

# antennae

THE JOURNAL OF NATURE IN VISUAL CULTURE



experiment

# antennae

THE JOURNAL OF NATURE IN VISUAL CULTURE  
edited by Giovanni Aloï

Antennae (founded in 2006) is the international, peer reviewed, academic journal on the subject of nature in contemporary art. Its format and contents are inspired by the concepts of 'knowledge transfer' and 'widening participation'. Three times a year, the Journal brings academic knowledge within a broader arena, one including practitioners and a readership that may not regularly engage in academic discussion. Ultimately, Antennae encourages communication and crossovers of knowledge amongst artists, scientists, scholars, activists, curators, and students. In January 2009, the establishment of Antennae's Senior Academic Board, Advisory Board, and Network of Global Contributors has affirmed the journal as an indispensable research tool for the subject of environmental and nature studies. Contact the Editor in Chief at: antennaeproject@gmail.com Visit our website for more info and past issues: www.antennae.org.uk

Front and back covers: *Hyperbolic Jellyfish* from the *Crochet Coral Reef* project by Margaret and Christine Wertheim and the Institute for Figuring. Plastic bin-liner bags, 2007. Photo © Institute For Figuring.  
Theme page: *Warm Winter*, Reed+wood+data, (detail) by Nathalie Miebach. © Nathalie Miebach

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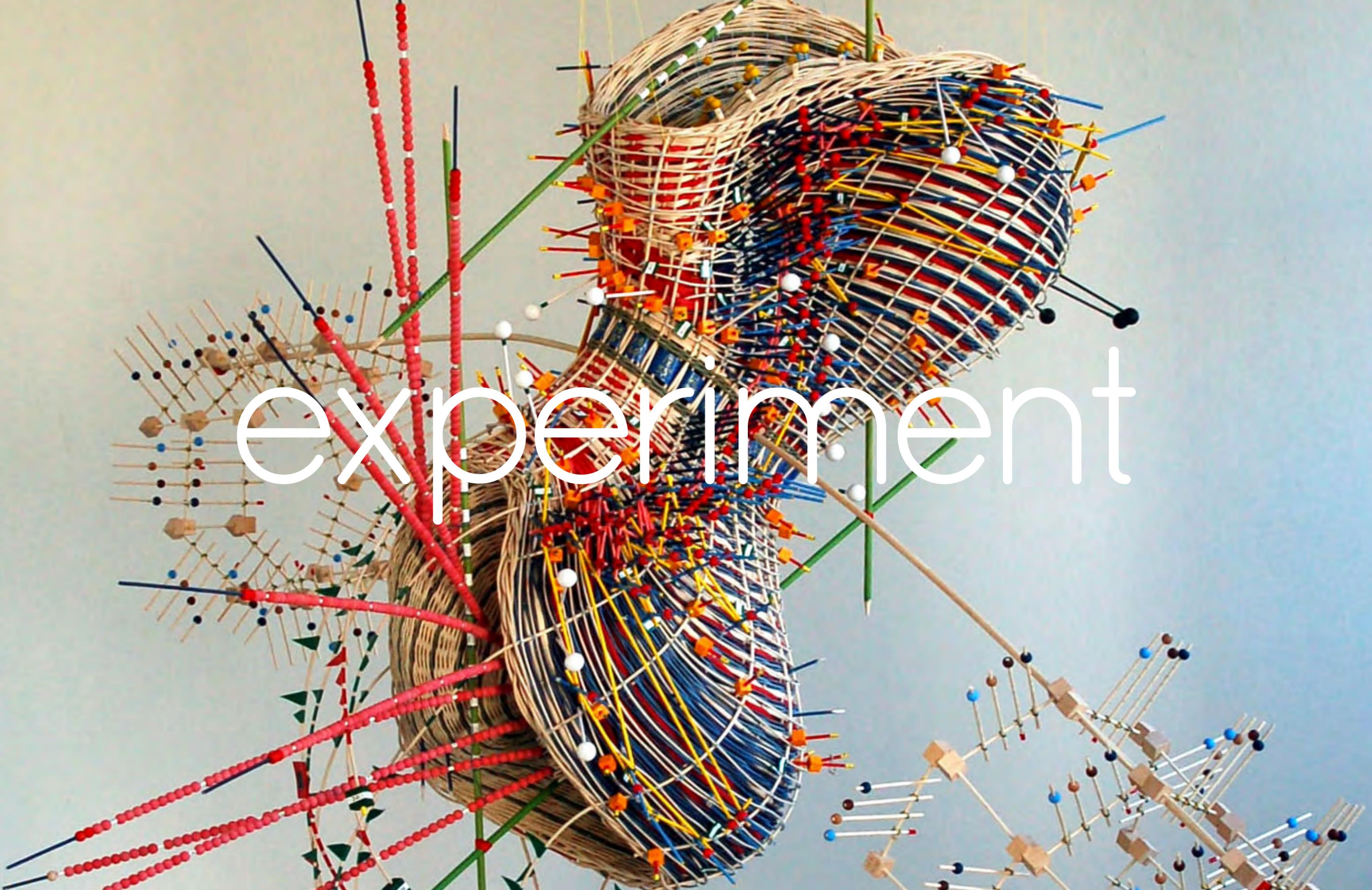
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Erik Frank and Giovanni Aloï

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A complex, colorful sculpture made of woven straw, sticks, and beads. The central part is a large, rounded, woven structure with a grid-like pattern of blue, red, and yellow threads. It is surrounded by various other elements: long red beaded strands, green sticks, and smaller woven structures. The background is a light blue gradient. The word "experiment" is overlaid in white, lowercase, sans-serif font across the center of the image.

experiment

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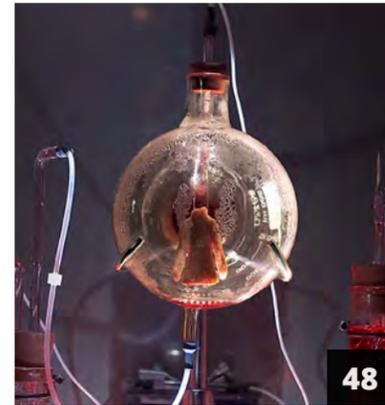


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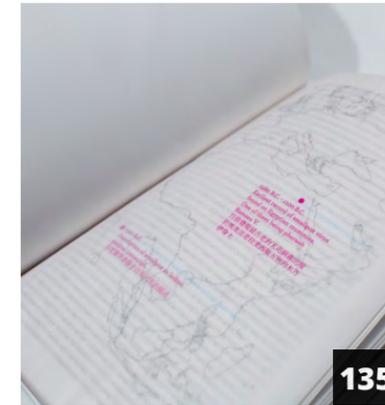


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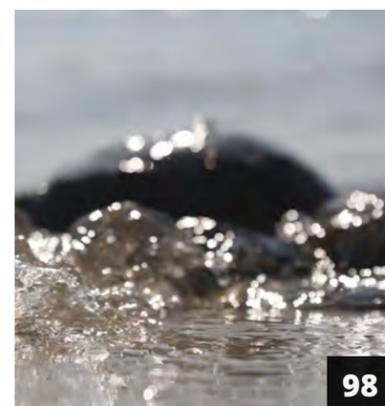


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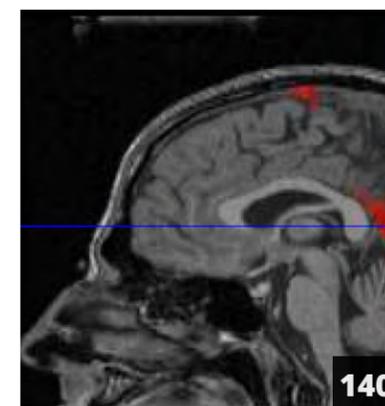


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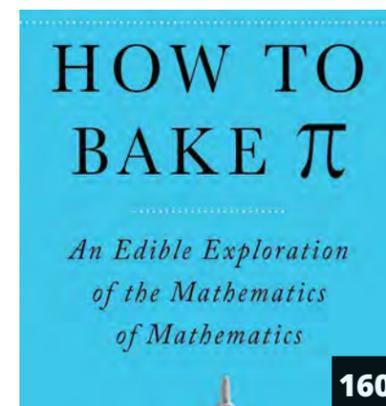


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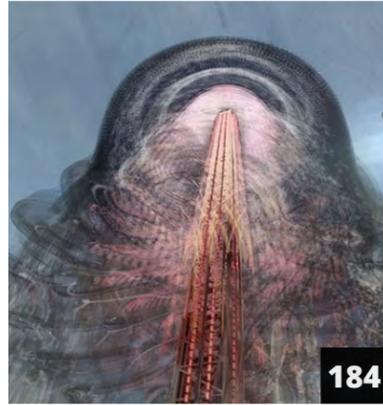
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A unique nexus of art, science, geometry, and environmental reflection, *Crochet Coral Reef* is an ever-evolving archipelago of woolen installations that not only emulates the structures of natural reefs but also enacts the evolutionary processes by which living things evolve.

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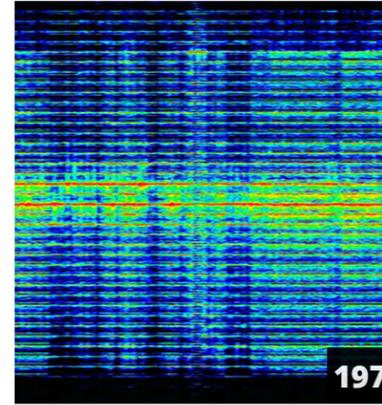
Algorithmic Photography is an innovative technique developed by artist Alex May, which explores the concepts of motion and time within contemporary digital photography.



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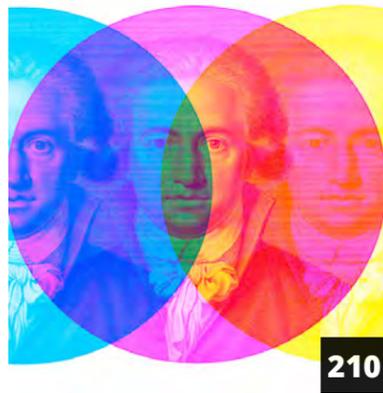
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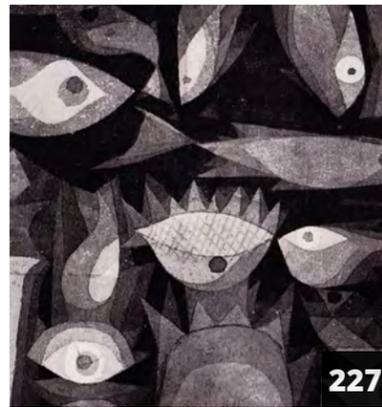
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Right: detail from the *Crochet Coral Reef* project by Margaret and Christine Wertheim and the Institute For Figuring as installed at the London SouthBank, 2008.  
Photo: Simon Greig  
© Institute For Figuring



# editorial

Giovanni Aloï

The world has just taken its first glimpse of a black hole. The image looks surprisingly fuzzy. It is somewhat reminiscent of those snapshots of a solar eclipse people take through their shades. But that's because it is a far cry from the sublime imagery of computer-generated black holes NASA has produced to help us envision the darkest corners of the universe. The voluptuously wavy crown of astral debris surrounding the core of nothingness just isn't there. In its place, we see a less alluring smudge of fiery orange, a halo of dust and gas situated 55 million light years from Earth.

The image was captured by Event Horizon, a network of eight radio telescopes situated in different countries by a team of 200 scientists. In essence, this image is a composite vision of the invisible whose history is deeply connected to the theories and philosophies of photography. From the early multi-negative photomontages of Oscar Gustave Rejlander to the subversive, political collages of Hannah Höch, photographers have always wrestled with the medium's proclivity to adhere to the real world. To Baudelaire, the camera was the enemy of the soul and true artistic inspiration; the ultimate insult to the "divine art of painting". "I prefer the monsters of my fantasy to what is positively real", said the most controversial critic and writer of the fin de siècle.

But photography's ambition has always stretched far beyond the desire to capture reality as we see it. Early scientific application of photography revealed its potential. The second half of the nineteenth century saw the rise in popularity of macro photography. The history of photography has always been about extending our sight in conceptual as well as practical ways, as seen in Auguste Adolphe Bertsch's unprecedentedly detailed images of fleas and mites, Wilson A. Bentley's snowflakes, and Talbot's obsession with diatoms and the omnipresent images of faked ghosts.

In the 1850s as John Whipple and George Bond brought the moon closer to us, albeit in black and white. The first photograph of Earth taken from space followed roughly a hundred years later. And then, in 1968, came the iconic image titled Earthrise which instilled in us the existentialist feeling captured in David Bowie's Space Oddity lyrics "planet earth is blue, and there's nothing I can do". Bowie poetically referred to the "overview effect", a cognitive shift experienced by astronauts during spaceflight as, from a distance, they see our planet as a whole—it's an event akin to Jacques Lacan's "mirror stage": the young infant's experimentations with their own body and identification with their reflected image. But these visual landmarks are more than just important scientific images—like the best kind of art, they are the result of endless experiments with ideas, tools, and materials. And they have the markedly artistic capacity to alter our perspectives and change our collective mind forever.

Experiments are the essential tools of both science and art. They are the starting point (and sometimes the endpoint) of long journeys defined by mistakes, trial and errors, eureka moments, dismay, and endless surprises. Experiments are charged with agency. They generate encounters, incidents, births, deaths, and transmutations. They are bridges grounded in the matter of life and thinking stretching across a dark abyss.

Experiments have been essential to the making of the image of a black hole we see today, yet they remain unseen. The public focusses on the final success, only the researchers will know about the experiments required to reach their aim. Black holes have always been speculative entities. They lie at

the last frontier of our ability to conceive the universe; their mysterious voracity has made them perfect sci-fi icons. They were first predicted by Einstein's theory of relativity, but it took over a hundred years to prove their existence through photographic evidence.

At a time in which the obscurantism of political leaders and wealthy elites discredits scientific knowledge, the photographic evidence of a black hole stands as a major testament to science's determination, drive, and ability to ask brave questions and to find answers. This accomplishment is an undeniable proof of the global collaborative spirit necessary to accomplish unthinkable feats and to envision the secret workings of the universe beyond our biological and conceptual boundaries. Unlike other images taken of more familiar celestial bodies, this image is drenched in an existentialist kind of poetic that transcends the purely scientific real. And could this image be considered art at a time in which many artists work like scientists, adopt scientific tools, language, and methodologies to produce their work? After all, so much art from across the globe has been concerned with materializing the invisible—this image accomplishes just that in a way that no other previous one could.

It is in this spirit that the next two issues of *Antennae* explore the rise of interest in art and science collaborations. Partly because of the resonance of the posthuman cyborg in the ontological turn; because of the rise of Bio Art; because of the prominence that multidisciplinary has acquired in academia; and surely in light of our fraught relationship with our environment and climate change, the intersections between art and science have recently become more complexly defined by new ethical, political, aesthetic, and poetic registers.

This project is co-edited in collaboration with American artist and philosopher Jonathon Keats whose bold experiments have raise serious questions and put into practice his conviction that the world needs more "curious amateurs," willing to explore publicly whatever intrigues them in defiance of a culture that increasingly forecloses on wonder and silos knowledge into narrowly defined areas of expertise.

A team of scholars and artists has also helped us with the task of selecting some of the most exciting representatives of this ever-growing movement. We are thankful to Andrew Yang (Associate Professor of Liberal Arts at the School of the Art Institute of Chicago), Daniela Silvestrin (Curatorial Assistant at Leuphana Universität Lüneburg), Julie Marie Lemon (Program Director & Curator of the University-wide Arts, Science + Culture Initiative, at the University of Chicago), Julia Buntaine Hoel (Conceptual Artist and Director of SciArt Magazine), Ken Rinaldo (artist and professor of robotics at The Ohio State University), and Piero Scaruffi (research on cognitive science and art) for their help and advice. And as always, we would like to thank everyone involved in the making of this issue.

**Giovanni Aloï**

Editor in Chief of *Antennae*project



# From 'SciArt' to 'Art Science'

*The increasing use of 'mash-up' terms like Sci-Art and ArtScience might suggest that we have sutured the 'two culture' divide. It might also indicate the opposite. We discuss the trend in Sci-Art collaboration and its early lessons, before exploring the emergence of the '3rd culture' through communities of practice and dialogic communication. Introducing the emergence of ArtScience, we situate it on the spectrum of multi-to transdisciplinary practice. We argue the importance of understanding the different forms of art and science interaction, and that precision of terminology matters for recognising respective validities and pushing interactions further into common practice.*

text and images by **Jenny Rock** and **Sierra Adler**

For over two decades the Sci-Art movement has been gaining momentum; it has been enriching and beautiful, and even, increasingly, funded. It is starting to infiltrate widely, even into the most returns-driven and performance-indicator-assessed government initiatives; it is nearly mainstream. For example, the New Zealand government funds its key research priorities through a National Science Challenge (NSC) programme, and one, the Sustainable Seas NSC, recently funded a 'transdisciplinary art-science postgrad position'.<sup>1</sup>

We have called art and science interaction many things (from Sci-Art to Art-Science, Art/Science and Art + Science), and variously described it as 'intersections' or 'collaborations' between individuals or institutions. Retaining their disciplinary distinctions within the intersections, these crossings exist in a binary or Mendelian sort of way; one collaborator is the artist and one the scientist, there's been little blurry blending of traits. But now we have ArtScience. One word, mashed together, with no hyphen or space. What kind of mix-up does this suggest? And is it any different from what we've already had? We will argue yes, but not make this a list of what is or isn't Sci-Art or ArtScience. The message we want to send is about how their distinction relates to some of the big issues we are grappling with in science and society today, and why the labels matter.

## Some decades of Sci-Art

One of the major drivers of the Sci-Art movement has been the British biomedical research institute, the Wellcome Trust. Between 1996 and 2006 their Sci-Art Programme funded around 118 projects, to the tune of nearly three million pounds. Typically, this programme involved artist-in-science residencies or collaborations that generally focused on artists using scientific tools and technology as a medium

for their art. Described as an "integrated arts practice within a scientific environment",<sup>2</sup> it provided a kind of experimental 'laboratory space' for artists to draw on the expertise of scientists and technologists.

