immediately evident, each demonstrator garden had a placard noting that the plants had been selected for their "special properties, either absorbing or channeling pollutants, or indicating particular pollutants with changes in their physiology and appearance."[49]

The material registers of pollution became more or less evident through the garden, toolkit, events, and different engagements with vegetal sensors. Yet as demonstration spaces, the gardens were zones of inquiry that were focused less on identifying immediate changes and more on learning about more-than-human sensing and the relations it activates. Plants in their milieus became sensors and teachers.[50] To this end, the toolkit documents how some plants are especially effective at taking up pollutants. These other organismal and vegetal ways of sensing environments served as a basis for investigating how to cultivate more breathable atmospheres, especially by developing planting scenarios that could be installed in other areas.

We selected plants for the gardens that included species that could bioindicate the presence of pollution, absorb or trap pollutants, or accumulate and transform toxins. Many plants work across these different ways of sensing and responding to pollution. The garden included bioindicating plants such as snowberry (*Symphoricarpos albus*), which is sensitive to ozone and will show leaf injury and impaired growth when ozone is present.[51] Snowberry can also take up heavy metals such as zinc and iron from the soil, but it will show signs of damage and impaired growth if it accumulates these contaminants. Thus the garden included plants that demonstrate how contaminants persist and transform organisms and their environments, often with deleterious effects.

Many of the plants in the air-quality garden trap or channel particulate matter through deposition and dispersal. Plants with hirsute or broad leaves can act as surfaces to capture airborne particles. When planted as a hedge or green screen, plants such as yew (*Taxus baccata*) can catch particles that wash into the soil during rainstorms. At the same time, many plants are respiring and contributing their own mix of materials to environments, including oxygen and other gases. Yew emits low levels of biogenic volatile organic compounds (BVOCs), which can combine with nitrogen oxide to form ozone. Many urban plants and trees emit

Figure 4.6. Air-quality garden installed at the entrance to the Museum of London; Phyto-Sensor Toolkit used as part of a walking tour of air-quality gardens to identify plants and learn more about how they respond to air pollution. Photographs by Citizen Sense.

BVOCs. For this reason, simply planting more vegetation because it is "green" does not necessarily improve air quality, and can instead exacerbate pollution in areas with high levels of nitrogen oxide that can react with BVOCs.

Plants bioremediate air pollution in ways that are not simple actions of scrubbing and removing the residue of fossil fuels. Instead, they absorb some pollutants while emitting others. They capture particles from the air while carrying them into the soil. They phytoremediate contaminants in the soil but often can only do this when in relation with other plants. They bioindicate the presence of pollutants such as ozone, but this form of sensing and signaling can also demonstrate that plants are likely to die. The air-quality gardens and Phyto-Sensor Toolkit document these bioindicating and mitigating characteristics, showing how plants such as yarrow (*Achillea millefolium*) can colonize soil in urban areas and provide a surface for particle deposition. Yet yarrow can also become damaged by ozone, a condition that becomes more or less severe in relation to the other species with which it grows.

Because these modes of sensing register through the form, growth, and distribution of plants and are typically more evident when they grow over time in environments, we also set up Dustboxes to monitor real-time pollution levels at several locations within and near the gardens. This Dustbox installation was also a process of consolidating our sensors for wider circulation as a sensor library, which might be used as a mobile and DIY air-quality monitoring infrastructure for installation in London and farther afield. We placed Dustboxes within the demonstrator gardens. We located Dustboxes with local residents. And we located Dustboxes at the official air-quality monitor adjacent to the Beech Street tunnel.[52]

Because the Beech Street tunnel has especially high levels of pollution in the form of nitrogen oxides and particulate matter, it was an area that local residents, the Museum of London, and the City of London were interested to gather additional data about. In the process of setting up Dustboxes alongside the Beech Street monitor, a City of London air-quality officer who provided access to the official monitor also undertook routine maintenance while at the site. Here, she collected a leftover particulate matter filter saturated with a black soot-like coating. The material residue of particles became evident as a layer of grime, which usually spreads through the air, circulates into the lungs and other organs of passersby, settles on urban structures, clogs instruments, and is taken up by more-than-human organisms.

The Dustboxes provided a way to compare pollution levels throughout the area while also looking at relationships across digital and vegetal sensors. However, the different modalities and durations of these sensing methods quickly became apparent, since moments of elevated air pollution did not correspond to