Evaluation of the programme revealed its several successes: "artist's communicative abilities had helped demystify and make more intelligible, aspects of contemporary science".<sup>3</sup> It helped develop new processes of working for artist's practice, and of communicating for scientists -with some becoming more open to risk-taking through their association with artists (although presumably more in their outreach than in their scientific research). The Sci-Art Programme also -at least temporarily- helped ease some of the funding disparity between arts and sciences.

In general, the interactions were mostly one-directional. Science-inspired art but not vice versa, rather, it helped inspire the viewing public of the science. While collaborators "learned something about each other's disciplines, they did not often develop any additional insights into their own practices".<sup>4</sup> Thus, Sci-Art functioned essentially as one-way science communication - communicating scientific research and ideas to the public, and delivering a general message about the science profession. Not only did this improve a perceived image problem for science, but it was also shown in different instances to increase advocacy, public awareness and interest in science, possibly extending its reach across new demographics, probably tapping into deeper engagement pathways (more sensory, emotive, memorable) and inspiring learning and potentially even behaviour change. Many of the scientists involved thought the collaboration had helped raise awareness about the wider context of their work and introduced the idea of public domain into work done in the scientific domain 'behind the scenes' - in effect enabling artists to act as the public's representative.<sup>5</sup> In essence, however, most Sci-Art interactions boiled down to activity that used artists to show science in an aesthetically pleasing way, with no perceived contribution to scientific process or outcomes.

In 2004 the British Arts and Humanities Research Council established a new scheme, the Arts and Science Research Fellowships, which funded 16 collaborations between university-based scientists and artists (mainly visual ones). Evaluation of this Sci-Art programme showed similar outcomes as those found from the Wellcome Trust. Looking critically at the relationships between artists and scientists, it was revealed that, if anything, the collaborations forged distinctions between art and science. "It seemed that practical and conceptual distinctions were made more real in the process of the collaboration itself".<sup>6</sup> Both artists and scientists actively maintained their disciplinary boundaries such that, ironically, Sci-Art initiatives could be seen as an effective device to help reify the cultural divide.<sup>7</sup>

...the seemingly open and exploratory space of so-called interdisciplinary practice can also be a means to efficiently corral and patrol the cultural borders of art and science. The

.....  
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.....

'inter' practices end up existing in a space that appears as overly permissible, making it more than easy to attack the authenticity of work that doesn't quite live up to some hypothetical standard projected from the proper disciplines.<sup>8</sup>

Indeed, some in the arts sector expressed concern about funding for reasons not strictly related to the arts. For example, "instrumentalisation of the arts in the service of biomedical science"<sup>9</sup> was seen to negatively impact arts practice as 'inauthentic' art projects arose from chasing Sci-Art funding. In what has been described as a service-subordination hierarchy, Sci-Art has often been seen as serving science.<sup>10</sup> Concern has also been expressed from within science, when often in Sci-Art "what is being counted as scientific content is nothing more than a remnant of scientific forms stripped of their content".<sup>11</sup>

Other recent evaluation of Sci-Art work continues to reveal critique from artists and scientists, respectively, asking of the work: "Where is the art? [or] Who do you think you are to tell me anything about science?"<sup>12</sup> Posturing and professional identity issues (remaining particularly feisty under continued financial inequalities) continue to prop-up a territorialism that propels the 'two culture' divide. This aligns with a false dichotomy that persists within the disciplines and among the public. Artists are seen to be the ones "making culture"<sup>13</sup> creative because they conjure up something personal and novel from their own creativity.<sup>14</sup> Whereas scientists are still seen to be objectively and meticulously examining the universe and all it contains: "science will do the essential counting, while art will extract the meaning".<sup>15</sup> In most evaluations of Sci-Art it is not really clear if these misconceptions come most from the artists, or scientists, or the public (or more precisely, the artists or scientists or the public subset most likely to take part in, or view, a Sci-Art collaboration). Whatever the root, this perception is limiting since our understanding of science has moved on.

The idea of scientists exploring a 'real' landscape in which science discovers and harnesses something that has always been there for the finding,<sup>16</sup> and operates the "highly technical process of revealing what is there"<sup>17</sup> (while arts grapple with a metaphysical world) is dated. Since Thomas Kuhn (and before) we know there is no such clean separation between science and culture or objective and subjective, because we understand the effect of culture and aesthetics on scientific paradigms, on what we study and how we study it. We know our scientific knowledge changes over time, that our understanding is often wrong and that there can be no progressive march to truth. However, misconceptions persist in part because we continue to capitalize on the false dichotomy of 'two worlds meeting', possibly because dichotomies have an easily exploitive commercial glamour.

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### **A 3rd Culture and Beyond**

Amidst the continued polarisation of popular ideas of art and science, talk of a 3rd culture has arisen. This involves observation that art and science share many similarities when understood as communities of practice.<sup>18</sup> It is also apparent that there is a 'culture of experiment' common in art studios and science laboratories, with both serving as places of curiosity and discovery. Art and science alike can be understood as exploring new conceptual structures and investigative methods and using new metaphors to reveal alternative directions and novel consequences.<sup>19</sup> In both practices, mastery of craft and expert judgement are important, whereby "crafting a work in progress towards a state of exhibition, inspection and judgement by fellow professionals, sponsors and the wider public [is] a strong driving force for scientists and artists alike".<sup>20</sup> Both are increasingly considered as a way of thinking, more than as an absolute body of knowledge.<sup>21</sup>

The 3rd culture has been described as a space where expert collaborators intersect to make work for the public domain. But beyond serving as a means to connect science to a public, it forms a three-way interaction between art, science and the public where boundaries are fluid and mutually enhancing.<sup>22</sup> As a society, we are moving beyond absolute specialist divides and hierarchical modes of communication and consultancy— quite likely because of wicked world problems we face, but also because of wider participatory and co-creation movements.<sup>23</sup> For instance, citizen science facilitators are starting to consider more co-creative interactions with the public beyond traditional contributory modes.<sup>24</sup> Meanwhile, science and society consultation approaches increasingly value local knowledge and reciprocity, to experiment in novel participatory spaces.<sup>25</sup> Concomitantly, there is a fresh emphasis on incorporating visual methodologies (e.g. visual ethnography)<sup>26</sup> and arts-based research (for example into health research).<sup>27</sup>

Despite interest and some intent, we are not in the 3rd culture space yet. Discourses and collaboration across the arts, sciences, and humanities are far from a mature or fully effective process.<sup>28</sup> However, the potential exists for more mutual interactions, and we are in the right time and place, for several reasons. Science has changed. Since the 'science wars' of the '80s and '90s science itself has become aware "of issues and problems such as the historicity of truth systems, and objectivity, the limitations imposed by short-term market constraints and the dramatic impact of the social and material environment on the work of individuals in laboratories".<sup>29</sup> Definitions of 'post-normal science'<sup>30</sup> embody our increasing understanding of connectivity and complexity theory, uncertainty and likelihood models, sensitivity and Bayesian probabilities, whose constructs accept openly a necessary blend of known data and unknown (subjective) possibilities.<sup>31</sup> Medical science, for instance, recognizes that "the narrativisation of bodily experiences [...] are no longer issues that can be addressed by reading figures and graphs on a screen [...] Medicine is today one of the spearheads of Art-Science".<sup>32</sup>

Art has also changed. Bourriaud characterizes the recent shift as a revision of artistic purpose whereby “the role of artworks is no longer to form imaginary and utopian realities but to actually be ways of living and models of action within the existing real”.<sup>33</sup> Contemporary art has shifted its focus to the production (or even co-creation) of works that encourage relational interaction, focusing on pieces and performances that entice audiences to assess their preoccupations and dig into the constructs of our immediate reality. “Artistic activity strives to achieve modest connections, open up obstructed passages, and connect levels of reality kept apart from one another”.<sup>34</sup> Situated more frequently outside the galleries, relational aesthetics art is better understood as a creative process allowing integration of knowledge, materials, techniques, and culture.<sup>35</sup> Indeed, there is a growing recognition of art’s cognitive practice enabled by the power of visualisation, haptics, and sensory pattern detection and an increasing tendency within arts towards more explicit social engagement.

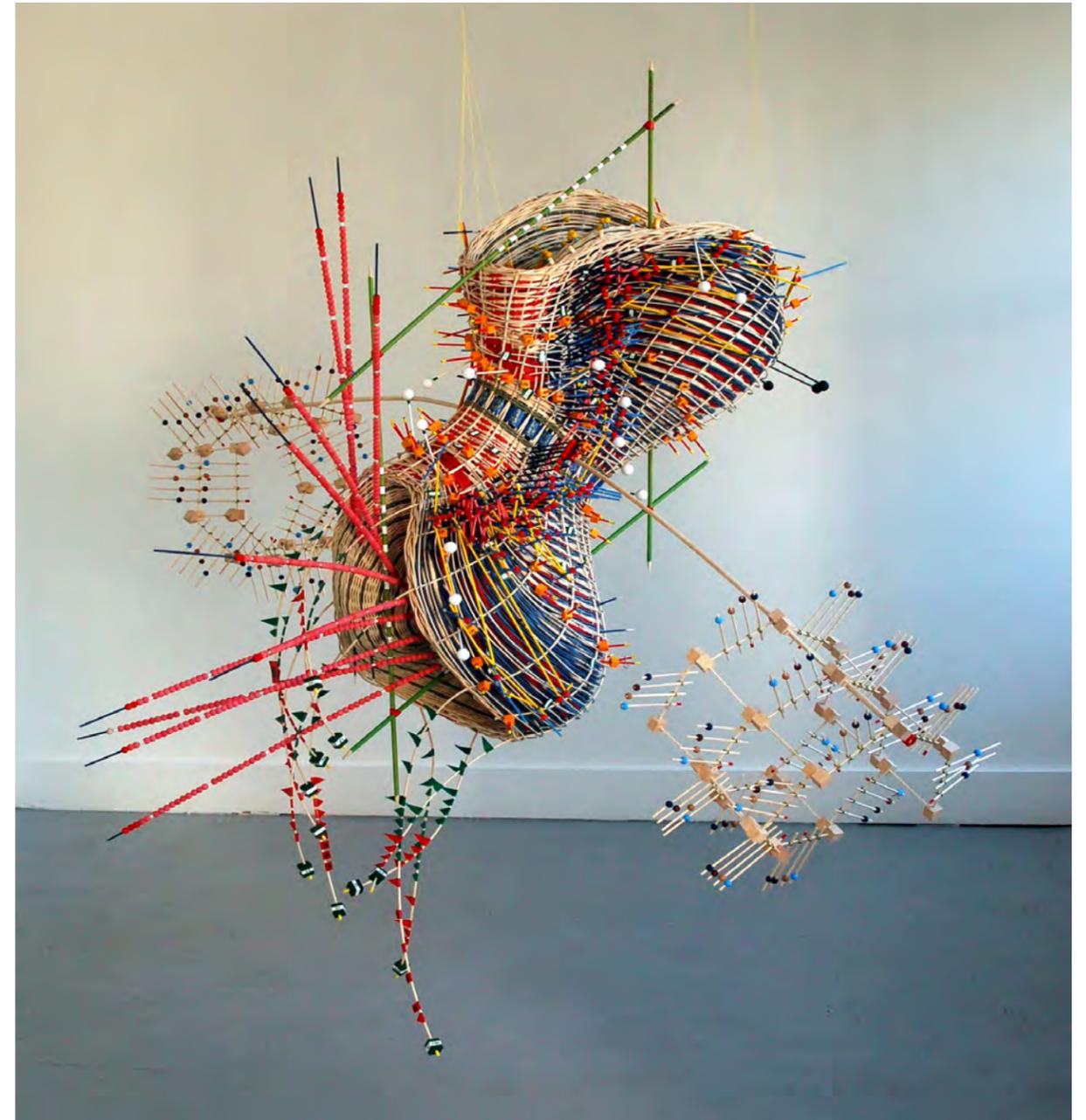
*We are witnessing a big trend in younger people combining science, high-tech engineering, design and art, with their hybrid works communicated through internet URLs, blogs and social networks, as well as, increasingly, recognised in galleries and museums.*

And society itself has changed. “The social turn” - as Bishop<sup>36</sup> terms it - is slowly breaking down rigid measures of self-definition. Young artists and scientists alike are increasingly at ease with distributed networked knowledge and how to interact with ‘big data’. The born-digital generation find themselves at home in a world of IT visualisations and model realities. There is a new and rapidly evolving group of artists, scientists and engineers networked together in a community of practice within ‘maker’/hacker communities, alternative arts centres and citizen science movements.<sup>37</sup> We are witnessing a big trend in younger people combining science, high-tech engineering, design and art, with their hybrid works communicated through internet URLs, blogs and social networks, as well as, increasingly, recognised in galleries and museums.<sup>38</sup> Some argue that a 3rd culture is now in fact too simplified a goal for art and science collaborations. Far more than two approaches are often involved in such interactions, and a wide range of amateur and professional participants from fields outside science or art (e.g. a range of technical experts from engineers to designers). As Vaage notes “the image of a ‘third culture’, disguises the plurality of perceptions and approaches within and across fields [and] occludes the multiple possible constellations of practitioners, roles and approaches”.<sup>39</sup>

### Emergence of ArtScience

We have started to enter a no-longer-polarised space of artistic and scientific research. And here emerges the ArtScience movement, which is described as an overarching synthesis that integrates knowledge through processes of invention and exploration. It also moves art out of its galleries and museums, and science out of its laboratories and journals, into newly invented spaces. According to the ArtScience manifesto published in the journal *Leonardo*<sup>40</sup> it is

not embodied in its products so much as it is expressed through its skills; [it] transcends and integrates all disciplines or forms of



**Nathalie Miebach**

*Warm Winter, Reed+wood+data, 2007* © Nathalie Miebach. ArtScientist Nathalie Miebach interweaves big data (e.g. from the National Oceanic and Atmospheric Administration) with her locally collected data (this piece translates temperature, wind, tide and moon data collected at Herring Cove, MA) and reveals novel temporal patterns (the time frame represented is Dec 2006-Jan 2007).

knowledge; [it] melds subjective, sensory, emotional and personal understanding with objective, analytical, rational, public understanding; [one] who practices ArtScience is both an artist and a scientist simultaneously and one who produces things that are both artistic and scientific simultaneously.<sup>41</sup>

How do we make sense of something that, as Andrew Yang puts it,

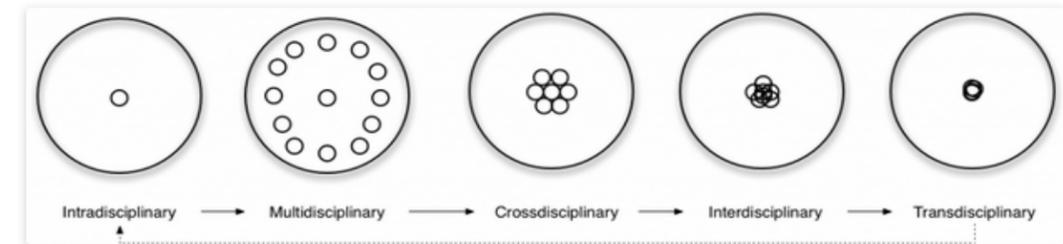
is neither quite this, quite that? It might be easier than it sounds if we acknowledge one thing: science and art's existing inherent blurriness. Indeed, a problem with art and science collaborations lies in the suggestion of their component disciplines as homogenous categories easily defined, rather than heterogeneous fields of practice: "Given their nature as historical and evolving domains of inquiry, what counts as art or as science is a moving target".<sup>42</sup> Any 3rd culture has to be more than the derivative of two, but instead nth cultures<sup>43</sup> - from chemistry, physics, biology, maths, anthropology, and psychology to abstract, realist, performance, gallery, street, visual, sonic, kinetic, and social forms. In moving further beyond assessment of the influence of science on art, or the influence of art on science we enter: "Deeper realms of enquiry [that] concern complex dialogues centred on issues of cognition, perception, intuition, mental and physical structures, the communicative and social action of images".<sup>44</sup> It could thus be argued that the name ArtScience itself might be problematic and broader terms like 'hybridity' might be more accurate.<sup>45</sup> It is certain that framing the interface around the terms art and science still "muddies the conversation",<sup>46</sup> when our focus should be based on collaborative problem-solving that is both creative and practical.

This has been called the new hybrid 'what-if' space for configuring new kinds of meaning by "having faith in uncertainty, finding pleasure in mystery, and learning to cultivate doubt [...] a constant rejiggering of the relations between theory and phenomena".<sup>47</sup> The common ground this space might occupy comes from art's and science's shared culture of uncertainty and experiment. This would move us away from the aesthetic fixation with the images or objects of science, and shifts us to the hows, whys, and with what cultural stakes science and art are practiced.<sup>48</sup> As Latour puts it:

...there is no possible reconciliation between art and science, no aestheticisation of beautiful results of science (fractals, galaxies, brain scans, etc.), but an immense building site where once again, just as in the 16th and 17th century, every intellectual skill from artists, scientists, politicians, statesmen, organisers of all kinds, merchants and patrons, are trying to reinvent an Art of Describing...<sup>49</sup>

This type of practice would align with a change of approach, from intradisciplinary (working within one discipline) and crossdisciplinary (working in one discipline with the perspective of another) or even multidisciplinary (different disciplines working together, each drawing on their disciplinary knowledge) to interdisciplinary (different disciplines integrating knowledge and methods to synthesise an overlapping approach) and, ultimately, transdisciplinary (a unity of knowledge and methods emerging beyond/transcending the disciplinary perspectives).<sup>50,51</sup> Sacha Kagan notes that interdisciplinary practice involves changes in

*This has been called the new hybrid 'what-if' space for configuring new kinds of meaning by "having faith in uncertainty, finding pleasure in mystery, and learning to cultivate doubt [...] a constant rejiggering of the relations between theory and phenomena".*



Alexander Refsum Jensenius

Sketch of Disciplinarity, 2012 © Alexander Jensenius

how scientists or artists work and that it can result into a practice that "may 'irritate' (in a Luhmannian sense, i.e. disturb according to an inner selectivity) the own discipline".<sup>52</sup> He then describes transdisciplinary practices as 'where different modes of knowing are engaged with on eye level', with a wider integrative vision that, presumably, can avoid such irritation. Like ArtScience, the fields of human ecology or ecological economics are also examples of transdisciplinary work in action. The latter, for instance, does not just combine skills from both disciplines, but "requires a common perspective that 'transcends' those that are standard of the two disciplines",<sup>53</sup> in which economics is modified to incorporate an understanding of humans as an animal species, and ecology recognises the distinct impacts humans have on ecosystems. Like transmedia or transgender, 'trans' recognises an essential blurring of boundaries. It releases us from identity-work to say 'hey, we see a bit of both in it all', or in fact 'I choose C, neither of the above' - something new, where the sum is greater than the parts.

So what kinds of making and thinking can ArtScience practice enable us to accomplish? For one, this label can help us to identify paradigms in science and in society; help us dissect and understand them, and propose new models. Works of art, like emergent patterns in Bayesian networks, can be models for identifying components and relationships within science and society. Arts practices help us by "tumbling together facts and intuition, perception and interpretation, documentation and comprehension", which gives power to "not to draw something you know but to know something you've drawn".<sup>54</sup> Christophe Schinckus<sup>55</sup> has examined financial economics as an art and the Efficient Market Hypothesis (EMH) paradigm as a 'non-representative story', using collage to conceptualise financial economics. He argues that arts practices can usefully investigate scientific knowledge and theories that do not necessarily have a pictorial dimension. By making a hypothetical construct we are imaging (yes, being creative) but essentially, we are making a model. Making projections not of realities but of speculative realities. The features of both artistic and scientific processes lie in inventing new design concepts capable of triggering people's imagination. Schinckus says his work provides "broadened perspective

*Like ArtScience, the fields of human ecology or ecological economics are also examples of transdisciplinary work in action.*

on an existing scientific theory by providing an illustration of the dimensions that are not directly captured in the theory [...] the visual contribution of the collages offers a non-causal and timeless representation of this [EMH] theory".<sup>56</sup>

For example, working from within quantum physics, artist Julian Voss-Andreae observes that it seems impossible to assign a quantum object any objective existence at all:

I believe that art in general, especially once we dispense with the requirement that it visually represent reality accurately, is uniquely capable of instilling an intuition for the deeper aspects of reality that are hidden to the naked eye. [...] This way, art can help wean us from the powerful grip that the worldview of classical physics has had on our every perception of reality for the past centuries.<sup>57</sup>

His sculptures work as metaphors for wave-particle duality theory (which exemplifies the phenomenon by which all matter exhibits wave-like or particle-like properties depending on the experimental question asked). He wants his artwork to lift relative quantum physics ideas and theory "into our collective conscious and aid us in intuiting the unfathomable deeper nature of reality".<sup>58</sup> These examples also show us how to start to assess the transdisciplinary effect of ArtScience. What has been dubbed 'Punt's proof of validity' of such practice is if the analysis makes sense (translates) outside the originating discipline(s) and "has a recursive productive function".<sup>59</sup> Provocatively, Zilberg suggests:

.....  
*His sculptures work as metaphors for wave-particle duality theory (which exemplifies the phenomenon by which all matter exhibits wave-like or particle-like properties depending on the experimental question asked). He wants his artwork to lift relative quantum physics ideas and theory "into our collective conscious and aid us in intuiting the unfathomable deeper nature of reality".*  
.....

If the outsider's analysis presents no new ideas or some form of productive value to internal debate and future research within the discipline and data being analysed, then the analysis or art one creates is mere voyeurism. Otherwise, we are merely recapitulating inter-disciplinary or multi-disciplinary studies or rather simply engaging in parasitology.<sup>60</sup>

These new ways of conceiving knowledge and its products, while creating opportunities, also create confusion about objectives.<sup>61</sup> For ArtScience to generate productive 'what-if' spaces, we must accept the blurring of institutional identities as well as conceptual boundaries, and disciplinary expectations must loosen their traditional standards of evaluation.<sup>62</sup> There are also challenges in how to facilitate spaces of mutual experimentation and how to curate and evaluate such activity and shared objects of knowledge produced collectively. We require "new spheres of operation, new formats of exhibition, models of engagement and outreach ... ultimately to rethink organisations in relation to 21st-century knowledge formations".<sup>63</sup>

So here we are in a new weird hybrid space of digitalized

.....  
*Evaluation For ArtScience to generate productive "what-if" spaces, we must accept the blurring of institutional identities as well as conceptual boundaries, and disciplinary expectations must loosen their traditional standards of evaluation.*  
.....

everything and a 'maker' society rebirth, of capitalism and co-creation, contemplating that deeper nature of reality with massive problems on our doorstep. Again, all this suggests the right time and place for ArtScience. As the executive editor of *Leonardo* journal, Roger Malina, observes: "technology, globalism, and relentless change are characteristics that are creating synergies between the humanities and sciences".<sup>64</sup> We are in relatively uncharted waters, but exemplars are now found around the world. Institutions like the MIT Media Lab (USA), La Laboratoire (France), Symbiotica (Australia) all combine scientific exploration, engineering, design and artistic display in a single space. Other academic institutions are bravely stepping into the unknown, like the University of California at Irvine's Masters Programme in Arts, Computation and Engineering.<sup>65</sup> Discipline-specific conferences in both arts and sciences have begun to dedicate symposia to art and science interaction. For example, the Kavli Frontiers of Science Symposia recently focused one of their core themes on considering the possibility of art and science as "co-dependent on each other [...] to catalyse interdisciplinary exchange and a new genre of experimentation that will move beyond what one of these disciplines can achieve on its own".<sup>66</sup> Even some high-level funding schemes are beginning to emerge. The Djerassi Residency is a programme funded by the US National Endowment for the Arts that brings artists (whose muses are informed by science) and scientists (with demonstrated interest in art) together for a 30 day live/work residency. Participants not only share what they do but how they work out problems and think about big questions.<sup>67</sup>

Major science funders are dipping their toes in; the US National Science Foundation (NSF) funded a five-year project assessing integration of arts and humanities integration into STEM education (that is: science, technology, engineering, mathematics and medicine). They are specifically looking at how arts can prepare students to be better problem-solvers and leaders, more creative and effective scientists and engineers and health care providers.<sup>68</sup> The central tenant of the STEAM movement (STEM + Arts and humanities) is that integrated perspectives and practices support project-based creative learning beyond disciplinary content; it aims to give students tools to 'work along the spectrum' for emergent effects. Other NSF-funding aiming to link introductory science and humanities courses has resulted in courses like "Physical Aesthetics" in the Physics Department of Wofford College (South Carolina). Here the students explore traditional physics topics (motion, velocity, acceleration) as metaphors and even their exams situate test questions within works of art.<sup>69</sup>

### **Intentionality and plurality of approach**

The value of Sci-Art is well recognised in its traditional functional forms where scientists serve artists by creating new materials and spaces to make art, and artists serve scientists by creating artworks to represent scientific concepts for the public.<sup>70</sup> It is also widely appreciated across

disciplines as inspirational, be it celebratory or cautionary, and at both personal and public levels of awareness and action. The Sci-Art movement has made it easier for more future ArtScience collaborations to happen. However, it has also flavoured the expected nature of such collaborations. Although frameworks and environments for Sci-Art are flourishing, for ArtScience they are not. More demanding and challenging of professional identities, funding and education structures, ArtScience work needs to be clearly differentiated from Sci-Art. If we confuse the two, we let down the respective merits of both and we delay building effective frameworks for ArtScience interactions that ensure shared power and equal voices in environments of mutual respect.<sup>71</sup> Consistent use of clear terminology builds understanding and respect for their different requirements for procedure and potential outcomes. Sci-Art and ArtScience require what Gould prescribed for art and science interaction as “a consilience of equal regard”.<sup>72</sup>

***We need to train and support individuals capable of boundary-blurring single-handedly, not just in collaborations. This entails STEAM education systems at all levels and a resurgence of the liberal arts degree.***

In addition to being clearly distinguished from Sci-Art, ArtScience needs to broaden its scope of application in several aspects. Most often ArtScience is found in R&D hothouses for social/environmental and/or technological innovation. Even within education programmes, like the US Art of Science Learning programme, the aim is to incorporate creativity training in science education to grow an “innovative STEM workforce”.<sup>73</sup> ArtScience also seems to situate more frequently in physics or science fields more reliant on systems thinking, where patterns and representations are more ‘unseeable’ and less constrained by visual representation methods (that serve to inspire many Sci-Artists, e.g. crystallography, or electron microscopy). ArtScience also most often involves high-tech science and high-tech art. Indeed, ‘post-industrial artists’ have been defined as using high technology as a medium, with highly charged cultural material like electronics, computation, robotics, bioengineering and smart materials.<sup>74</sup> However, ArtScience need not be so necessarily shackled to technological innovation in output or method. It can be just as generative in ‘old school’ realms of ecology and evolutionary biology and the slow messy domains of ink and paper and clay.

Finally, ArtScience approaches are generally dominated by collaborations between individuals. In part, it achieves transdisciplinarity through numbers of diverse collaborations (as well as the nature of the interaction and of the individuals collaborating). However, more attention needs to be paid to that latter aspect: the quality of the individual. As biologist/philosopher/artist/historian C. H. Waddington went so far as to say:

The acute problems of the world can be solved only by whole men [and women], not by people who refuse to be, publically anything more than a technologist, or a pure scientist, or an artist. In the world today, you have got to be everything or you are going to be nothing.<sup>75</sup>

We need to train and support individuals capable of boundary-blurring single-handedly, not just in collaborations.<sup>76</sup> This entails STEAM education systems at all levels and a resurgence of the liberal arts degree. It demands that we put aside this endless march towards ‘progress’ through applied innovation, and escape the utilitarian neoliberal grind we’ve bought into for so long. It asks us to recognize that the problem-solving effect of ArtScience may be practical but it, and the inspiring effects of Sci-Art, are also beautiful. It is an enriching rebirth for the individual to return to questioning, understanding and revelling in the magnificent, chaotic complexity of this world.

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# Squatting for SciArt

*In this essay I examine the – seemingly marginal – practice of occupying abandoned and/or neglected spaces (literally “squatting”) within university and institutional spaces. Started as an attempt to secure exhibition space for SciArt exhibitions, the practice revealed potentials that certainly surpass momentary entertainment: in fact, repopulating cabinets with art and science collaborations opens up the messiness of spaces, instruments, and organisms of science (often locked in labs, petri dishes or sterile woods) to the outside world, illuminating the complex relationships and exchanges that fuel their activities.*

text and images by **Roberta Buiani**

This story takes place at the University of Toronto, the biggest higher education institution in Canada with a major faculty of Science located right downtown Toronto. It is in this context that the art-science collective ArtSci Salon initiated a – seemingly marginal – practice of occupying abandoned and/or neglected spaces (literally “squatting”) within the university campus. Started as an attempt to secure exhibition space for SciArt exhibitions, the practice has revealed potentials that certainly go beyond providing a space for momentary entertainment.

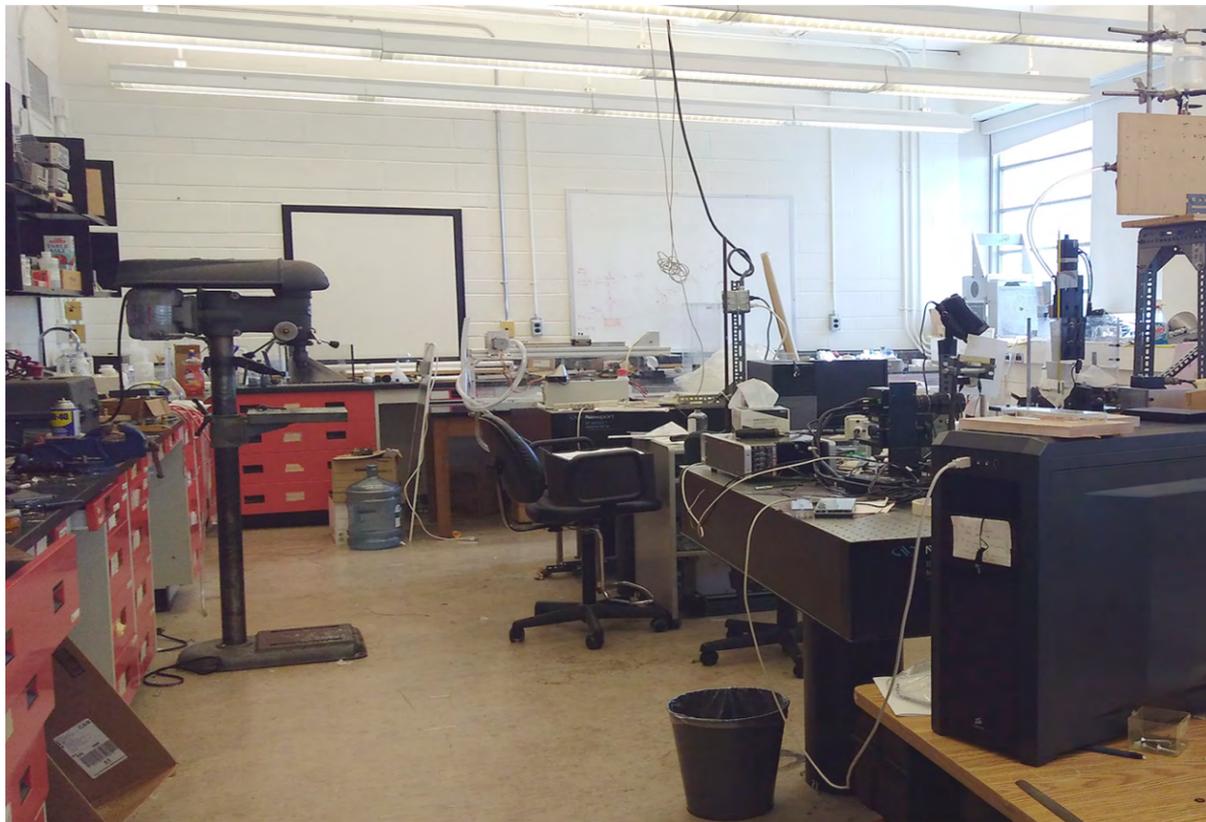
## An alien body

Imagine countless corridors and closed doors that only open with a swipe card; rooms marked by numbers and acronyms describing research projects, but so obscure that nobody can guess what they mean...What lies behind those doors? Should one expect sterilized and perfectly clean rooms; never-seen-before instruments that appear to have emerged out of a science fiction movie; secret experiments led by the typical charismatic and a bit mad scientist? Maybe behind those doors lie material amassed in no particular order, but ready to be used by the occasional graduate student for a new experiment; piles of books and scattered boxes; framed journal covers proudly hung as some sort of trophies. As we learn from those who have spent considerable time observing and studying laboratories and their cultures, the second scenario is more likely to be true. But “...the social world and everyday life”, Knorr-Cetina argues, do not just enter the laboratory. They do not affect and shape the outcomes of experiments and scientific discoveries directly. The social usually becomes incorporated in the lab activity and “..turned into an epistemic device in the production of knowledge”, that is, it becomes “capitalized upon and upgraded to become an instrument of scientific work”.<sup>1</sup> This important process, Latour observes, is typically not apparent, as science exiting a lab, along with its objects and instruments, its social conflicts and negotiations are

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*Maybe behind those doors lie material amassed in no particular order, but ready to be used by the occasional graduate student for a new experiment; piles of books and scattered boxes; framed journal covers proudly hung as some sort of trophies.*  
 .....

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The full title of this essay is ‘From ‘Sci-Art’ to ‘ArtScience’: What do we mean and why does it matter?’



**Roberta Buiani**

*A typical non-linear Physics lab. Courtesy of Stephen Morris (Dept of Physics UofT)*

.....  
*The average city dweller sees the university as largely inaccessible. Non-academics have no business in the university: they walk, ride, drive across it, they use it as a shortcut, but they never feel the urge to visit...*  
 .....

immediately “blackboxed:” they are obscured, cleaned and sanitized; they are packaged into a nice press-release or a journal article; they are transformed and downplayed, arbitrary elevated or carefully obscured.<sup>2</sup>

In addition to being factories of knowledge and innovation, laboratories are spaces where humans, machinery, walls, and specimens interact in messy ways. Laboratories burst with excitement (and boredom), frustration and euphoria. Their machinery is constantly fabricated, rethought, dismantled or replaced. Like other places where teamwork and collaboration are at the core of the profession, laboratories and science departments teem with life, engage in intricate social and political relations, and make and break rules for science. Isabelle Stengers mentions how unspoken rules and obligations, as well as rank and social hierarchies, regulate scientific ecologies not only as distinct disciplinary areas but also as cultural clusters.<sup>3</sup> Janet Vertesi reports on the ways that scientists and lab technicians embrace and internalize the modes of seeing and operating of the instruments they use, as performances of social form; they become one with their instruments and the processes they engage with.<sup>4</sup> As a result, “visualiza-

tion and embodiment together produce and enforce a particular social order”. Similarly, Natasha Myers observes how individuals working in labs often engage in performative behaviors that seem to mimic the visualizations and imaging tools they use in their research.<sup>5</sup>

Most non-scientists will never see the inside of a lab. Many will never even try to access one, as cinematic views (always portraying pristine and squeaky-clean biology labs of unspecified varieties) will often suffice to satisfy their curiosity. Well-established ideas about science institutions as reclusive spaces full of secrecy, or as institutions uninterested, even forbidden to communicate with the outside world, are very much alive today.

But assumptions are not just the product of ignorance. The university itself, in its endeavour to seek and maintain authority, is doing little to shutter them. Its imperative to save or make money as a result of funding cuts, or as a direct consequence of a relentless managerial turn, has led to a general preference to focus on big-bucks science, on sensational discoveries, and on trendy innovations often involving state-of-the-art technologies. Of all research performed in academic institutions, it is only sensational breakthrough or multimillion-dollar projects that become public.<sup>6</sup> The rest is deemed marginal. A while ago, unscrupulous administrators have declared the university ‘private property’. It has become – and it has always been, for different reasons – a segregated institution, an architectural jumble often sitting in the middle of the city, stuck in a suspended reality. Thus, the average city dweller sees the university as largely inaccessible. Non-academics have no business in the university; they walk, ride, drive across it, they use it as a shortcut, but they never feel the urge to visit if only occasionally, during official outreach events or at science fairs. Lying in the middle of the city or in proximity to a community like an alien body, the university is mysterious to many and intimidating to most.