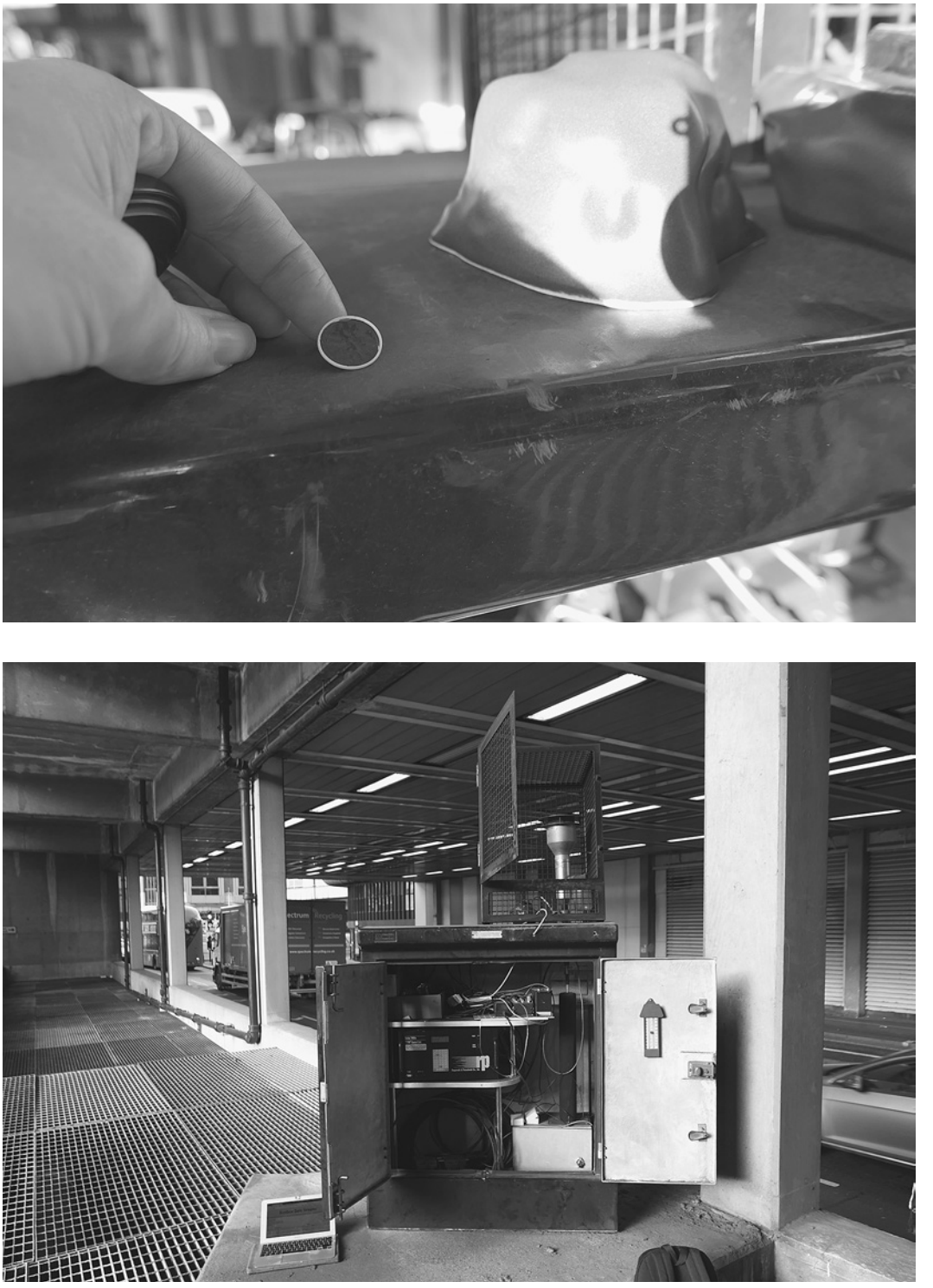


Figure 4.7. Installation of Dustboxes in the Beech Street regulatory air-quality monitor. This monitor, sited at the edge of the Beech Street tunnel and near the Barbican Tube Station, regularly registers high levels of nitrogen oxides and particulate matter. Photographs by Citizen Sense.

an automatic wilting of plants. Instead, vegetal sensors became a way to tune in to different approaches for cultivating less toxic atmospheric exchanges. In turn, the Dustboxes and other air-quality monitors throughout the area drew attention to where pollution was occurring and suggested how these patterns could inform proposals for developing other gardens in the area.

Distinct patterns of urban pollution began to surface through the Dustbox data and alongside the vegetal sensors. The demonstrator garden at the sheltered entrance to the Museum of London often showed the lowest pollution levels. However, when regional air pollution events occurred, this Dustbox showed levels similar to those of other monitors in the network. Pollution levels at the Beech Street tunnel location were consistently the highest, with pollution concentrations often exceeding the WHO twenty-four-hour guidelines. One resident on an upper floor of a Barbican tower typically recorded lower levels, likely due to the monitor height. Yet during windy conditions, this monitor would register some of the highest levels in the network. At all locations within this central area of London, however, levels of particulate matter were comparatively high overall, with monitors typically registering readings of 20 to 35 $\mu g/m^3$ over a twenty-four-hour period. When winds circulated from the east (and from regional European locations), levels would often register at least 50 to 70 $\mu g/m^3$, three to four times above the 2005 WHO guideline of 15 $\mu g/m^3$ over twenty-four hours.

At the same time, the regulatory monitor in the Beech Street tunnel typically recorded levels of nitrogen dioxide at nearly double the EU twenty-four-hour standard, at 80 $\mu g/m^3$. Looking more closely at pollution levels using our Airsift tool, we established that nitrogen dioxide was circulating from the nearby intersection and station to the west. At the same time, particulate matter was circulating from the east, both locally at the tunnel and regionally from farther afield. Digital sensors, vegetal sensors, and citizen sensors combined into observational techniques and experiencing entities registering both that pollution was occurring at high levels and that different approaches to addressing this problem might be created by reworking trajectories of sensing and action.[53]

How to Transform Citizen Sensing through Citizen Gardening

Citizen sensing and citizen gardening began to merge in the search for more breathable urban conditions. In this polluted location adjacent to the entrance of the Beech Street tunnel, the Dustbox and regulatory monitor shared the same airspace as one of the nineteen community-planted clean-air gardens. Existing concrete planters designed within the Brutalist architectural style of the Barbican were situated at the base of the forty-four-story Lauderdale Tower, where residents and volunteers had installed numerous air-quality plants. Small birch

(*Betula pendula*) trees occupied planters, where their waxy leaf surfaces were meant to trap particles, absorb nitrogen oxides, take up heavy metals, and phytoremediate the air and soil. Silverbush (*Convolvulus cneorum*), a plant with small leaves covered in numerous fine hairs that capture tiny particles, filled planters nearer to the entrance of Lauderdale Tower. The microclimate in this area was not only polluted but also dry and windy, making for conditions within which the more drought-tolerant silverbush was able to thrive.[54]

Citizen sensing could, in various ways, contribute to and align with citizen gardening and citizen infrastructure. But this juxtaposition of clean-air gardens, air-quality sensors, and highly polluted roadways inevitably raises the question of whether these relatively contained and diminutive planters would be able to mitigate the high levels of pollution occurring in this traffic-clogged area. Regulatory and citizen-led monitoring can establish that high levels of pollution occur and even demonstrate the location of emissions sources. However, the intensity and persistence of pollution often require further measures to address this problem. Air-quality gardens alone do not "solve" the problem of air pollution. Yet these engagements with more-than-human sensing also bring to the surface the dilemmas of how to realize feasible citizen actions with more intractable political processes. Such engagements work toward strategies for intervening within and transforming unbreathable urban conditions.