### **Unseen spaces**

Just outside the anonymous laboratories dotting the university campus, at the entrance of science departments, or in busy areas of transition, lie dusty cabinets, bizarre wall enclosures, and deserted atriums. Most are empty, some display posters advertising services that no longer exist, some contain objects that appear to have been forgotten there for a long time. Once parading specimens, instruments, illustrations of preeminent experiments and recent discoveries, these cabinets used to be a rare opportunity for a laboratory team or a scientific unit to present findings to their colleagues in nearby departments and, importantly, to at least a fraction (typically donors, family and friends, rarely members of the community) of the outside world. In other words, these cabinets were rudimentary tools of science communication.

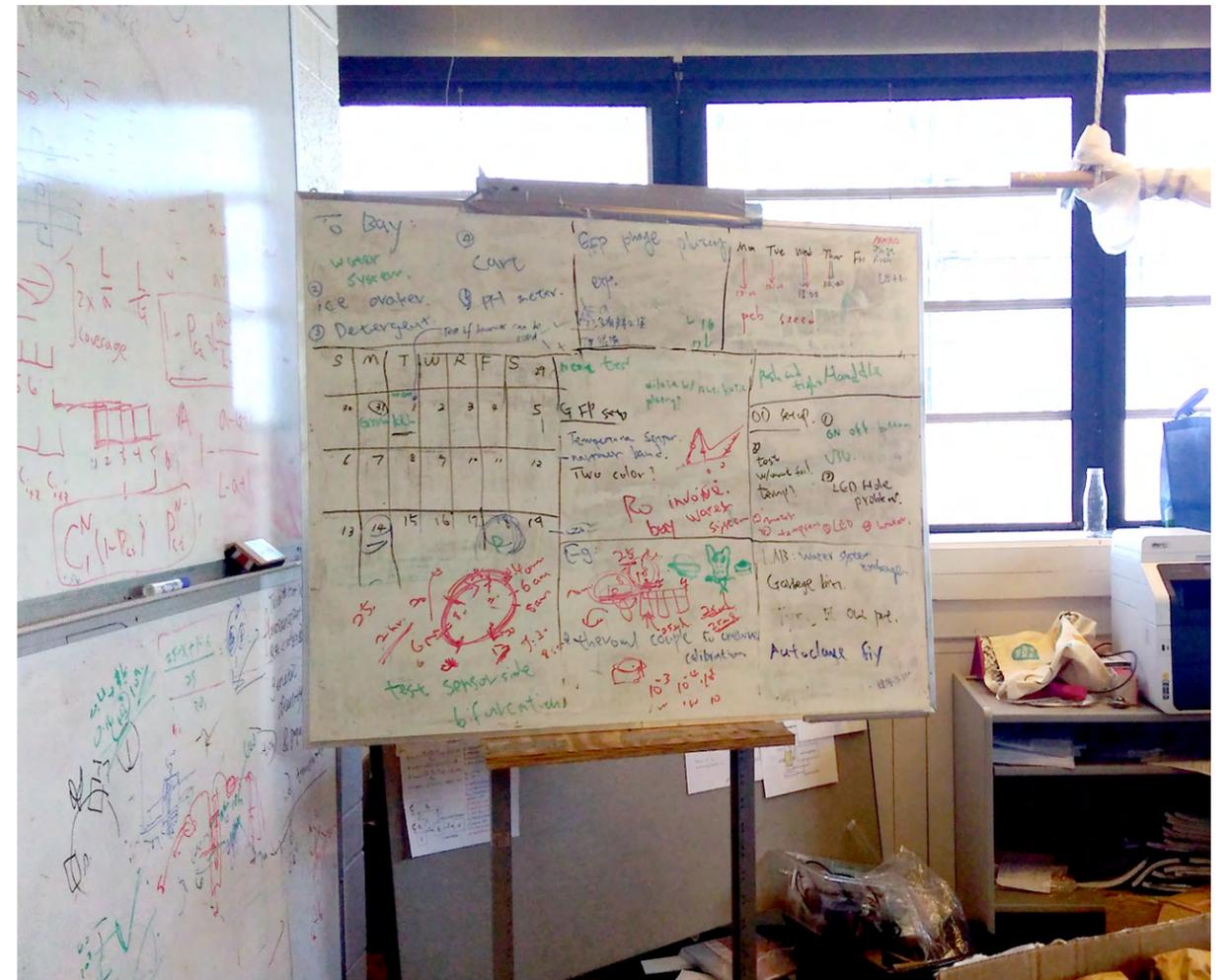
In fact, it was the final – preferably successful – result of an experiment, a project with a happy ending and conspicuous

resonance that took priority over the process of making science. Yet, their presence represented a much more diverse sample of what we can see today on those flat big screens or on whatever announcement that can make it into the media. Their existence was an opportunity for the potential visitor to get a glimpse of the rich world thriving inside the lab, functioning as connector between this space – still perceived as mysterious yet somehow rendered more grounded, and familiar –and the outside. Now they lie there unnoticed. Believed to be just obsolete containers, these cabinets are on the verge of extinction. They are sad remnants of a pre-digital era: annihilated by the next wave of university renovation and its desperate need to save space, and by the irresistible rise of the digital and its obsession for data imaging and visualization. As a result, most of them have been gutted and substituted by ubiquitous (and never up to date!) flat screens or by yet another tiny administrative cubicle which has been magically carved into those cabinets, dispensing more university ids, more student discount and memberships cards etc.

*The current status of the cabinets confirms ideas about science institutions as reclusive and incapable or unwilling to communicate. The old-fashioned items sitting in those cabinets are a testimony to this state.*

Although playing a substantial role in the process, technological change and architectural transformation are not the only elements responsible for the near disappearance of the cabinets. Inertia and lack of vision caused their decline in the first place: the paralyzing and disabling power of routine, which prevents anybody from noticing them in the first place; as well, the inherent inability to imagine any potentials in those cabinets beyond their original functions.

The current status of the cabinets confirms ideas about science institutions as reclusive and incapable or unwilling to communicate. The old-fashioned items sitting in those cabinets are a testimony to this state. As Jonathan Crary appropriately puts it in his *24/7*, they are part of a “...disenchanted world in its eradication of shadows and obscurity and alternate temporalities”.<sup>6</sup> The cabinets constitute this shadowless world, a world that is there, but that has been “unseen,” absorbed into our routines and that we no longer see and value as worthy of our attention. But inertia does not just lead to erasure. It is a quintessential quality of the bureaucratic machine of academia. At the University of Toronto, the dismissal of what was there before contributed to actually saving some of those cabinets from architectural annihilation. In fact, some are often built into the very fabric of the buildings, supported by slabs of concrete or meant to double as showcases and windows to the inside. This is the case of a virtually indestructible cabinet located at the very entrance of the Physics Department, whose solid buildup and thick glass doors are connected to a back closet equipped with switches and plugs built to hook up various technological wonders. A similarly un-erasable structure could be found in three side-by-side cabinets in the Koffler Student Centre building. The latter could easily double as a mini gallery. However, the administration had preferred to lazily fill them with unassuming ads. In fact, it was made clear to me that giving the choice of what to display to the numerous organizations associated with the Koffler Student Centre,



**Roberta Buiani**

*A typical physics lab. Courtesy of Stephen Morris (Dept of Physics UofT)*

would have caused bureaucratic chaos. Other cabinets had been spared to avoid asking permission from the families of individuals who had initially donated them to remove them. This is the case of the “Banting Cabinet”, an antique armoire donated by Frederick Banting, which was used as random storage of old documents. According to secretaries and other administrative figures, the cabinet could “neither be moved nor modified”. This rather cumbersome piece of furniture was hiding in plain sight and carefully ignored.

Although poorly or not used at all, these spaces had been spared. In fact, because of their very invisibility, nobody had bothered dismantling them or putting them to a different use. It is this special condition of being there and being simultaneously ignored that not only contributed to putting them back in the spotlight but also revealed unexpected uses.

What if these cabinets no longer communicated glorious achievements, promoted competitive spirit, narrated mythical stories about single-minded and heroic star professor – all old-time favorites of universities PR routinely trumpeted during official functions and major events? What if they were used to make the messiness, the human and non-human liveliness populating the labs nearby visible and prominent? What if the cabinets could serve to reestablish, and even emphasize, a more meaningful and critical connection between spaces of scientific knowledge and the city?

**The Cabinet Project: not just an exercise in cabinet dressing**

The Cabinet Project was conceived as a distributed exhibition and research-creation endeavor aimed at repopulating empty cabinets across the University of Toronto with installations featuring a range of art and science collaborations. Between April 4 and May 15, 2017, twelve interdisciplinary artists active in a variety of practices at the intersection of Art and Science exhibited the results of several months of research working with instruments catalogued at the University of Toronto Scientific Instruments Collection (UTSIC), and with the environment and the scientific activity being conducted in the proximity of 10 cabinets from 5 different locations across campus.

An open call invited artists engaged in any form of interdisciplinary practices to send proposals that resonated with the sciences practiced in the surrounding areas; interacted with current or historical instruments used to assist in said sciences or envisioned potential collaborations with scientists or technologists working near on in areas connected to the cabinets. Armed with a map of the university and a link to the UTSIC database, an unexpected number of artists submitted their ideas.

The selected artists experimented with and formulated a variety of strategies to bring to life the ecologies unfolding out of the entanglement of human bodies, objects, instruments and space produced inside labs, departments, and archives at the University of Toronto. Ecologies emerged in many ways, by establishing links between the instruments displayed and their history and uses, by unveiling the presence and humanity of the scientists operating these instruments, by reconnecting them with their industrial applications and the lives they affected outside of the lab, or with the conditions they helped measure, reveal, and improve. Artists worked with archival material and teaching instruments used in the mining industry, in acoustics, geology and microbiology, producing BioArt, kinetic and mixed media installations, manifesting not only a range of media uses and modes of interactions with the objects located in the collections and the environment surrounding the cabinets, but also demonstrated a diversity of approaches that sometimes prioritized the context that had produced the scientific instruments and that had contributed to their socio-cultural legacies. Sometimes they exposed the significance of these objects and instruments in a



**Roberta Buiani**

*Unseen spaces at the university of Toronto: Koffler Student Centre Cabinet*

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*What if the cabinets could serve to reestablish, and even emphasize, a more meaningful and critical connection between spaces of scientific knowledge and the city?*  
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mutating and transforming world, or just their potentials and imaginary uses outside the lab and the classroom. Sometimes artists preferred to interact with the surrounding environment.

For instance, in her installation Dust Counters and Gas Collectors, Nicole Liao selected several occupational health instruments from the Gage Research Institute at the University of Toronto's Dalla Lana School of Public Health. These instruments were used in the mining industry to measure dust in open air mines, small particles in hemp mills and toxic gases in enclosed mines. Some of these instruments are still used in the mining and textile industry to measure toxicity and inhabitability of the working place. Liao used different strategies to connect the work of scientists and their instruments with everyday life and to draw attention to the historic and cultural significance of these ecologies. She exhumed these instruments from the teaching collection and returned them to their historical and social contexts by skillfully locating them next to photographic evidence of the working conditions of mining and textile workers (in the form of scientific



**Roberta Buiani**

*Unseen spaces at the university of Toronto: Banting Cabinet at University of Victoria College*

and artistic books and catalogues) and raw material such as sand and cotton. A list of ailments and diseases caused by chronic exposure to the latter and by hazardous working conditions appeared on the glass doors of the cabinet. Liao not only illuminated the function of old scientific instruments but also humanized their narrative, opening up the condition for critical reflections on the role of science in facilitating and mitigating the effects of occupational hazards on its workers.

In *A New Geology*, Stefan Herda connected lab research and studio activity, education and research, academic research and the environment, through his work with crystals and minerals. His work consisted in a deceitful, as much as intriguing, installation of two collections that had long been forgotten and archived (or better dumped) in a dusty room in the subbasements of the University of Toronto: Derek York's teaching collection of minerals and some crystals used to demonstrate spectroscopy. To these, he added a series of pseudo-geological objects that he himself had fabricated in his studio turned-lab, using fertilizers, various sodium-based compounds and wood. Leaving any label out but the chemical formulas of the

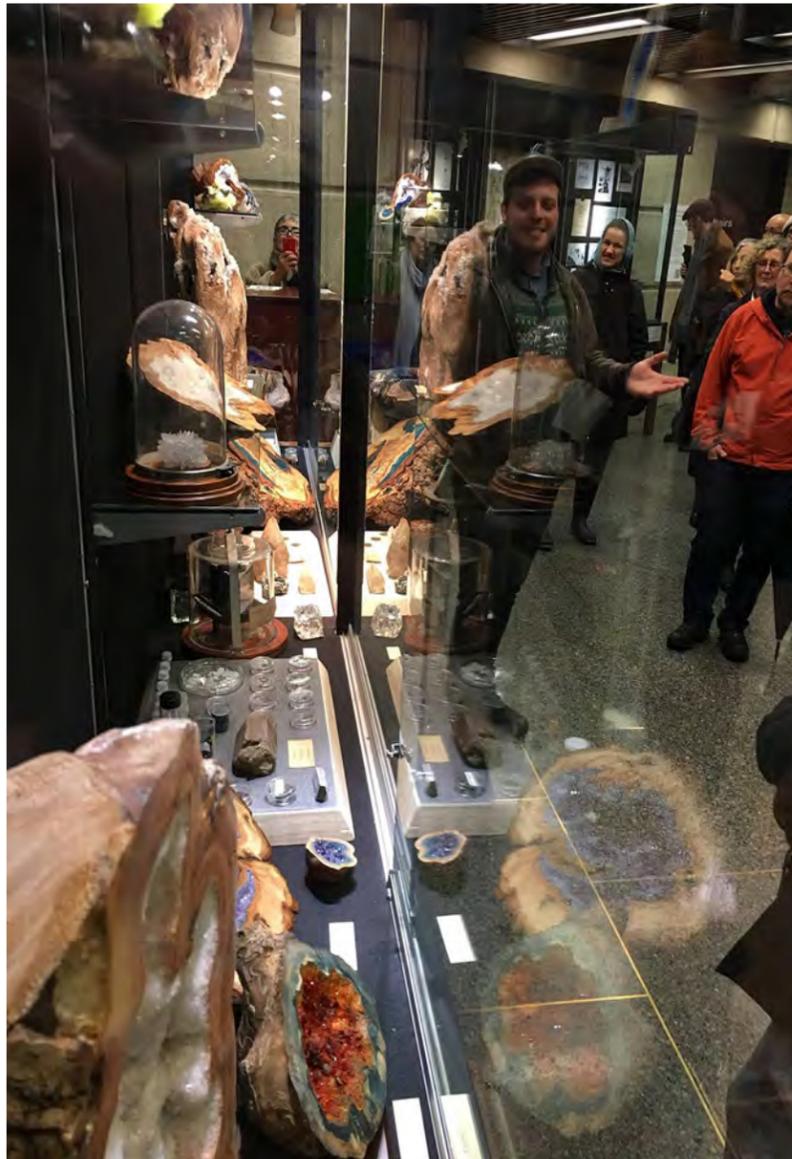
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*Many had no clue that these cabinets had always been there. But the merit of this sudden realization certainly goes to the types of installations that compelled passers-by to stop and keep coming back multiple times, sometimes on the same day.*  
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manufactured minerals, Herda was able to initiate a conversation about what we can call natural and what we should consider artificial, and whether we should separate these categories at a time in which new geological items such as fordite or plastiglomerate are emerging as a product of that human-induced era named the Anthropocene.<sup>8</sup> Interestingly, Herda had found ways to turn his installation into an interactive piece in which visitors and casual passers-by would engage in lengthy discussions about the nature of the objects on display. Those teaching minerals had finally found a physical way outside of the basement and into the non-academic world.

During *The Cabinet Project*, one set of three cabinets in particular, located in a busy corridor connecting two building, had proved to be of particular interest to everyday passers-by. Once the first two installations, respectively by Bio Artist Nicole Clouston and duo Dave Kemp and Jonathon Anderson had been finalized, people seemed to slow down and suddenly notice these spaces. Many had no clue that these cabinets had always been there. But the merit of this sudden realization certainly goes to the types of installations that compelled passers-by to stop and keep coming back multiple times, sometimes on the same day. In fact, Clouston's Bio Art installation *Mud* featured colonies of bacteria teeming in mud, which she had sourced by drawing a perpendicular line between Lake Ontario and the University of Toronto. In this installation, the bacteria enclosed in thin acrylic columns kept growing for several months forming constantly changing colorful patterns. Light coming in from an above window would also change their look at different times of the day. Passers-by frequently asked what caused such kaleidoscopic changes and kept coming back at different times to check their transformations. Sitting next to Clouston's installation, Kemp and Anderson's "Floating Points" involved "a combination of motion parallax effects and line-moiré interference patterns to produce a perceptual amplification of the viewer's movement (Kemp and Anderson – *The Cabinet Project* 2017)." The hypnotic motion effect produced by the Moiré effect turned the passers-by eyes away from their default path and compelled them to look towards and often stop to inspect the installation. In both cases, passersby could not help but take notice of the two installations and wondered whether the two pieces were there as a science experiment or as entertainment, as an extension of the lab or as an external project that had been given permission to be installed there.

#### **Towards a new curatorial practice**

Museums have perfected the art of installing specimens, small and big instruments, and other artworks in cabinets and showcases for some time. Thus, unavoidably, seeing works in a cabinet is often reminiscent of those objects. According to Jean François Gauvin, once objects are trapped in glass containers, they are "robbed of their function: they are functionless".<sup>9</sup>



**Stefan Herda**  
*A New Geology*, mixed media installation

Enclosed in these containers, the objects are removed from their initial context and located in a space that is supposed to protect them. But this act alienates the objects from their public since the public does not understand their function or their connection to their surroundings. "The performing object then becomes a 'pure object', an object pushed onto an aesthetic plane that no longer belongs to the practical and tangible space of functionality." For Gauvin, "most museum objects face this situation". For Helen Graham, glass showcases in museums are not just there to separate the public from the object on display. They also illuminate it



**Nicole Liao**  
*Dust Counters and Gas Collectors*, mixed media installation

as a precious part of our cultural or historical heritage to be protected from the curious hands of the visitors, or conversely, to protect them from its hidden or unknown dangers.<sup>10</sup> This is an operation of purification, or to stay with the scientific metaphor, it is an *in vitro* approach to the object, reminiscent of the way that the scientist isolates the fragile specimen and the dangerous pathogen in the petri dish in order to assign it an aura of authority. Thus, while the use of cabinets may cause a further loss of connection between the object and its public, it may also contribute to their enhancement.