This inquiry into how to construct air-quality gardens investigates different practices for working with more-than-human sensors, spanning from identifying plants and outlining different planting scenarios for installing vegetation to building community networks. At the same time, these practices for working with vegetal environmental sensors and transforming urban air toward less hazardous and more collaborative environments point to the struggles that arise when attempting to address and mitigate air pollution. Citizen sensing and citizen gardening collide with different formations of power that can surface through practices of making and transforming environments.

From draining swamps to establishing plantations, cultivation is often an expression of power that materializes and reproduces dynamics of resource capture and extraction.[55] Planting is a way to reclaim, rework, and establish relations with land and more-than-human entities. Engagement with plants can become a form of resistance or otherwise inhabitation. As researchers and contributors to the Black/Land Project note, practices of urban gardening can form very different ways of engaging with land for Black gardeners, who also see this "as a way to stake a claim to permanency, education, economic citizenship, and community leadership, rather than only as a vehicle for food security."[56] Practices of gardening and inhabiting land can become forms of collective "geo-theorizing,"

where environments are made and remade as expressions of self-determination and openings into other ways of relating to land. In other words, this is a way of becoming citizens with land as well as worlds.[57]

In a similar register to the previous chapter, where people sought to protect green space to stake a claim to self-determination, the Black/Land Project describes how expressions of citizenship materialize through other and distinct ways of being in relation to and becoming with land. In parallel, Kimmerer discusses how gardening can generate practices of reciprocity that not only inform relations with land but also influence political relations and ways of undertaking exchanges with multiple entities. Reciprocity with the land is an invitation to reciprocity with all creatures. Such an orientation amplifies citizenships through the constitution of subjects, relations, and governance practices that work toward mutual exchange rather than domination.[58]

The cultivation of air-quality gardens signals the presence of air pollution in London, while proposing strategies for how to remake urban environments. Making and remaking environments are practices for attending to other entities, for cultivating their contributions to expand breathable worlds, while establishing and reinventing relations with more-than-human sensors. These are different ways of learning from and engaging with environments. They cultivate other relations that can depart from established inhabitations.[59]

The intervention that air-quality gardens make, both in the form of the demonstrator gardens we developed in collaboration with the Museum of London and in the form of the residents' nineteen clean-air gardens, is also worth considering in more depth in this discussion of how to construct air-quality gardens. While these gardens do not instantly absorb the many pollutants in London's air, they do constitute practices for transforming environments as multiple inhabitations, different durations, and collective exchanges that could generate more breathable worlds.

The Phyto-Sensor garden, events, and toolkits present scenarios for how to construct air-quality gardens and how to transform citizen sensing through multiple citizens' sensing and planting. These scenarios include how to work with community groups to start a garden project, how to identify sites for installing air-quality gardens, and how to select plants. They also encompass how to monitor pollutants, how to form different planting scenarios (from street trees to green walls), how to monitor along with vegetal sensors, and how to develop more expansive engagements with environments and more-than-human entities.

As collective environmental projects, these propositions for how to construct air-quality gardens resonate with community gardens. Yet even more, they connect with forms of near-future gardening. Many garden plots are now being

developed not only as food-based projects but also as spaces for realizing environmental justice. These expanded forms of cultivation can especially be found in community gardens that address and mitigate climate-change inequality, where climate change and increasing urban temperatures make apparent the effects of redlining, lack of vegetation, and urban heat islands.[60] One such initiative, Groundwork USA, is working to make more "climate safe neighborhoods" in US cities by using digitized historical maps and data analysis to identify areas at risk of extreme heat and flooding due to climate change.[61] These analyses sense and overlay different forms of spatial inequality. Such groups are working toward more breathable urban environments by developing tree-planting initiatives and community gardens, which cultivate green space as a reconfiguration of environmental and political collectives.

Similarly, air-quality gardens could generate other counter-practices of cultivation that rework relations, entities, and environments through shared inhabitations with—and even beyond—pollution. Such gardens do not merely signal that an event has occurred or is occurring. Instead, they also materialize the relations at stake and environments that are harmed when pollution accumulates. The breathability of worlds multiplies through these exchanges that attempt to amplify rather than diminish environmental and social justice. Gardening becomes a sociopolitical practice for cultivating more breathable worlds along with more-than-humans, and a way to address and rework unprecedented environmental change through the co-constitution of citizens and worlds.

OPEN-AIR TOOLKITS

The open air has been a guiding concept and practice throughout this study. It designates ways of moving propositions into practice and experience. In this way, we explored how to put the Phyto-Sensor Toolkit to work in the open air.[62] We tested the toolkits through walking, workshopping, mapping, and inquiring into what conditions might be needed to construct air-quality gardens beyond the museum environment. These are ways of aerating gardens and toolkits. Yet this was less a project of reproducing air-quality gardens across London and farther afield than it was an attempt to explore how sensors, citizens, vegetation, and gardens come together in the open air. By testing the Phyto-Sensor Toolkit in these ways, we further inquired into different possibilities for activating more-than-human and multiple citizenships. Here, we encountered how pluralistic modes of sensing could open other environmental inhabitations.