The above loss of functionality and enhancement play different roles in *The Cabinet Project*: objects had already lost their original function



**Nicole Clouston**  
*MUD*, mixed media installation

long before the project had started. They were leftover material that no longer drew the attention of the scientist and whose significance was no longer valued by the teacher. Once resuscitated as part of the artwork, they not only immediately reclaimed some long-lost qualities, but they also acquired new meanings, becoming once again part of an inclusive narrative that prolonged and enhanced their lives.

In working with historic objects from UTSIC and with the sciences near the cabinets, the artists involved in the Cabinet Project had found themselves challenged in several ways. As a first experiment in distributed pop-up (literally a type of squatting as I will explain later) curation in art and science, *The Cabinet Project* immediately revealed a double barrier artists had to face in presenting their artworks: one that separated the cabinets from the labs and a second, possibly more resilient, that consolidated the skepticism of the non-academic public to consider the university a potentially exciting or even remotely interesting

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space to visit, not to mention enjoying an art exhibition in random spaces.

In fact, if in the case of university employees, the cabinets are generally unseen because they are just part of a routine, in the case of city dwellers, they are unseen, because they are assumed to be conceptually inaccessible and therefore out of their range. Assumptions regarding academia's reclusiveness and its monolithic structure prevent any cross-contamination with the outside world and any dissemination of alternative content. However, once the exhibition was up and people from all walks of life started flocking, it became clear that the cabinets were more than just a sterile exercise in furniture decoration. In fact, repopulating cabinets with installations featuring art and science collaborations had opened up the messiness of spaces, instruments, and organisms of science (often locked in labs, Petri dishes or sterile woods) to the outside world, thus offering the public a glimpse into the complex relationships and exchanges fueling their activities. To that point, many of the objects chosen by the artists had been archived and forgotten in a remote corner of the university: they constituted odd objects to them and certainly were not well known to the public they were trying to engage. Yet, they strangely ended up resonating with visitors in many different ways: the strictly scientific aspect ceased to be the only concern for the observer, as the objects could be re-located and re-purposed in imaginary worlds without being necessarily tied to their originally meant function.

Furthermore, all the material had to be exhibited behind glass cases, as the locations (in the middle of transit areas, at the entrance of a department or in busy hubs) were too exposed to potential damage. This was an initial cause of concern for some of the artists involved, as they feared that the segregation of the objects from the public would affect their participation. However, the audience demonstrated a surprisingly intense curiosity for these objects exhumed from the darkness of the vault. I ascribe this sort of engagement and continuous interest to the particular context that the cabinets were interacting with. In other words, the new display had created a short-circuit: it had not only broken the tediousness of the institutional space, but it had also seemed to destabilize ideas of what is "science" and what is "art", what is "private space" and what is "public space", where the latter end and the university begins. The institution and the fabric of the city grew a bit closer and overlapped, as the university unravelled as a kaleidoscopic space rather than a monolith, as a vibrant part of the urban environment, rather than as a well-protected bubble of knowledge.

In describing the necessity of curators to establish some form of connection between objects in a showcase and a hypothetical audience, Graham mentions the use of strategies of re-contextualization through props, interactive activities or recreation of a historicized environment to partially reconnect the object to the public. But these strategies are formulated with exclusive attention to the content. Here there is an urgency to create order, a legitimate preoccupation when

these cabinets and showcases are located in a museum. *The Cabinet Project* took place in the public spaces of a university. Most analyses of “cabinets of curiosity” and showcase in museums focus on the content behind glass as if it was the only element that counts. These analyses seldom mention the context where cabinets and showcases are located, what surrounds them, whether this environment can be found in a dedicated space such as a museum or in a non-conventional space such as a corridor or the entrance of a department or a library as in *The Cabinet Project*. However, the significance of the works, and the aspects that ultimately established a connection with and drew the attention of passers-by lie in the relation with the surrounding context, not necessarily, or not only, in the content they exhibit. In this case, a map acted as connector between the cabinets. However, instead of giving directions, this map only showed the locations, allowing the visitors to roam and decide their preferred trajectory and viewing order.

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*In addition to tours, the public took it upon themselves to roam the campus and the university buildings, to reach the cabinets – and as someone recently told me, go on a sort of scavengers hunt, map at hand – or to further explore the surrounding areas, as if they were taking a stroll in an unknown neighborhood or as if they were visiting an alleyway full of graffiti.*  
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In addition to tours, the public took it upon themselves to roam the campus and the university buildings, to reach the cabinets – and as someone recently told me, go on a sort of scavengers hunt, map at hand – or to further explore the surrounding areas, as if they were taking a stroll in an unknown neighborhood or as if they were visiting an alleyway full of graffiti. This produced a different level of engagement: visitors deemed it worthwhile to embark on a personal exploration of the space, thus perusing it as their own. By walking across the heterogeneous and structurally diverse buildings where the objects exhibited are used and produced, visitors could appreciate the changing aesthetics of architectures and departments. They listened, felt, smelled, looked around, experienced the journey and the cabinets differently. They were encouraged to interpret these human, social and material ecologies as intimately connected and part of, rather than separate from, the urban environment.

The ecologies that *The Cabinet Project* helped reveal are a hidden facet of the city: in fact, the overlapping and intersecting stories – untold and forgotten, both physically and conceptually – emerging from this project may not only have facilitated a better comprehension of the history of the institution that produced them. They may have also helped the visitor locate them within and link them to the cultural history of the city, thus emancipating the cabinets from their supposed self-referential isolation. *The Cabinet Project* made these ecologies evident, by entrusting the arts to help recover the lost connections between the – very human, very diverse, very lively – space of the lab and the socio-cultural fabric of the city, and by letting the public realize that the space of the university is a public space too. In other words, this operation of reterritorialization encouraged the public to explore and re-appropriate those spaces, thus making them familiar, and effectively re-annexing them to the very fabric of the city.



**Roberta Buiani**

Visitors to *The Cabinet Project*

### **The practice of squatting**

Libby Robin explains how “our grandparents had 30 items, now the average household has 10,000.” This excess has made sure that we all mastered the art of not paying attention. The everyday, the dull, Amitav Ghosh reports, is overlooked, until something comes to shake things. This has been at the core of Western fiction and its narratives for a long time.<sup>11</sup> “Can the older practice of looking carefully at curious objects surprise us afresh and help us live in times of rapid change?”<sup>12</sup> The art of creating cabinets display, for Robin, especially in today’s “strange times” has recently gained traction not as an explanatory and pedagogical tool, but as a different way of making a sense of the disorder of the world, in the same way that the first cabinets of curiosity challenged established categories of what ought to be in the natural world. In a sense, the practice of taking over cabinets, repopulating them with something unexpected, something previously buried, creating a short-

circuit, fit the above description. *The Cabinet Project* is a new version of the traditional cabinets of curiosity. Illuminated by unusual objects, these cabinets are suddenly turned from invisible into extraordinary.

*The Cabinet Project* was the first of a series of pop up exhibitions that later appeared at more or less regular times in the now retrofitted and ready to be dressed cabinets. In fact, after this project, nobody reclaimed ownership over them; nobody asked for their keys back. In a city, like Toronto, hungry for exhibition space and where space is either ridiculously expensive to rent or already booked years at a time, artists operating at the intersection of art and science are particularly penalized as their work often doesn't fit any particular category or satisfies the tastes of any established art circle. Reclaiming these empty cabinets seemed a great opportunity: not only are these spaces completely available and at no or little cost, but they are also located near the scientific institutions where the types of science these artists address takes place. Thus, since the first experiments, three more exhibitions have filled the cabinets in the Koffler Students Centre and the cabinet at the main entrance of the Physics Department.

In his *Ecological Aesthetics*, Nathaniel Stern makes a quick but important distinction between "Art with a capital A, as in its techniques, or ideas, or largest category" and 'art' lowercase a, "as in individual pieces and series and events".<sup>12</sup> He explains that 'the former, 'Art,' encompasses practices and objects that enable, facilitate, and are an adventure in and around thought... The latter, 'art,' connotes specific artworks; it is not the category, but a work of art that does things, thinks and provokes thought (4)." I believe that *The Cabinet Project* and all the projects that came afterward fit the latter definition: it is not a single event or a series of events unfolding on a variety of topics while enjoying the same conditions. It is rather "an action, a conduct, a practice" of experimentation outside the "safety of the category (be it medium, form, or self) (3)."

Specifically, I think of this practice of occupying empty spaces at the university as an important way to break the boundaries between academic spaces and city spaces; to exit the enclosed and protected space of the lab and expose it to public engagement; to break free from spaces and disciplinary boundaries; and to think of new ways to practice sustained interdisciplinary exchanges. The arts here play a crucial role: in fact, in this context, they cease to be mere tools at the service of science. Instead, they become, themselves, catalysts that can be potentially incorporated into the methodological apparatus of research (and not just as decoration or aesthetic attraction) and become connectors between disciplines, as well as between the scientific community and the general public.

Importantly, *The Cabinet Project* can also be seen as a practice of "squatting academia." Its significance in fact, did not

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**Matteo Farinella**  
*Narrating Neuroscience*, October 2017

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*As the curator of this series, I belong to the growing army of individuals only partially affiliated to any institution. They call us 'contingent faculty.' I am neither a teacher nor a researcher, according to the preferred taxonomy of the university.*  
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just lie in its – perhaps less conventional – exhibition's structure and content, or in its research-intense approach, but in its use of the spaces of the institution. The current use of the cabinets is based on an informal agreement. In fact, no written consent was ever given, but it was often granted orally by mid-level admins who had no initial recollection of the cabinets' existence and later granted me access with no particular interest in mind. No department in particular ever endorsed this activity. As the curator of this series, I belong to the growing army of individuals only partially affiliated to any institution. They call us 'contingent faculty.' I am neither a teacher nor a researcher, according to the preferred taxonomy of the university. I am part of a ghostly cohort of professionals doing curatorial and mentorship services deemed too marginal to count, just like those cabinets I reclaimed from the dead: invisible to my non-colleagues and ignored by the department I occasionally call home. During the making of *The Cabinet Project*, I was not even employed at the University of Toronto, but self-appointed as the artistic director of the *ArtSci Salon*, a title that has remained uncontested at the time of

writing. The Fields Institute for Research in Mathematical Sciences, the hosting institution of the *ArtSci Salon* has never objected to it.

This condition turned out to be both a hindrance and an advantage for the projects conceived for the cabinets. In fact, no department has ever claimed ownership over the project since I don't belong to any department. To the administrators and managers who supposedly regulate events at the university, I don't exist. This means that this curatorial experiment cannot rely on the university PR machine to promote itself. However, it also means that I have no obligations towards any department and do not have to follow any particular guidelines or bureaucratic procedures. This has guaranteed complete freedom on the themes, the artists, the material used, and the programming of the cabinets.

At the moment, *ArtSci Salon* has continuous dedicated access to at least four cabinets and has installed exhibitions on a regular basis. The making of these exhibitions is very fluid. Proposals and ideas are processed on a case-by-case basis and happen very quickly. This was the case of FACTT Toronto, a traveling exhibition curated by Marta DeMenezes, the resourceful and energetic BioArtist from Portugal: the show was conceived in two months only and mounted in two days (FACTT Toronto, 2018). At the same time, funding for installations are inconsistent and vary according to the different circumstances. As a result, exhibitions will be more or less complex depending on the budget, the availability of the artwork and the good will of the artist.

In this context, artists are turning into squatters too: they are relatively free to turn collaborations and pre-existing artworks into whatever they wish, as long as a few important rules of safety is respected. Generally speaking, their projects grow free inside the cabinets with little or no constraints. A relationship of trust grows between the artist and the curator. By the same token, not all artists enjoy this challenge. Working in non-traditional spaces often flooded by the intense traffic of completely aware, cell phone-immersed and careless passers-by can be frustrating and physically intense. Gaining access to basic services or collections locked away in basements or archives well-guarded by observant administrators can be a grueling operation (although the latter might not be due to the non-official status of this curatorial endeavor but rather the sad result of the extreme bureaucratization of the university). It also means shifting the focus from creating a sleek, perfectly finished product to a more messy, more process-oriented durational performance.

This activity does not involve the artists and the curator only but mobilizes also all levels and hierarchies of the institution, from the administrator to the caretaker and the janitor. They too are complicit in this semi-legal process of squatting, by agreeing to grant access to a cabinet and sort through keys that had been accumulated over time, by deciding to help cleaning the space, change



Ken Rinaldo

*Borderless Bacteria / Colonialist Cash*, mixed media, 2017 © Ken Rinaldo

a bulb without filling several forms, by advising on the material to use or on the aesthetics of the piece. Once completely oblivious of the spaces available, many university employees have transformed into active spectators instead of just passive users of their own environment. And squatting does the public with their exploration, map at hand, of the campus and its buildings, – in some cases described as a scavengers' hunt – to reach the cabinets or to discover some unexpected surprise hiding in the unknown folds of academia.

Given the open format and the informal structure of this initiative, it is no surprise that many non-academics (professionals, retirees, teachers, independent artists involved in the art and science community) attend the cabinets' exhibitions. This has always been a goal since the beginning: the re-saturation of empty cabinets is meant to be an attempt to recover the nexus between the university and the city, by inviting visitors to re-appropriate spaces they once assumed inaccessible. Most of these spaces are actually very accessible: accessible by a person with a disability, but also conveniently open after hours (Koffler building is open until 7:00 pm and sometimes even later). Scientists and students in science appear to be very interested too: mostly, they appreciate the presence of the arts

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**Andrew Carnie**

*Unfolding sheets*, installation view, Oct 27-Nov 30, 2018 © Andrew Carnie

in the proximity of their departments. They wonder at the uses of instruments they thought had very limited technical functions. They admire and take note of the conceptual and ethical interpretations artists are displaying of scientific visualizations, measuring devices, or technological and scientific innovation. While the interest of several scientists in the artworks located in the cabinets is very welcome, it is also surprising. It means that the artists involved have produced installations that have managed to break, albeit temporarily, old narratives of neglect and segregation dominating scientific knowledge, and to enable a prevalently non-academic audience to enjoy unexpected collaborations between artists and scientists and to explore the university space as a newly re-appropriated public space. But I am left wondering if the same crowd could be convinced to attend a more conventional art exhibition. I am also wondering if, given the current success of this initiative, the university will take some decisions to make the spaces more formal? At the moment, no long-term plans have been made to preserve, continue or move away from this initiative. Only time will tell. Meanwhile, we continue to squat.

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## Footnotes

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**Roberta Buiani** is an interdisciplinary artist and media scholar, and the artistic director of the ArtSci Salon at the Fields Institute for Research in Mathematical Sciences (Toronto). Her recent SSHRC-funded research creation project draws on feminist technoscience and on collaborative encounters across the sciences and the arts to investigate emerging life forms exceeding the categories defined by traditional methods of classification. Her artistic work has travelled to art festivals (Transmediale; Hemispheric Institute Encuentro; Brazil), community centres and galleries (the Free Gallery Toronto; Immigrant Movement International, Queens, Myseum of Toronto), and science institutions (RPI; the Fields Institute). Her writing has appeared on *Space and Culture*, *Cultural Studies* and *The Canadian Journal of Communication* among others. With the ArtSci Salon she has launched a series of experiments in “squatting academia”, by re-populating abandoned spaces and cabinets across university campuses with SciArt installations. She holds a PhD in Communication and Culture from York University (CAN) <http://atomarborea.net>



**The Tissue Culture & Art Project (Oron Catts & Ionat Zurr) in dialogue with Mike Bianco**

*Vessels of Care and Control: Prototypes of Compostcubator & Hivecubator.* compost, beehive, bees, acrylic dome, clay, wood, glass, water, tissue flasks, pumps, plastic tubes, thermostat and Water Storage Crystals, Kenpoku Arts Festival, Japan 2016 © Catts/Zurr

## Oron Catts and Ionat Zurr: Art and the Semi-Living

*Over two decades, Oron Catts and Ionat Zurr have challenged disciplinary boundaries and aesthetic parameters in order to forge new tools through which to understand the world live with. Their practice is an ongoing experiment grounded in the manipulation of life forms, consideration of the ethics at stake, and awareness of the cultural context in which their inquiries unfold. In this interview with Giovanni Aloï, Catts and Zurr unpack the role played by different cultural institutions, research settings, cultural workers (artists, curators, and critics), popular media, and industry in their dealings with biotechnological artifacts.*

interviewer: **Giovanni Aloï**

interviewees: **Oron Catts and Ionat Zurr**

Oron Catts is the Director of SymbioticA, The Centre of Excellence in Biological Arts, School of Human Sciences, The University of Western Australia. He is an artist, researcher, designer and curator whose pioneering work with the Tissue Culture and Art Project, which he established with Dr. Ionat Zurr in 1996, is considered a leading biological art project. In 2000 he co-founded SymbioticA, a biological art research centre at The University of Western Australia.

Under Catts' leadership SymbioticA has gone on to win the inaugural Prix Ars Electronica Golden Nica in Hybrid Art (2007) the WA Premier Science Award (2008) and became a Centre for Excellence in 2008. SymbioticA's residency program has had more than 120 researchers, coming from art, design, philosophy, art history, geography, cultural studies, science, and other disciplines. All residents are required to conduct hands-on research in the biological labs. In addition to its residency program, SymbioticA has developed an academic program, it is the only place to offer a Masters of Biological Art, as well as Ph.D.s and undergraduate units. SymbioticA also produces exhibitions, conferences, and workshops.

In 2009 Catts was recognised in Thames & Hudson's book *60 Innovators Shaping our Creative Future* in the category "Beyond Design", and by *Icon Magazine* (UK) as one of the top 20 Designers, "making the future and transforming the way we work". Catts interest is life; more specifically the shifting relations and perceptions of life in the light of new knowledge and its applications. Catts has extensively collaborated with Dr. Ionat Zurr and scientists, to develop a body of work that speaks volumes about the need for new cultural articulation of evolving concepts of life. Catts's and Zurr's ideas and projects reach beyond the remit of art; their work is often cited as an inspiration to diverse areas such as new materials, textiles, design, architecture, ethics, fiction, and food.

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*During my studies in the early '90s, I recognized something that is very obvious now: that biology is becoming an engineering pursuit, life becomes a raw material, and that designers, in some stage, will be called to do design living biotechnological products. I found this prospect both disturbing and very challenging.*  
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**Giovanni Aloï:** What were Oron Catts and Ionat Zurr like as children?

**Oron Catts:** I grew up in a village. I grew up around life and death, learning to recognize that we rely on other lifeforms for our existence and that we depend on the relationship between other lifeforms and the environment. I grew up knowing the difference between the perspectives on life of those who work on farms and those who live in cities. As a young boy, I remember that I wasn't so much interested in taking clocks apart and putting them back together, but I would try to do that with animals. I used to find mice and rats, then I would open them up. Never managed to put them back together, though.

**Zurr:** I would very much rather leave my own childhood a mystery...

**Aloï:** Wow! That's a start. I sympathize with the rural vs. urban life contrast. It is certainly valuable to learn about different perspectives from a young age. I had that too. Can you tell us about how you ended up being professionally involved in the 'art and science' interface?

**Catts:** I have always been interested in biology. So, I took the opportunity to specialize in biology during my high school years. But what I really wanted to study was art. I wanted to make sculptures. Howe-



**The Tissue Culture & Art Project (Oron Catts & Ionat Zurr)**

*Pig Wings*, Pig mesenchymal cells (bone marrow stem cells) and biodegradable/bioabsorbable polymers (PGA, P4HB), 4cm x 2cm x 0.5cm each, 2000-2001 © Catts/Zurr

ver, I decided to be practical and opted to study product design. From the very beginning, since the first year of my degree, I tried to find links between design and biology and design and biotechnology.

During my studies in the early '90s, I recognized something that is very obvious now: that biology is becoming an engineering pursuit, life becomes a raw material, and that designers, in some stage, will be called to do design living biotechnological products. I found this prospect both disturbing and very challenging.

I was particularly interested in tissue engineering and at the time, that field was just beginning to emerge. Back then, I approached Professor Miranda Grounds at the University of Western Australia, she was a scientist who shared an interest in the in tissue engineering. Rather than throwing me out of the room, she invited me to work in her lab to explore the potential of growing sculptures using living tissues. Ionat Zurr started to collaborate with me, then. She was studying photography at the time, and I invited her to join me. That's how we formed the *Tissue Culture and Art Project* in 1996. We started to look at the potential of using living tissue as a medium for artistic expression.

That project became quite successful in the sense that we were able to exhibit. We also received funding to support our research. In 1999, Ionat & I were invited to give a lecture at the MIT Media Lab in Boston, and we also met with Professor Joseph Vacanti, who was the leading figure in tissue engineering. After about a half-an-hour meeting with him, he invited Ionat and me to serve as research fellows at his Tissue Engineering and Organ Fabrication lab at Harvard Medical School.

At the same time, The University of Western Australia, where I started working with scientists in the mid-'90s, realized that our project had substance. As we started to exhibit our work, more and more artists approached us and asked us how we were able to negotiate access to all those resources—how we were able to do work with scientists? That's what led to the establishment of SymbioticA. We got some funding from the university and from the local lottery commission to build a dedicated space for artistic research into the life sciences.

Of course, they thought we were going to set up an artist's studio, but we wanted it to be a wet lab. We established a residency program. Later, we developed academic programs, so that we

could offer masters of biological arts and Ph.D. programs, and undergraduate units. SymbioticA really evolved from this model that Ionat and I established as part of *The Tissue Culture and Art Project*.

**Aloi:** As an artist working at the intersection of art and science within an academic institution, what challenges have you faced?

**Catts:** The beginning was not easy. SymbioticA can be seen as a result of fruitful misunderstandings. There always are differences in expectations with regard to what role artists can play when they work outside of the traditional context. SymbioticA was set up as a hands-on, experiential, artistic research lab within a biological science department at a university, therefore we had to run it somewhat like a scientific lab.

Because we're part of an institution, all of our work must comply with the protocols and ethics as well as health and safety regulations and rules set by institutional committees. And as it's still the case, we constantly have to convince colleagues and officials that what we're doing is research. There's always a tension between what artistic research stands for and what scientific research deals with.

**Aloi:** Can you tell us more about the interdisciplinary challenges that you have faced?

**Catts:** Often, when scientists learn about us for the first time, they conceive us as illustrators, or decorators - not artists. We need to explain what contemporary art can bring to the mix and how different that contribution is from what they usually have in mind. In a sense, we constantly have to justify our position. However, we are never alone. Other researchers and colleagues work with us at the school. It's an amazing environment where to carry out this work and it's very diverse. What we have here in Perth, at the University of Western Australia is a very unique set of circumstances that really allows SymbioticA to exist, to thrive and to be a permanent fixture. The main interest of SymbioticA is life, and how our relationship to life is changing and shifting. It's obvious that the most radical shift in our relationship to life happens within the scientific and engineering contexts.

Here at SymbioticA, we are able to engage in artistic research that is both deeply informed and literally wet with the life sciences technologies - but is also critical.

**Zurr:** SymbioticA is now an almost "fixed" feature in the School of Human Sciences. Since I joined the School of Design at the University of Western Australia in 2017, I experience some misconceptions or misunderstandings coming from the fine arts... while in the sciences there is a rooted culture of collaborations and interdisciplinarity, this is something that can be sometimes challenging within arts. From an academic perspective, we face the challenge to explain that artistic research is a valuable research with its own methodologies. Fortunately, in our university, at the postgraduate level, a student can choose supervisors from any discipline, and this flexibility enables unique research opportunities.

**Aloi:** SymbioticA was established in 2000, the same year Eduardo Kac's *GFP Bunny* was presented. How different and how similar would you say your practice is to Kac's approach to BioArt?



**The Tissue Culture & Art Project (Oron Catts & Ionat Zurr) in collaboration with Corrie Van Sice**

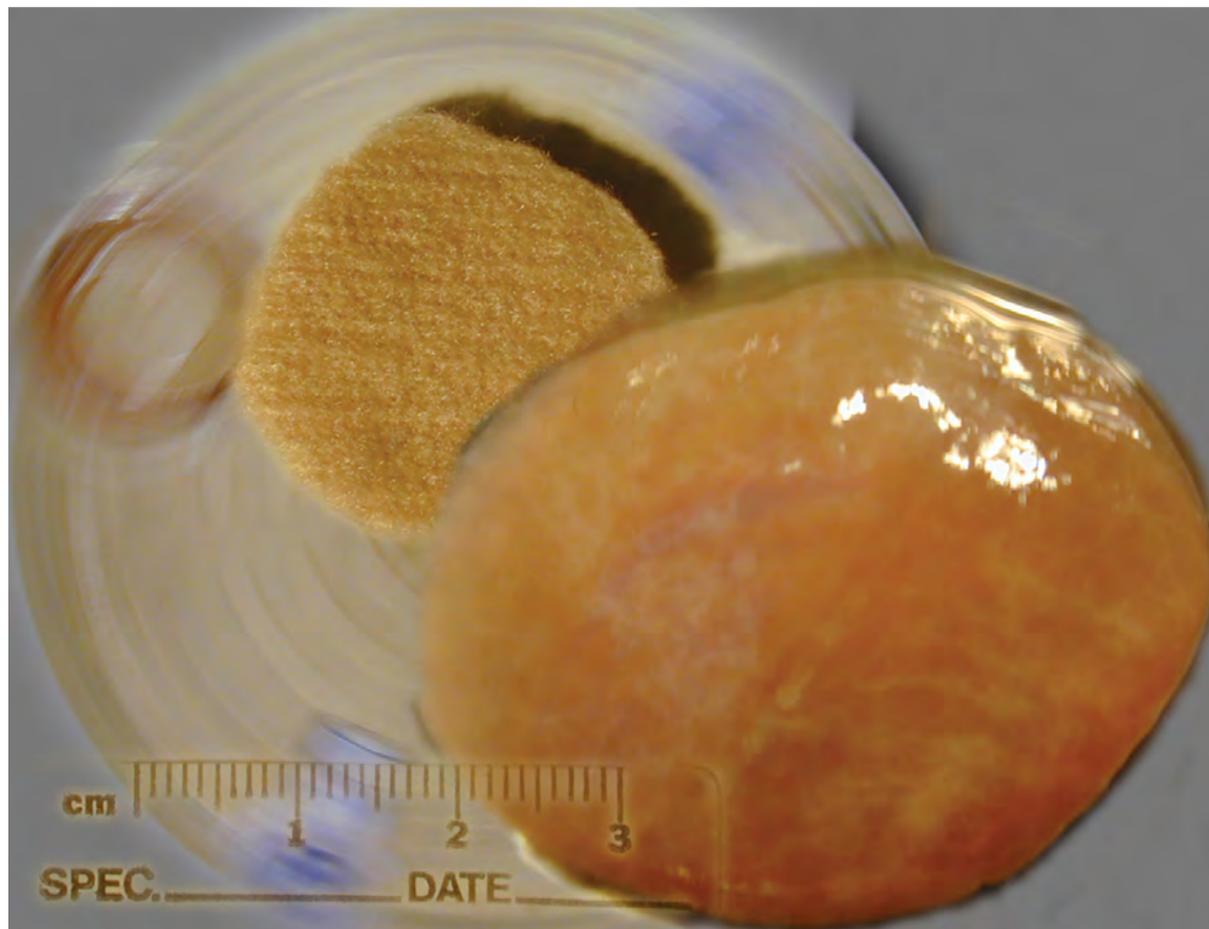
*The Mechanism of Life - After Stephane Leduc, Custom design rapid prototype printer, computer, chemicals and dyes, 2013 © Catts/Zurr*

**Catts & Zurr:** I think the main difference is that Eduardo doesn't work in the lab. Eduardo is a conceptual artist who collaborates with scientists to carry out his vision. We directly manipulate life in the lab—this is the main essence of SymbioticA, the idea of experiential engagement and direct responsibility and involvement with the lifeforms that you are, or that the artists are engaged in manipulating and dealing with.

For us, it's really important that the relationship is direct, and if something goes wrong, the responsibility is ours, we never blame scientists. But we're equally very interested in how other artists engage with important questions concerning our relationships with the concept of life or how they use living biological systems in a cultural context.

Working hands-on in the lab enable the artists to realise the limitations of the technologies; the difficulties, frustrations and mostly "un-spectacle" results that can be generated when trying to control life or living matter. It is more difficult to "hype" the technologies. We refer to these results as "The Aesthetics of disappointment". Also, working with the matter of life creates an uneasy feeling. The artist is implicated in a visceral way with the consequences of caring and controlling life.

**Aloi:** Which ethical values underpin SymbioticA and how have they changed over time?



**The Tissue Culture & Art Project (Oron Catts & Ionat Zurr)**

*Semi-Living Steak*, Biodegradable polymer connective and bone cells, The Tissue Engineering and Organ Fabrication Laboratory, Harvard Medical School 2000 © Catts/Zurr

**Catts:** I just found the paper I published back in 1996 before I even started to do work in the lab; that was still part of my design studies. Even then, I already explored questions that are important to me today, like “what does it mean to objectify life?” or “what does it mean to instrumentalize life?”, and “what happens when life becomes raw material to be engineered and manipulated for human ends and desires?”

That line of inquiry seems to be fairly consistent in my life. Twenty-three years ago, the idea of exploiting living systems in an artistic context was a very disturbing and challenging prospect for many people. Now I would say it’s pretty common. I’m not a philosopher, I never trained to be a philosopher. But I engage deeply with the ethics of the art I make.

What SymbioticA deals with is responsibility towards life. What we see more and more is that artists are being used as ways to exaggerate the powers of technologies, feeding false narratives about progress designed to capture the public imagination for commercial purposes, or to drive a neo-liberal agenda.

SymbioticA sells no illusions. Artists who come to work with us realize how much more difficult everything is, how unruly life is, how uncontrollable it is, even with our best accomplishments, in the

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*What SymbioticA deals with is responsibility towards life. What we see more and more is that artists are being used as ways to exaggerate the powers of technologies, feeding false narratives about progress designed to capture the public imagination for commercial purposes, or to drive a neo-liberal agenda.*  
 .....

art that comes out of SymbioticA the direct engagement with life keeps one humble.

**Zurr:** in other words, we are not afraid of the “Aesthetic of Disappointment”; our outworks are far from being a symbol of success and tend to look fairly humble and even disappointing. We also discuss a lot the ‘aesthetics of care’ but without being idealistic or self-righteous. The “collaboration” with the living material is not equal and we are responsible for any death that occurs.

**Aloi:** In 2003, you and longtime collaborator, Ionat Zurr, developed the world’s first semi living steak grown from frog cells. It was marinated in apple brandy and fried up in garlic and honey. It apparently didn’t taste particularly good. Is that true?

**Catts:** Actually, the first piece of meat that we grew was back in the year 2000, but because we’d done it in a biomedical research lab we were not allowed to eat it. However, this original piece of lab-grown meat looked way better than the frog meat we grew in 2003. We used Lamb cells, rather than frog cells. It looked much juicier and more like a stake than what we were able to accomplish in 2003, where we basically set up a fully functioning lab in a gallery that was as part of the la Art Biotech exhibition.

The problem was mainly with the texture. We were growing it over this polymer structure, because of the limitation of the time scale of the exhibition, and the polymer didn’t really break down much. Frog cells ended up having the consistency of jelly. It was really like trying to chew jelly on fabric. The sauce was pretty good though because I was really concerned about health and safety. We marinated it in a garlic and honey dressing—well known antibacterial agents.

**Zurr:** Taste is also an aesthetic choice. It built on a person’s exposure to food from childhood; expectations, context etc. In different cultures different food associated with different reactions (think frog legs for example). However, most of the very few people who tested the frog-steak spat it out. That may mean something...

It was a good opportunity for us to collect these spat-out bits and present them in the follow-up exhibition titled *The Remains of Disembodied Cuisine*. It was also encouraging to see that people do not swallow every new technology given to them.

**Aloi:** Dressing is important! In relation to this stake, you stated that growing meat in the lab was never about trying to solve the problems of meat production, but rather to highlight the strangeness of our relationship to other life forms. Ten years later, the first cultured beef burger patty was created by Dr. Mark Post at Maastricht University. It cost \$300,000 and it took two years to produce. Finally, last December, the first stake was grown in a laboratory from cow cells as a cruelty-free meat alternative was developed by Aleph Farms in Israel. This time, texture and flavor were claimed to be similar to conventional meat. Have your views on meat production and cruelty-free meat changed since 2003?

**Catts & Zurr:** Yes, and perhaps not for the better. We’re also credited to be the first people to grow leather in the lab. We’ve been doing these critical art projects in order to draw attention to our

relationship to life and it's interesting to see that a decade later, those things are being embraced as potential narratives of the production and consumption of edible products supposed to be cruelty-free. This label is incorrect because in most cases, animal products are used in order to grow the cells in the first place.

Even worse than that, I see the attempts to produce in-vitro meat as symptoms of a cultural malaise rather than as solutions. We clearly acknowledge the problems associated with a contemporary model of meat production, but in-vitro meat is a false neo-liberal techno-fix and it is not going to reduce our consumption of meat or its price.

Like many other products, we buy meat on credit. We don't pay the real costs of products, because we pass that on to the next generation. All the environmental costs are rarely being factored into the price of products we're buying today.

In the case of in-vitro meat, the technological system required to produce large amounts would be unsustainable. The cell cultures necessary for the production of meat also need to be fed—they don't just magically grow. The whole thing is essentially performative. It doesn't make any engineering, economic or efficiency sense, but it does remind us that many of the decisions we make, framed as engineering solutions, are fundamentally aesthetic. This is what it's all about. I guess that the real problem with it is that it suggests that we will not need to change our behavior and that science will save us through the paradox that the only way we can dig ourselves out of the ecological mess is by creating more products to be consumed.

**Aloi:** Indeed... Can you describe the *semi-living* as a concept in your body of work? What ethical responsibilities in your opinion, do we have towards a semi-living being, and can we even call it a being in your opinion?

**Catts:** When Ionat and I entered the lab, the very first lab we worked in was part of an eye research institute. We would get half rabbit heads. The rabbits were killed in the morning for food consumption, the heads were sent to a brain research lab, where they would take the brains out, they would then arrive at our lab where we'd take the eyes out and put them in an antibiotic solution overnight. 24 hours after the animals were slaughtered the skin from the eyes would be removed to start to culture the cells.

We realized that there are different definitions of life because the cells from the eyes of the rabbits were alive well after the animal's death. But they were not alive in the same way that the rabbit as an organism was alive, of course.

We started to use the term *semi-living* in order to describe the existence of living fragments of complex organisms that are supported by technological means in that they need to have sometimes a different set of relationship with us and they have different agencies in the world. I think that semi-living are beings in the sense that they are something in the world, they are alive in the most basic way of the term, and that they need considerations. Ionat and I are materialists. We don't believe that there's a vital force in life, but we still believe that that life is special. We are trying, and this is our artistic lifelong journey, is to try and formulate a theory of secular vitalism. The recognition that there's something special about life from materialist perspectives is a challenge.