As a thinker of multiple worlds, William James has suggested that by moving into the open air, experience might transform and undo the dogma of philosophy.

On one level, James uses the term "open air" to refer to something like "nature." Yet on another level, experience in the open air compels philosophy to undo a potentially self-referential focus to engage with worlds in process. Open air is not simply a synonym for the outdoors. Instead, it is an opening and an aeration of philosophy as well as subjects, experiences, and worlds. Because it is open-ended, the open air is propositional.

Breathability of practice can, then, generate breathability of thought. The open air instigates an aeration of theory and practice. Thought, as Crawley has similarly suggested, has been rendered airless and breathless through the pursuit of "categorical distinction," which has formed a rigid and racializing project.[63] By putting air into theory, Crawley proposes that difference and the "otherwise" as "a word that names plurality as its core operation" might open into forms of "radical sociality" that he calls "black pneuma."[64] Such a condition involves attending to "how breath moves and changes and performs in the world, the world that is made at the moment of the emergence of being together with others."[65]

Air—and the open air as I read it here through pragmatism, Black studies, Indigenous studies, and feminist technoscience—injects possibilities for otherwise and pluralistic thought and practice. In this way, the aeration of the Phyto-Sensor Toolkit involved working with museumgoers to investigate different sites and strategies for constructing and studying air-quality gardens within and beyond the Square Mile. Concrete proposals and observations, as well as different conditions for being and becoming citizens, assemble through these open-air excursions. They form other conditions of exchange, reciprocity, and searching toward more breathable worlds. So too, multiple citizens materialize through these co-constitutive and expanded relations across entities and experiences.

How to Aerate a Phyto-Sensor Toolkit

Because the construction of the demonstrator air-quality gardens took place primarily as an institutional collaboration, Citizen Sense hosted a workshop and walk at the Museum of London where the Phyto-Sensor Toolkit could be opened into dialogue with interested museumgoers. The workshop and walk allowed for the further development of the toolkit by drawing on input from participants. While existing residents had made the above-described monitoring projects (and were involved in monitoring with Dustboxes and meeting to describe their monitoring activities), the publics that attended the museum were much more diffuse, with visitors to the *City Now City Future* exhibition traveling from locations across London, the UK, and the world.

Citizen Sense developed the Phyto-Sensor Toolkit as a resource and guide to aid in the citizen-led research and development of air-quality gardens. The