**Zurr:** In a sense, today, more than any time in human history, we



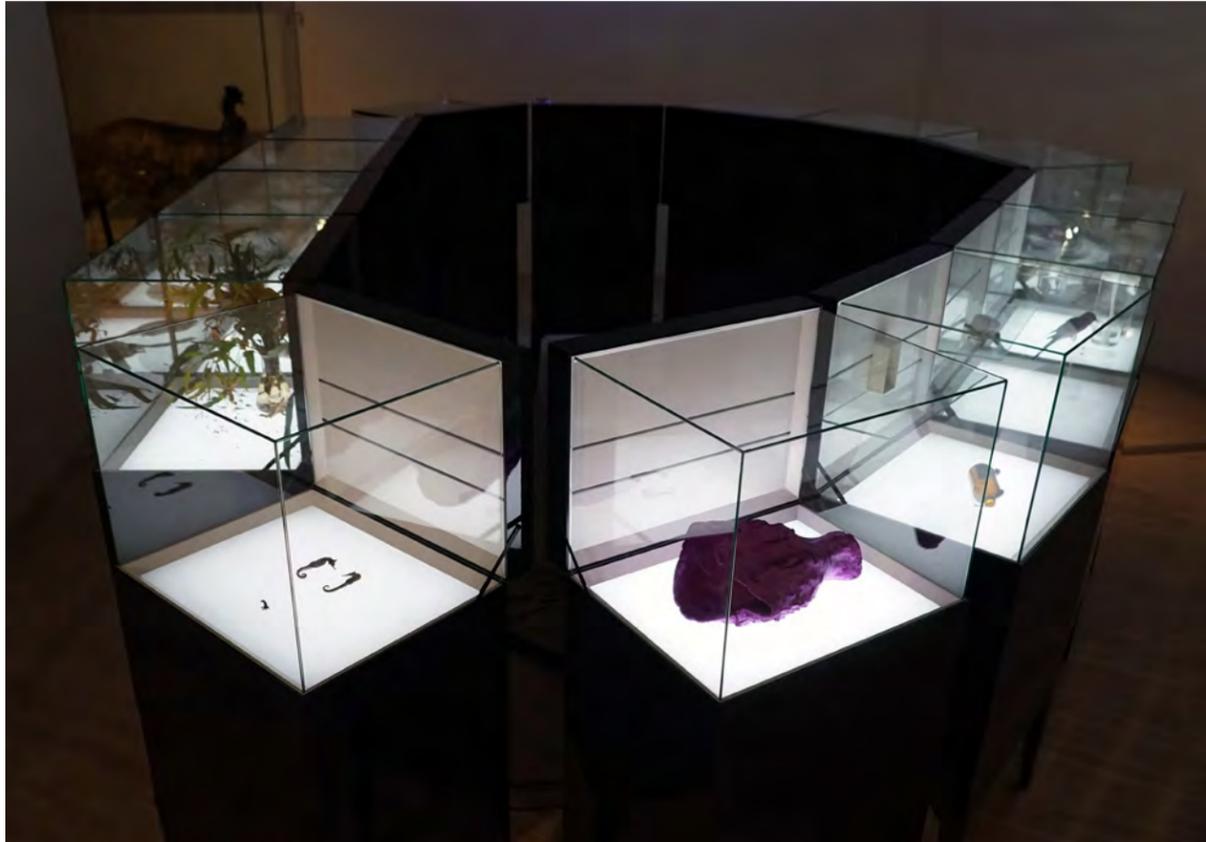
**The Tissue Culture & Art Project (Oron Catts & Ionat Zurr)**

*Disembodied Cuisine Installation*, Le Lieu Unique, installation, Nantes France, 2003, photography: Axel Heise © Catts/Zurr

are technologically dependent for our survival. We are becoming semi-living. Oron and I discuss how, paradoxically, the more we, humans, relinquish control to non-living systems which were built from scratch by us (think AI and drive-less cars), the more we try to assert full control on living systems which evolved before we became "humans".

**Aloi:** In 2004, as part of *Tissue Culture and The Art Project*, you produced the "victimless leather" we mentioned earlier; a prototype of stitchless jacket grown in a techno-scientific body. In this instance, a leather jacket made of culture cells was developed over a polymer substrate. Victimless leather questioned empathy, our relationship to identity constructs and it challenged the classical definitions of livingness. Is this an area of research that you're still interested in?

**Catts:** We are currently working on two major projects. One of them is about bringing back the incubator to the forefront as something that



**The Tissue Culture & Art Project (Oron Catts & Ionat Zurr)**

*Biomess*, installation, Art Gallery of Western Australia 2018. Bioreactor constructed by Nathan Thompson; display system constructed by MasterPlanners, Australia. Photography: Bo Wong © Catts/Zurr

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*We are asking whether this is a realistic dream or a Frankensteinian fantasy stitched together from out-of-control hubris?*  
 .....

incubator. We are working on a pseudo-sustainable format in which the heat is being generated when bacteria break down compost. Basically, waste, in this case, it is wood and mulch (and some horse manure) that will generate the heat that then warms an incubator where we can grow cells. In other words; it is an off the grid incubator.

The idea is part of a series of works concerned with expressions of care and control. The first order cybernetic device was a thermostat. The thermostat was the first instrument relying on feedback loops to execute orders. It's funny because, obviously, it was also created in order to outsource the caring for other life forms and delegate care to a technological device. You give technology the ability to look after living things.

The other area that we are currently focusing on another area that we are getting more and more interested in has to do with where biotechnological artifacts exist in the world? We work on this with natural history and cultural history museums to look at those artifacts that fall between life and technology. It's essentially about classification, taxonomy, and the question of categories. Richard Pell has been doing some interesting work on this already at The

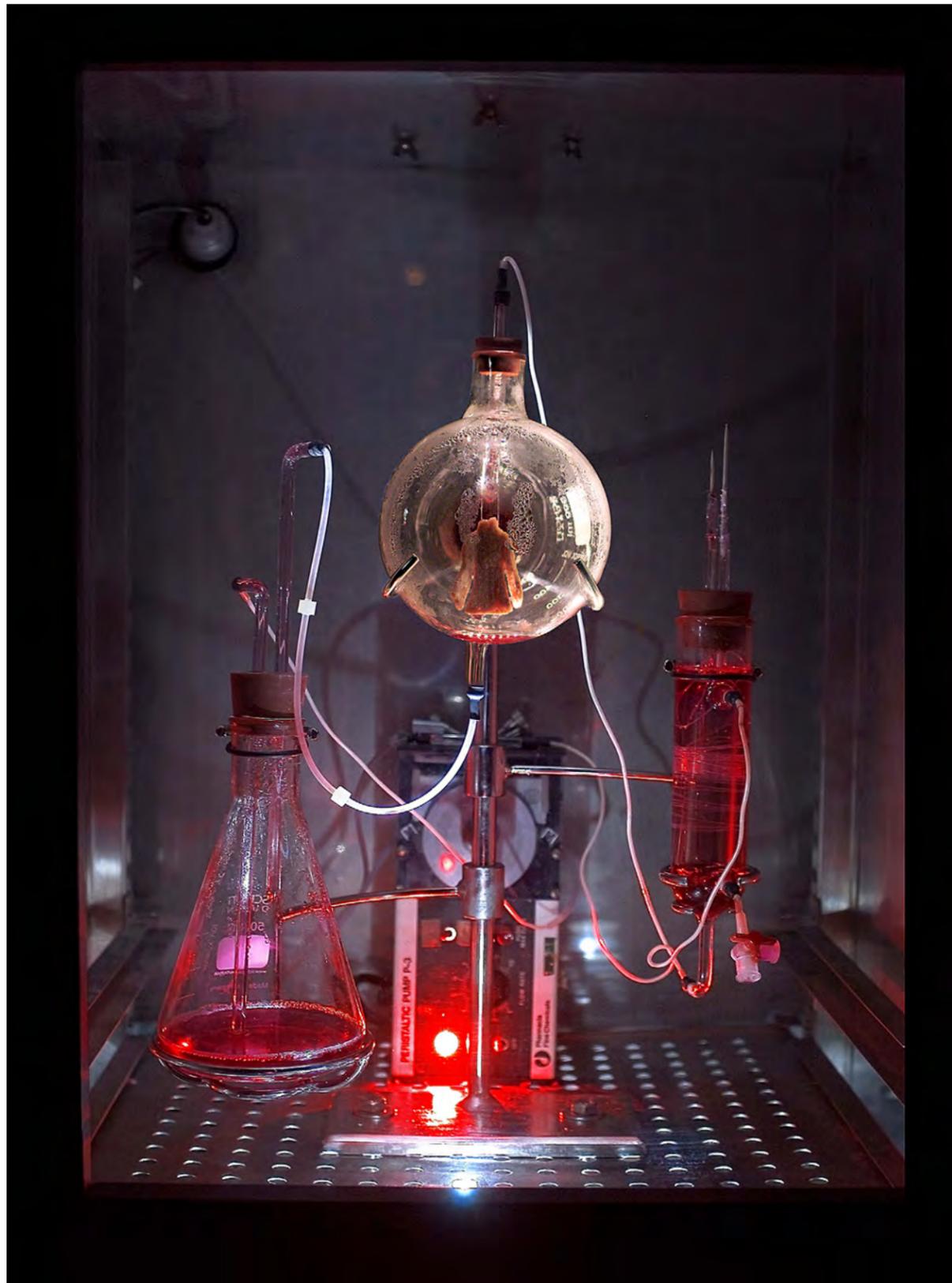


**The Tissue Culture & Art Project (Oron Catts & Ionat Zurr)**

*Biomess*, installation, Art Gallery of Western Australia 2018. Bioreactor constructed by Nathan Thompson; display system constructed by MasterPlanners, Australia. Photography: Bo Wong © Catts/Zurr

Center for PostNatural History in Pittsburg. We're working with the Smithsonian in Washington DC. We're also working with the local museums here in Australia. Our recent piece titled *Biomess*.

**Zurr:** In *Biomess* we explore how "Nature" seems to be broken while living systems and biological processes promise to bring about a new industrial revolution, undoing environmental destruction, and provide a guilt-free time of plenty. In order for us to continue our limitless consumption, life and nature must be tamed and non-charismatic biology must become our new object of desire. We are asking whether this is a realistic dream or a Frankensteinian fantasy stitched together from out-of-control hubris? In *Biomess* there are two rooms which mirror each other; one presents organisms living, evolving, and adapting to our shared environment. The other presents organisms designed by humans in the name of 'progress'



**The Tissue Culture & Art Project (Oron Catts & Ionat Zurr)**

*Victimless Leather- A Prototype of Stitch-less Jacket grown in a Technoscientific "Body". Custom built bioreactor, Biodegradable polymer connective and bone cells, 2004 © Catts/Zurr*

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*Especially living in a post-truth age  
 scientists and artists occupy very  
 different positions in relation to  
 truth. Artists are celebrated for what  
 scientists are demonized.*  
 .....

who are dependent on human technology for their survival (Semi Living). Both are mysterious and not under our full control and comprehension. However, the design of the installation, reminiscent of a luxury retail outlet, brings into question human forays into a new era of exploration and exploitation of biological life as a new commodity to satisfy unfulfilled desires.

The notion that the art object is eternal, never changing, and commodified is still rooted in the ethos of the art museum. Our artworks embody the complete opposite and contest this anthropo-assumption. The commodification of life is a monstrous act. These times, known as 'the biological turn', are characterised by human attempts, on a global scale, to engineer and commodify life, including our own. The notion of the commons is being fragmented into saleable objects. This artwork celebrates the messiness, subversiveness and rule-defying nature of life. It is about reminding us of human animals that we are an integrated part of the wonderful monstrosities called living systems.

**Catts:** I'm also a part of the International Advisory Group for a new Museum, which is going to open up in Munich called Biotopia, which is run by Michael John Gorman. Biotopia is trying to reimagine the natural history museum for the 21st century. I think this is an extremely important area.

**Aloi:** What's the most exciting part of working in a lab?

**Catts:** In the lab, life becomes raw material. This enables unprecedented possibilities of manipulation. Working with life in the laboratory, in a way that is very different from what scientists do, allows us to accept failure as part of a productive process.

**Zurr:** I joined the project as a photographer whose role was to document the processes in the lab. However, once I started to work with the living materials, I realized that for me, at least, there was a much more visceral, embodied (as well as intellectual) engagement that surpassed the dimension of representation. The relationships with living material involve a delicate and unsteady balance between care and control; between pleasure and uneasiness (or even pain). To me, this (unequal) relationships/collaboration with the living or semi-living artwork is the most interesting part.

**Aloi:** *You said that: "Art and science are very different fields of human endeavor. They can be complementary at times and oppositional at others. Artists using the same technological tools as scientists are not doing science, and scientists who are producing images are not doing art. In my lab I talk about the integrity of disciplines; both the methodology and context in which the work is being developed are what make its meaning and the ways in which it is being read". What's at stake in the "integrity of disciplines"?*

**Catts:** Truth. Especially living in a post-truth age scientists and artists occupy very different positions in relation to truth. Artists are celebrated for what scientists are demonized. The fabrication of stories is the artists' domain. Truth isn't necessarily what we work with. Many of the artists in the field that I operate in tell stories. They claim that the work is one thing while it's actually not, but that's all

right, as long as people are aware of it.

The problem we have in the field of art and science is that of perceptions. Now in many cases, artists are being used to create seductive narratives in regard to the power of the technology and the science, and engaging with so-called art and science in order to generate excitement, and mainly investment into those speculative attempts to control life in different ways.

I think the integrity of the discipline is really important. I run a research lab in a biological science department but I'm an artist. It's important that when I present myself as an artist, people would be skeptical about what I'm telling them and question my position. But the blurring of those disciplines opens up the very real risk of exploitation of our relationship to this idea of knowledge. I wouldn't talk about truth in ways that science produce verifiable knowledge and knowledge that can be generated in order for you to understand the world in new ways. I think both art and science help us understand the world, but they help us understand and engage with the world in very different ways.

**Aloi:** You did say that there's a danger that artists are being used to excite. Can you tell us more about it?

**Catts:** All right. For instance, I'm very concerned about what's happening in Europe at the moment. There are festivals giving prizes to artists who are working in techno/scientific fields. These prizes are increasingly given to inventors of speculative gadgets. Artists are now becoming part of this narrative in the sense of generating excitement about where venture capitalists and investors put their money in. Artists are used to generating a false sense of control of complex systems. Sometimes it has happened to our work. It has been used in promotional campaigns that we are not involved in or support. Startup companies use our work as a basic indication of the shifts in our relationship to life in order to be able to exploit it for consumer goods. I'm safe with my own work but it's getting more and more dangerous when the funding structure is inviting artists to do exactly so.

**Aloi:** How important is performance in your practice?

**Catts:** First of all, when we show our work in museums, it's still difficult for us to show living, biological material. This is because of their institutional histories. Those institutions are basically places designed to preserve dead things as dead as possible for as long as possible. When you exhibit something living in a museum many fears become central: contamination, maintenance...

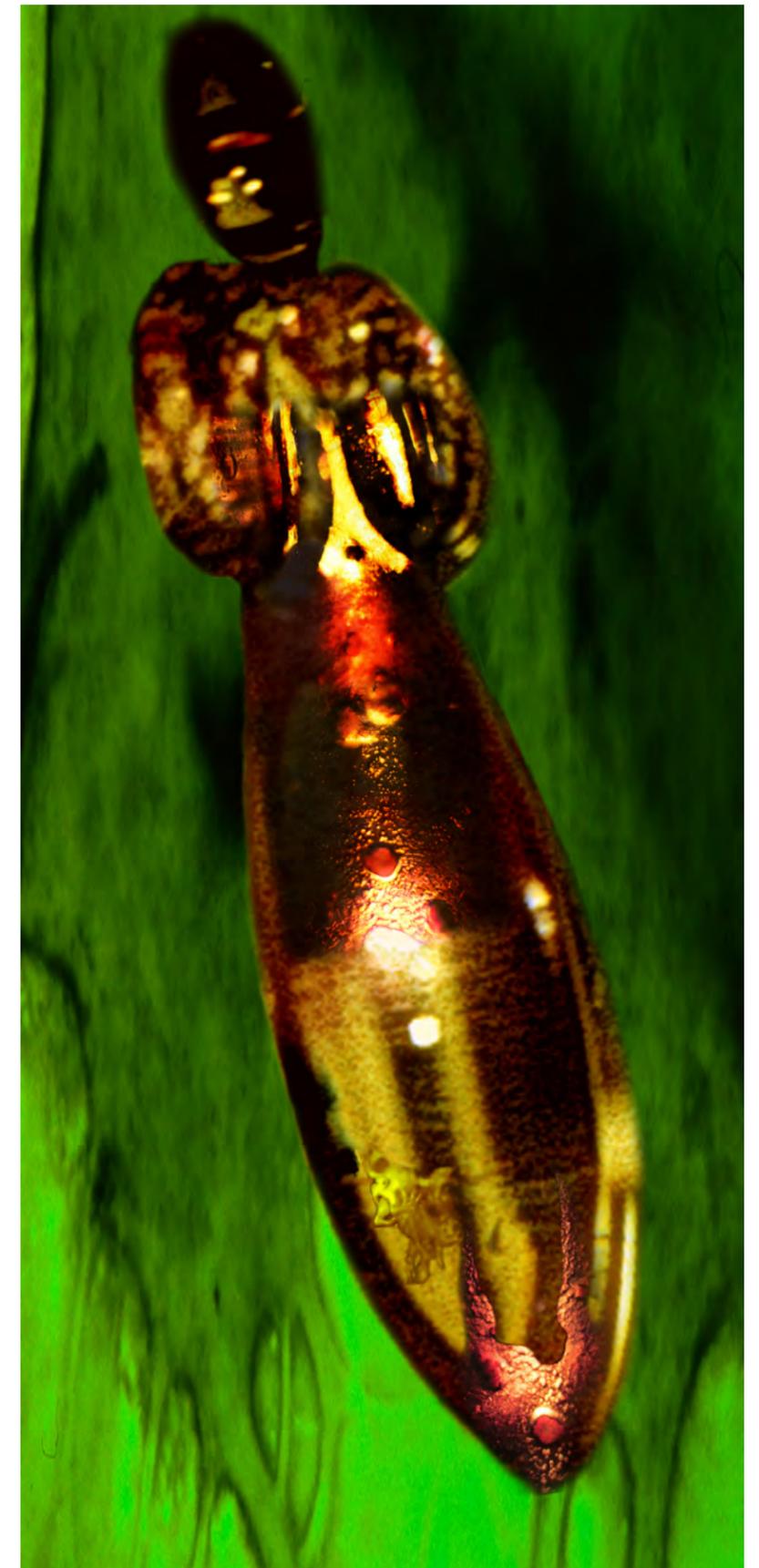
Performance has always been important in our practice not in the sense that we cast ourselves as living human performers, but actually our sculptures, our work, our living work is performance in a sense. We're not really interested in generating too much conversation around the human because we feel that people have ready-made responses to that while we want to challenge them into realizing that there are so many things out there that we don't understand—things for which we don't have a cultural language to deal with or ready-made responses.