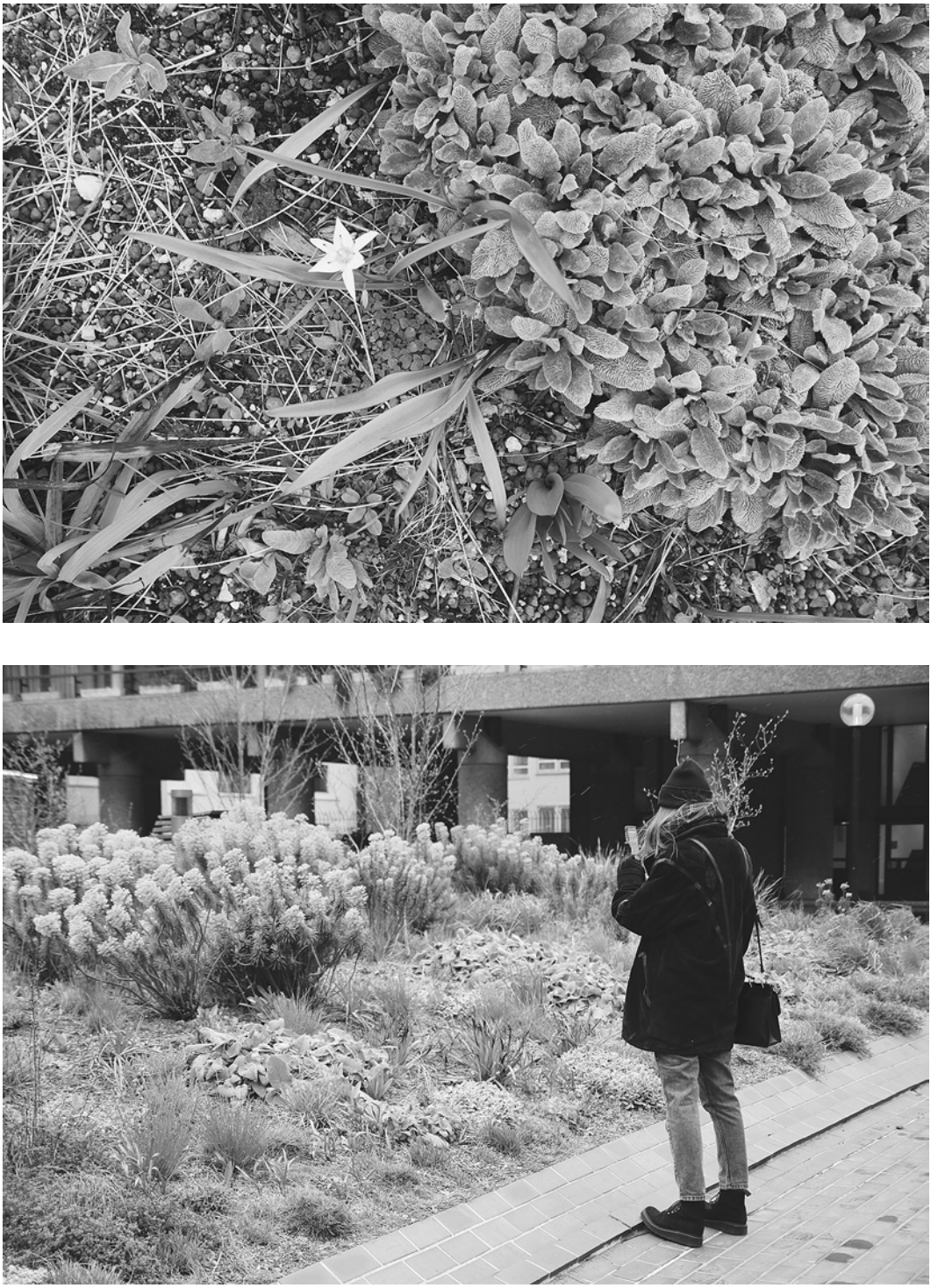


Figure 4.8. Air-quality garden walking tour with visits to air-quality plants, including *Euphorbia* and lamb's ear. Photographs by Citizen Sense.

toolkit focuses on how phyto-sensing processes can bioremediate air quality, especially in urban settings. As a pedagogical toolkit, it introduces participants to an array of herbaceous and woody plants, as well as trees, that respond to and mitigate pollution. The toolkit allows people to identify plants in the field while at clean-air garden and green infrastructure sites and to learn more about how they bioindicate or mitigate pollution. Consisting of ten sections, the toolkit first provides an introduction to phyto-sensing and an explanation of citizen sensing. It then gives an overview of the problem of air pollution and describes the Low Emission Neighbourhood initiative and garden. The core content of the toolkit includes a series of plant-identification cards that describe key vegetal responses to air, soil, and water pollution. Also included in the draft version of the toolkit is an outline of the workshop and walk (where the provisional version of the toolkit asked for participants to record comments and propositions for the final toolkit). As part of the walk itinerary, the toolkit introduces the air-quality gardens and air-quality monitoring infrastructure in the Square Mile of London. The final sections of the guide include suggested planting scenarios for constructing air-quality gardens in relation to likely emissions sources, and a list of resources for further researching air-quality plants and gardens.

To test the Phyto-Sensor Toolkit, we held a workshop and walk as part of the Barbican OpenFest, an annual free event to explore the outdoor and indoor spaces around the Barbican. On the day of the walk, a Saturday in mid-March when temperatures might ordinarily be mild, we were instead visited by a cold snap dubbed the "mini-Beast from the East." Grappling with temperatures of –7 degrees Celsius with wind chill, we worried that people might not attend or be equipped to handle the temperatures that were unusually cold for London. However, many participants did turn up sporting full-body outerwear suitable for extreme winter sports, as well as wearing heavy gloves, woolly scarves, and bobble hats, fully layered up and ready for an investigation of air-quality gardens.

After a brief introduction to the Phyto-Sensor project and an overview of the workshop, walk, and toolkit, we set out to look at air-quality plants in the area. We started our walk at the two demonstrator air-quality gardens at the entrance to the Museum of London. Here, we discussed the different plants installed, their bioindicating and mitigating properties, and how they process pollution in different contexts and in relation to other organisms. Paul McGann of Grow Elephant joined Citizen Sense for the workshop and walk, during which he explained the development of the planters and the installation and care of the plants.

With the frigid temperatures, plants were not yet in full bloom, but many were still identifiable when compared to the field guide in the Phyto-Sensor Toolkit. We struck a balance between lingering to investigate the fine or hairy leaves of

Figure 4.9. Air-quality garden walking tour across the Barbican site. Photographs by Citizen Sense.

plants that capture particles, to walking briskly to the next stop where we might be able to fend off the cold. We walked around the Barbican podium, discussed residents' initiatives to address air quality, and made our way to the Beech Street monitoring station. As mentioned previously, this enclosed hard space of concrete and traffic tends to have especially high pollution levels. We then looked at how urban architecture, vegetation, monitoring, and urban processes assemble to create more or less polluted environments, and discussed other approaches we could take to construct more breathable conditions.

In the open air, the Phyto-Sensor Toolkit began to unfold as a logbook, plant-identification guide, map, and observational device for recording, considering, and proposing different ways of engaging with vegetal sensors and air-quality gardens. Given the cold temperatures, this unfolding was at times marked by a rapid jog-walk to the next garden. At various stops, we would wave to a stand of *Euphorbia* and quickly move on to observe lavender, lamb's ear, and jasmine while hopping in place to learn about clean-air gardens developed by residents as part of the City in Bloom initiative in 2017. We also discussed the proliferation of air-quality plants and gardens in numerous other locations that we would not be visiting, including at the Barbican Tube Station, where a community garden of air-quality plants had been installed to green the urban canyon of the station. On a disused rail track, coral bells and ivy filled planters, where their broad leaves and masses of green surfaces were meant to capture particles and nitrogen oxides. We speculated about how large a planted area would need to be, especially in this area of London, to take up pollutants in an effective way. One participant asked if there was a way to measure plant mass needed in relation to pollution levels. Many people wondered: Was this a feasible strategy, given the intensity and pervasiveness of air pollution in London? Did we need a how-to guide for aerating London's atmospheres on a wider scale?

As we expeditiously made our way to the Moor Lane pop-up garden, we discussed how air-quality gardens could also be a way to make more evident the role and benefit of vegetation in improving air quality. The Moor Lane garden had developed through a considerable volunteer effort. Populated with corrugated steel pipes that sprouted a burst of air-quality plants, the site provided a striking visual display that collided with the hard concrete and brick edge of the Barbican podium and parking garage. Numerous air-quality plants jostled together in this space, including ivy, ferns, birch, *Hebes*, silverbush, and juneberry. Plants with smooth but small leaves such as *Hebes*, as well as vigorously spreading plants like ivy, came together in a display of plants that we discussed and imagined to be sensing, absorbing, capturing, and filtering air pollution. We noted that small trees such as juneberry can mitigate pollutants including particulate matter and

Figure 4.10. Air-quality garden walking tour visits the pop-up garden developed through the City in Bloom initiative. Photographs by Citizen Sense.

Figure 4.11. Barbers' Physic Garden at the edge of the Barbican and Museum of London sites; viewing plants in the Barbers' Physic Garden, including *Camellia*, previously used for treating asthma. Photographs by Citizen Sense.

nitrogen dioxide as long as their canopies do not mass together and trap pollution at street level. At the same time, this species is particularly beneficial for wildlife, providing berries, pollen, and nectar for birds and insects. The cultivation of urban environments began to draw in multiple other organisms that form ecologies specific to air-quality gardens.

We then made our way to the final stop along our walk, visiting the Barbers' Physic Garden to consider the restorative and curative qualities of plants. This historic garden was developed in the sixteenth century and was a site to which the botanist John Gerard later contributed.[66] The garden was originally developed with plants required by surgeons, and the most recent version of the garden was planted in 1987 on a derelict bomb site. In this series of plots, forty-five different species of herbs lined gravel pathways, with each specimen having a placard noting its distinct properties for treating wounds, bruises, and burns. In this site of former bomb damage, strewn with the ruins of a Roman fort and Victorian walls, we investigated the relationship between plants and health. We considered how plants as curative organisms could contribute to healing environmental health problems. Finally, we asked: Could we make a twenty-first-century how-to guide and Physic Garden for restoring the health of environments?

Once we had returned to the Museum of London, we regrouped over a much needed tea-and-biscuit break before reviewing the air-quality garden walk and beginning a discussion of the Phyto-Sensor Toolkit. Drawing on observations and propositions that participants recorded along the way, as well as generating additional proposals that arose in the course of the workshop, we spent some time thinking and working through what communities would need to construct air-quality gardens in areas of London and farther afield. Paul offered advice on plants and gardening techniques, while we reviewed the difficulties of working with local councils and the complexities of ensuring maintenance of vegetation so that air-quality gardens would not expire from neglect.

The final version of the Phyto-Sensor Toolkit incorporated these proposals and observations from workshop and walk participants. As a how-to guide for air-quality gardens, the toolkit developed through several iterations in the open air. The construction of gardens, the installation of vegetal and digital sensors, the testing and expanding of the instructions and resources through a workshop and walk, and the compiling of the toolkit as a print and online manual available on the Museum of London website all became ways of aerating the toolkit and expanding the designations and practices of citizens and sensing. We developed the toolkit through these open-air modes of inquiry so that it could contribute to additional air-quality gardens and community projects. Just after we published the toolkit online in May 2018, we learned that community groups were taking

up the toolkit and using it as a guide for making air-quality gardens, including on Clean Air Day. Aeration is, then, an invitation to incorporate, attend to, and participate in more-than-human sociality and sensing. It presents an openness to expanded and more-than-human modes of sociality that work toward more breathable worlds.

How to Multiply Citizens in Worlds

Plants are participants in urban ecologies, and they contribute to urban environmental communities. The Phyto-Sensor Toolkit tunes in to these expanded processes of environmental sensing that occur across multiple entities. This is another way of thinking about and working with sensing beyond an anthropocentric approach to environments, where organisms and environmental relations are differently brought into view and activated through their interrelations with and experiences of pollution.

As Crawley suggests, "everyone is held within breathing as process."[67] And yet, this breathing involves multiple engagements that are differently situated and experienced. Humans unequally experience exposure to air pollution, which can in turn even affect their capacity to sense. Plants absorb and exchange pollutants, while multiple other organisms are caught up in sensing and processing the effects of polluted atmospheres. Multiple organisms act as sentinels, bioindicators, and more-than-human sensors that express the conditions of environmental toxicity and change. These practices constitute differential and at times collaborative modes of sensing. Such expanded sensing practices offer different ways of cultivating urban air and working toward more breathable worlds by tuning in to the unevenly shared conditions of breathing, sensing, and exchanging atmospheres.

These collective contributions to environmental sensing provide an invitation to cultivate more expansive citizens and worlds in the making as "pluralistic realism."[68] As discussed throughout this study, citizen-sensing practices often challenge the "one-world world" of scientific realism. Different experiences, modes of evidence, and encounters with air pollution materialize through these practices, which do not assemble into a singular epistemological or ontological plane.[69] So too does more-than-human and vegetal sensing shift and multiply the worlds of experience that could be brought to bear on the problem of pollution.

Such an approach requires that other worlds of relevance register as significant, rather than attempting to fit these practices into a singular world of experts and amateurs, humans and more-than-humans. Citizen sensing can be an example of a project that is meant to aid an already established trajectory of scientific inquiry.[70] Yet this chapter outlines an approach to multiple citizens to

indicate how worlds, political subjects, relations, and actions form through different engagements with sensing organisms and sensing technologies. As John Law notes, these are the conditions that challenge a "one-world world," since practices are a way of activating different realities. Such practices have sociopolitical relevance, since they draw together different collectives, activate different versions of the real, and require contingent and specific strategies for working with and across pluralistic conditions.

Air-quality gardens and more-than-human sensing practices are conditions that might be encountered and cultivated in the middle of things. Pollution and environmental change are unequally bearing down on humans, more-than-humans, and ecologies. Yet these are also conditions that generate different political subjects and political work. Such conditions require strategies for being and becoming citizens of worlds along with multiple other entities in the open air. This turn toward the open air involves attending to concreteness and worlds of experience.[71] By working from within the particulars of multiple and differential experiences, it is possible to realize the possibilities of pluralism as what James calls "a translocation of experiences from one world to another."[72] As discussed here, this translocation of experience spans from the vegetal to the digital and beyond. Worlds are not a total surround. Instead, they are vectors of engagement and experience. They form a multiverse or pluriverse, rather than a universe.[73] Worlds involve constitutive processes, exchanges, and intensities. They establish conditions of breathability and reciprocity, as well as of unbreathability and subjugation. Environmental sensing unfolds through these distinct yet pluralistic registers to explore and establish how multiple modes of sensing make and remake citizens and worlds.

HOW TO CULTIVATE RELATIONS

Environmental sensing across multiple entities requires and contributes to the reconstitution of citizens and worlds. In this pragmatist orientation, citizens and worlds are co-constituted and in the making, as well as the unmaking. Multiple citizens involve not merely the multiplication of worlds but also the expansion of ways of being citizens, engaging in relations, and sensing, exchanging, and breathing together. The hard lines between humans and other organisms could begin to blur and be reworked as a vegetative process in this approach to multiple citizens. As Monique Allewaert suggests, drawing on eighteenth-century investigations into coloniality and botany, this could be a way of "vegetating" the subject through and toward more ecological configurations (and even against the citizen of nationalism and colonialism) that complicate "clear distinctions

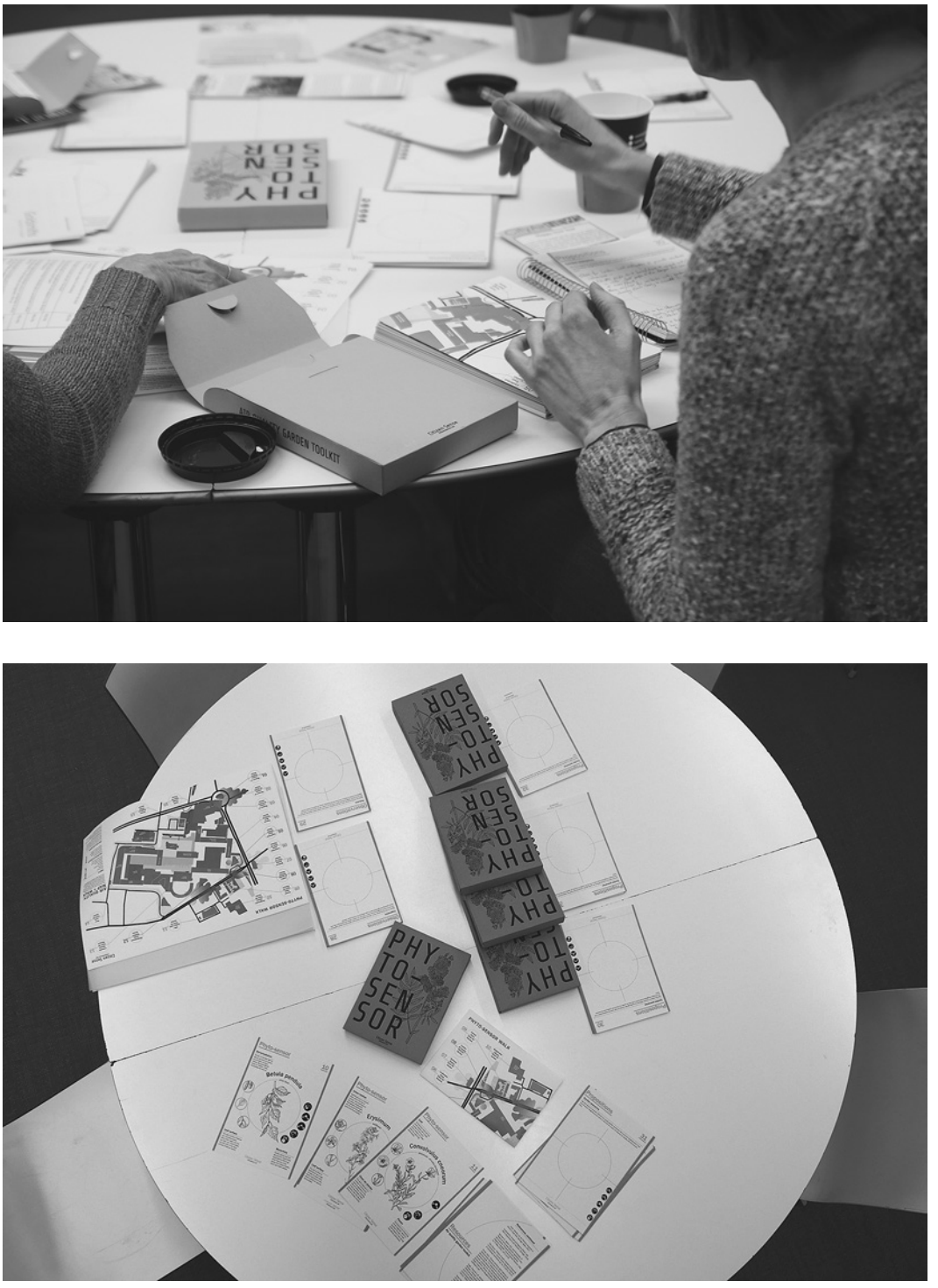


Figure 4.12. Phyto-Sensor Toolkit workshop, participants developing proposals for air-quality gardens to be included in the toolkit. The final version of the toolkit was made available through the Museum of London and Citizen Sense websites. Photographs by Citizen Sense.

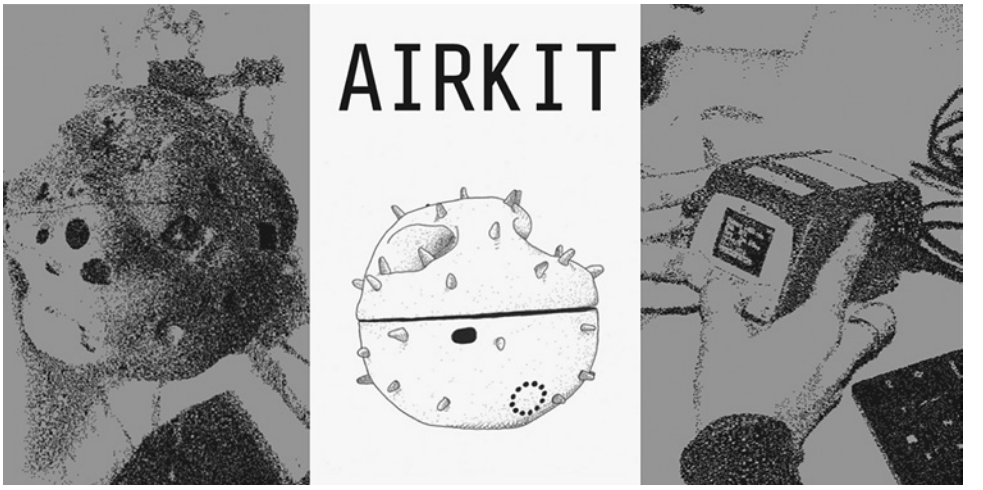
between human beings and the natural world."[74] Through a discussion of *marronage*, Allewaert identifies how ecological configurations of subjects and environments could generate political force by reworking the categories of human and nature while recasting and abandoning categories of slaves as objects. Practices of making and remaking citizens and worlds toward expanded ecologies involve political work, as discussed earlier, that has distinct consequences for the breathability of worlds.

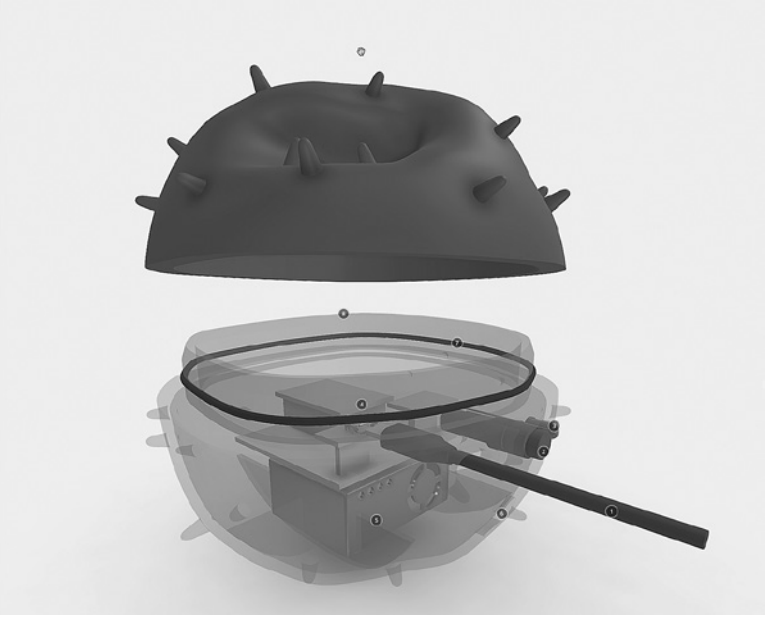
Within processes of constructing, testing, and circulating plans for air quality, multiple citizens surface as such vegetating entities. They are more-than-human collaborators, plucky cultivators, enduring sensors, open-air exchangers, aerating world makers, and political workers. This aeration of citizens and citizenship provides a guide for how to reconstitute citizens through relation, action, and environmental inhabitation. This is an aeration and ventilation of citizens, which seeks to cultivate multiple and recomposed subjects, relations, and worlds. Here, pluralism is not simply an accumulation of more entities. Instead, it is a site of possibility and a provocation to constitute citizens through relation and action. This investigation into multiple citizens is a proposition to consider how worlds are composed through other experiences, and how this might in turn generate forms of "engaged pluralism."[75] In working toward pluralism, James sought to move away from foundationalism, substantialism, and fixed terms, and toward worlds of experience and their a/effects. Yet these forms of action often lead to struggle when attempting to make sense of and compose breathable worlds across different experiences.

As *Citizens of Worlds* emphasizes, encounters with difference and struggle are persistent features of political engagement and democratic life. These conditions are political, moreover, because the conditions of breathability cannot be taken for granted. Air pollution is an often intractable problem that generates differential conditions of struggle. Multiple practices proliferate in attempts to aerate the polluted conditions of urban environments while transforming the confined domains of extraction and despoliation, the diminished breadth of violence and extirpation, and the airless spaces of thought and politics. These are struggles for environments, for constitutive exchanges, for action, and for reciprocity. "A struggle to achieve reciprocity," as Kimmerer suggests, involves working toward breathability and democracy of and for all species in ways that could reinvent possibilities for political subjects, justice, and governance.[76] In this guide for how to construct air-quality gardens and vegetate citizens, you might find also suggestions for how to cultivate and work toward reciprocity by transforming the subjects and relations through which environmental problems come to matter and are acted upon.

TOOLKIT 5

AIRKIT TOOLKIT





The AirKit toolkit creates a citizen-sensing infrastructure for monitoring air pollution. It consists of a logbook, a second-generation Dustbox, an Airsift platform, and a tool for writing data stories. More information is available at https://citizensense.net/projects/#airkit. Illustration above by Sarah Garcin, illustration below by Andrea Rinaldi; courtesy of Citizen Sense. This toolkit can be found in a more extensive form online at https://manifold.umn.edu/projects/citizens-of-worlds/resource-collection/citizens-of-worlds-tool1kits/resource/airkit-logbook.