When something in your exhibition is "living" then there are also moments in which you engage in performances like feeding ritu-

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*The problem we have in the field of art and science is that of perceptions. Now in many cases, artists are being used to create seductive narratives in regard to the power of the technology and the science, and engaging with so-called art and science in order to generate excitement, and mainly investment into those speculative attempts to control life in different ways.*  
.....

**The Tissue Culture & Art Project  
(Oron Catts & Ionat Zurr)**

*B(W)omb*, Rabbit epithelial, custom designed glass figurine, 1.5cm x 1cm x 1cm, 1997 © Catts/Zurr



als or when we do the killing rituals of our work. Since 2012, I've been involved in cooking shows we call *ArtMeatFlesh*. Zack Denfield, Catherine Kramer, and I run cooking shows where scientists, philosophers, chefs, and artists to cook against each other and have a conversation around the future of our relationship to life and food. It started with Mark Post as our first guest cook, I invited him to the original a cooking show, as part of the Dutch Electronic Arts Festival in Rotterdam in 2012.

I never ever imagined in my life that I would become a cook show host and an MC but it seems to work really well. Ultimately, performance means engagement but on a meta level, everything we do can be classified as performance.

**Aloi:** What's your take on CRISPR technology and its possible artistic applications?

**Catts:** I like to say that I'm a DNA skeptic in the sense that there is so much more to life than DNA. CRISPR is obviously a very powerful technology, but it is extremely problematic in the sense that it's not as precise and accurate as the popular media wants us to believe. There still are so many off-sight and off-target events. First of all, what we are is an interplay between hereditary factors, which are not just the DNA, and the environments we grow in. CRISPR is another tool, but it's not the huge thing that it's being portrayed as. As for artistic purposes, I think it's an interesting option. It's another brush in your pallet. It's another way of manipulating the artist materials, in this case, life. But it's also going to highlight the fact that life is not that controllable.

But rather importantly, we focus so much on DNA as if it were the only important thing about life because this is the only thing contributed by the male. I think that we'll look back and realize that our obsessive focus on DNA is an extremely chauvinistic notion of the way life operates and hopefully soon we'll get away from that.

**Aloi:** Very interesting point. One more thing on CRISPR. Do you find that different ethical considerations should apply to it or you don't see a difference between other manipulations, genetic manipulations?

**Catts:** I think we all have to have some kind of understanding of the impact of what we're doing in the world. When we build a dam, we have a substantial impact on the future, perhaps more than that we have in manipulating a gene of a specific organism. In principle, I don't like to alter "nature" too much. But I don't really see genetic engineering or CRISPR as an operation against nature. It's more about the impact? The cascading impact of what we do now to the future and again, because I don't really think that DNA manipulation is as powerful as it's being portrayed, I'm less concerned. My main concern is about the mindsets of control. When world leaders are told that they have the power to engineer life forms including humans—that concerns me.

**Aloi:** What challenges have you encountered in working with scientists?

**Catts:** The main issue usually is that they don't really seem to understand what art is or what it does. I would often meet scientists

who would pull out an image they took and say, "Here, we're artists too" and show me smiling cells. They would think that I'm there to make their work look better or that I have come to illustrate their work. Engaging with scientists from many different countries and cultures and realizing first of all that science has its own culture and that it's very localized. Despite the fact that we tend to think that science is monolithic and that there are protocols, almost every lab has its own tissue culture culture.

But after many years of work, I'm now in a very interesting position where scientists approach me in order to collaborate. They come along with an understanding of what we do and what we can accomplish together—so the collaboration is much more enjoyable.

**Aloi:** Which conversations do you think are essential at this moment in time in Bio Art?

**Catts:** I must admit that the most important conversation is about the difference between artists claiming things about life that have very little connection to reality and artists who are engaging with the realities and the bitter reality of life. Researchers come to the Lab and do work in an honest way. How important it is for artists to have some honesty because a hoax can be a really important artistic strategy. But hoaxes only work if the hoaxer reveals the hoax at the end of the exercise. What we see now, more and more is artists who are claiming things that are totally unfounded. I think that curators, institutions and the media are extremely lazy with fact checking so as a result, really exciting narratives are being hijacked and exploited.

**Zurr:** Another important aspect is the phenomenon of less artistic and critical (and ironical) works and proliferation in artworks that are pseudo "gadgets -ring". Many "artworks" are about making sincere gadgets or offering solutions. The reality is much more complex than that and I am not sure this is our role as artists.

**Aloi:** Where are Oron Catts and Ionat Zurr heading to?

**Catts:** In my mind, I'm heading to a cabin in the forest. I wouldn't mind retiring into an off-grid survival mode and just end up in a forest somewhere in a cabin, being directly involved with un-manipulated life for a while. I think that might be a good idea.

**Zurr:** I am less sure that the forest will be so hospitable (in Western Australia there are bush fires...). I'm in Donna Haraway's words, "staying with the trouble". I have some life to look after...

.....  
*I don't really see genetic engineering or CRISPR as an operation against nature. It's more about the impact? The cascading impact of what we do now to the future and again, because I don't really think that DNA manipulation is as powerful as it's being portrayed*  
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Award winning Artists, researchers and Curators, **Catts and Zurr** formed the internationally renowned Tissue Culture & Art Project in 1996. Catts is the Co-Founder and Director of SymbioticA: the Centre of Excellence in Biological Arts, School of Human Sciences at the University of Western Australia (UWA) and was a Professor of Contestable Design at the Royal College for the Arts UK. Dr Ionat Zurr is a researcher and lecturer at the School of Design UWA and SymbioticA's academic co-ordinator. Both are Visiting Professor at Biofilia – Based for Biological Arts, Aalto University, Finland (2015-2020). They have been visiting scholars at The Centre of Arts and Art History at Stanford University (2007) and Research Fellows at The Tissue Engineering & Organ Fabrication Laboratory, Harvard Medical School (2000-2001).

Catts & Zurr's interest is *Life*, more specifically the shifting relations and perceptions of life in the light of new knowledge and its applications. Often working in collaboration with other artists and scientists, they have developed a body of work that speaks volumes about the need for new cultural articulations of evolving concepts of life.

They are considered pioneers in the field of Biological Arts; they publish widely and exhibit internationally. Their work was exhibited and collected by museums such as Pompidou Centre in Paris, MoMA NY, Mori art Museum, NGV, GoMA, Yerba Buena Center for the Arts, San Francisco, Ars Electronica, National Art Museum of China and more. Their research was covered by The NY Times, Washington Post, Wired, New Scientist, Time, Newsweek, Nature, Science, and other TV, radio, print and online media.

# Move as non-human migrators...

This essay explores the enlistment of the nonhuman animal as a conceptual model in the work of composer Alvin Lucier, and its vestigial presence in the work of artist James Turrell, two contemporaries who have transgressed the essentialist boundaries of their chosen disciplines to offer glimpses of nonhuman sensory worlds. Through collaboration with individuals outside their fields, their relationships with scientists and technical specialists has extended beyond the content of particular experiments to embrace methodological approaches otherwise anomalous within the visual and sonic arts, into what Siegfried Zielinski has referred to as a *cultura experimentalis*.

text by **Jim Supanick**

The nonhuman animal is by turns effective and resistant as a means of estrangement; that tension is perhaps no more dramatically felt than in Thomas Nagel's "What is it like to be a bat?";<sup>1</sup> an essay which has stood since its 1974 publication as a default citation for anyone claiming interest in "the animal question." While its title points toward a thought experiment calling for imaginative extension, Nagel essentially declares his hypothetical bat—and the nonhuman animal in general—to be a veritable *black box*,<sup>2</sup> a being whose inaccessibility dispenses with the very question posed at the outset. The narrow constraints he sets forth—"to know what it is like for a *bat* to be a bat"<sup>3</sup>—push toward an all-or-nothing outcome, preempting any satisfying answer.

Nagel's choice of species for investigation of an alien subjectivity was based on a unique sensory feature; the bat's hearing symbiotically evolved its acute sensitivity in conjunction with nocturnal feeding habits and the barely lit environments in which it dwells. Quite rightly, Nagel had identified a new and scientifically inflected angle on an old philosophical problem: Aristotle's five senses<sup>4</sup> and their association with a corresponding organ had long served as a fixed point of Western thought, a schema deemed "sufficient," according to zoologist Maurice Burton, "until about the year 1940."<sup>5</sup> The categorical dissolution since then is to a great extent attributable to new avenues of research opened into the sensory worlds of nonhuman animals, whether toward the heightened powers of those senses shared with humans, or as capacities altogether separate from the human sensorium. The desire to maintain respect for the living organism and to minimize suffering through noninvasive procedures is at once a welcome development and an undeniable challenge to previous bases of scientific inquiry, and is why, as Hermann Schöne has written, "[a]nimal studies have concentrated more on motor orientation, i.e., on the motor aspects, since it is difficult to demonstrate perceptual processes in animals."<sup>6</sup> The result is a curious reversal of previous research initiatives positing the nonhuman animal as a sufficient stand-in for humans—here, speculation about animal sensoria is left to depend on the inadequate model of the human.

## In the dark... listening

In 1958, zoologist Donald R. Griffin proposed that "[i]f faced with the hypothetical choice of evils, to become deaf or blind, few but the most devoted musicians would choose blindness."<sup>7</sup> Most readers would cast aside such a statement as little more than a fleeting thought experiment. For the composer Alvin Lucier, however, it sounded with a deeper resonance; shortly after reading Griffin's *Listening in the Dark*, his pioneering work on the echolocation of bats derived from research conducted over the previous twenty years (as well as the steps and missteps of his predecessors), Lucier set out to explore the sonic and philosophical implications opened up through Griffin's book.

For Lucier—and for many general readers—one of *Listening in the Dark*'s most compelling aspects was its vivid evocation of another creature's sensory world so distant from our own vision-centered existence. Intimations as to the extent to which Griffin's work might be reimagined by Lucier were already contained within the first composition he considered truly his own: *Music for Solo Performer* (1965) was based on the sonification of the performer's alpha brain waves—in audible in themselves—to generate signals then amplified and sent through a band-pass filter to simple transducers triggering a set of drums dispersed across the concert stage; in order to do this, "[t]he performer assumes a state of minimal visual stimulation."<sup>8</sup> The inherent paradox was that alpha waves would only occur once the performer reached a state of mental repose akin to meditation; the risk of "nothing happening" was considerable. Lucier was surely well aware of the dramatic impact of the piece's staging; video from an early iteration shows the composer himself in a chair, eyes closed and electrodes applied to his forehead and hands. Experimental music here takes on aspects of experimental psychology, with laboratory apparatus conspicuously present: the composer doubling as performer, a researcher who in turn doubles as test subject, from whom the energy driving the signal emanates.

*Music for Solo Performer* was preceded by a period of creative crisis. His early successes as a student at Yale and Brandeis, where he was considered a promising young composer at work in a neoclassical vein, had nevertheless left him strangely dissatisfied. Despite early accolades, he viewed his own early work as a dead end, that of "a second-rate Stravinsky."<sup>9</sup> Following a trip to Italy and postgraduate studies at Venice and Darmstadt, Lucier returned to Brandeis to teach and conduct the chorus there; it was then he met Edmond Dewan, a physicist working for the U.S. Air Force (and father of musician/instrument builder Brian Dewan); the elder Dewan was conducting experiments at the time to better understand the relationship between aircraft propeller speed and the epileptic seizures then experienced by military pilots with an alarming frequency. Lucier's meeting with Dewan came at a crucial juncture—painful at the time, but in retrospect a moment of "emptying-out" necessary for the work to come, corresponding in an uncanny way to the meditative precondition necessary to activating sound in *Music for Solo Performer*.<sup>10</sup>

Dewan's encouragement to experiment with the equipment and generous offer of access was met with enthusiasm, as at that point Lucier felt that, "I had no good reason to write one note af-

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*The inherent paradox was that alpha waves would only occur once the performer reached a state of mental repose akin to meditation; the risk of "nothing happening" was considerable.*  
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**Alvin Lucier**

*Alvin Lucier with Solar Sounder I.* Photo courtesy of Alvin Lucier © Alvin Lucier

ter another. <sup>11</sup> Yet he was about to discover a gift for what Gordon Mumma has called “system-concept thinking”, defined as “one in which the composer created a system which a composition was conceived.”<sup>12</sup> That seeming tautology pointed in fact to a quality at the heart of Lucier’s larger contribution: the ability to track the standard signal-flows within Western concert music, diagramming their circuits and rerouting currents in radically new ways; this meant, if not undermining his own authority entirely, then redefining its role. Although investment in a 19th-century image of the composer within the classical music community remains to this day more or less a given, Lucier’s gambit (like that of Cage) was to challenge patterns

of the preceding two centuries in order to, as composer Michael Nyman put it, “extend and re-define the traditional (and avant-garde) performance sequence of reading-comprehension-preparation-production.”<sup>13</sup>

Following *Music for Solo Performer’s* externalization of inaudible, internal phenomena, his next work *Shelter* (1967) went on to explore the sonic properties of the enclosure and amplification system within a darkened performance space as an instrument in and of itself, using amplified sounds immediately external to the room as its raw material. Through this excursion into acousmatic listening,<sup>14</sup> Lucier again demonstrated his remarkable ability to create an emotionally and psychologically charged situation through radically economical means. It is here, I would argue, that the nonhuman animal first appears in his oeuvre, albeit in covert form: we are reminded of the protagonist of Franz Kafka’s *The Burrow*, in which a creature of indeterminate species narrates an existence listening to sounds emanating from outside its lightless subterranean abode. Is that distant sound a predator, or some other potential threat? To listen and determine, without visual cues: one should note this restriction of visual stimuli as a key component of *Shelter* and other subsequent works.

Shortly after this, Lucier’s attention turned to bats; the fortuitous encounter with Griffin’s book marked yet another influence upon the young composer’s work, evident in his inclusion of an illustration of echolocating bats that adorns the cover of *Reflections*, a 1995 collection of his interviews, scores, and writings whose title itself alludes to the careening sound waves of echolocation. Clinging upside-down in their hours of repose, these nocturnal creature-inhabitants of dark and resonant spaces were perhaps emblematic of the composer’s homely inversion of long-standing musical values that defined the Western concert tradition. In addition to that, Lucier was drawn to the careful design considerations within each of Griffin’s experiments and detailed documentation of his process, recognizing a convergence of his own new musical direction with that of experimental science. For the composer, *Listening in the Dark* “gave me a lot of ideas. I began thinking of sounds in terms of short and long wavelengths, not as high and low pitches or notes written in time from left to right on a page. I was truly impressed by these creatures that employ sound so exquisitely for survival.”<sup>15</sup> Reflecting more recently upon Griffin’s research, the primatologist Frans DeWaal has outlined the intricacies of the echolocatory process:

.....  
*Clinging upside-down in their hours of repose, these nocturnal creature-inhabitants of dark and resonant spaces were perhaps emblematic of the composer’s homely inversion of long-standing musical values that defined the Western concert tradition.*  
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The bat works with plenty of sensory input, even if it remains alien to us. Its auditory cortex evaluates sounds bouncing off objects, then uses this information to calculate its distance to the target as well as the target’s movement and speed. As if this weren’t complex enough, the bat also corrects for its own flight path and distinguishes the echoes of its own vocalizations from those of nearby bats: a form of self-recognition. When insects evolved hearing in order to evade bat detection, some bats responded with “stealth” vocalizations below the hearing level of their prey.<sup>16</sup>

Several aspects of the two preceding statements deserve more detailed exploration, but for now, I will adhere to their primary points: implicit within the words of both Lucier and DeWaal is a notion of

the bat's vocal utterances as *measurement*, a precision technique analogous to today's laser rangefinding tools, and yet beyond mere capture of a single static moment by virtue of its pursuit of a target in constant, unpredictable motion. The word *sound* itself is in its contemporary English usage a complex etymological convergence;<sup>17</sup> one less frequent use as a transitive verb (derived from the Old French *sonder*) can signify an act of measuring depth in a body of water impenetrable to the eye, so performed by other means. Viewing Griffin's echolocatory discovery, one can identify a still more striking analogy in the contemporaneous wartime research conducted on anti-missile systems at MIT by Norbert Wiener, work that contained a number of the founding principles for the nascent field of cybernetics. Considered alongside one another, the connections between their respective projects are immediately apparent.<sup>18</sup> Perhaps such connections were serendipitous; thus far, any possible direct contact between the two endeavors—carried out in such geographic and temporal proximity—remains obscure.

Griffin's breakthrough undoubtedly owed a great deal to the physicist George W. Pierce, a professor of physics at Harvard whose recording equipment and techniques provided the first conclusive proof of a bat's ultrasonic vocalizations.<sup>19</sup> Pierce's first investigations into sound outside the audible spectrum were conducted during WWI under the aegis of the US Navy's Anti-Submarine Laboratory; following the war, his interests evolved toward living sound sources, and led to his recordings of insects and later, birds and bats.

In *The Songs of Insects*, written a decade after his collaboration with Griffin, Pierce defined sound as "mechanical vibrations in a ponderable medium, propagated in the medium from a source in mechanical vibration by waves of pressure and motion in the medium";<sup>20</sup> this radical separation of *sound* from *what is heard* marked a distinct paradigm shift, and ought to be viewed today as an early posthumanist approach to sensory worlds well before posthumanism itself had been formulated as a concept. Such a definition, however, was (and still remains) anomalous, in direct opposition to that of Jonathan Sterne, one of today's preeminent scholars within the field of sound studies in North America. Invoking the physiologist Johannes Muller, Sterne lays out his own definition while conceding his own anthropocentric bias:

You can take the sound out of the human, but you can take the human out of the sound only through an exercise in imagination.... When the hearing of other animals comes up, it is usually contrasted with human hearing (as in 'sounds that only a dog could hear').<sup>21</sup>

Pierce brought ultrasonic sound to human awareness not "through an exercise in imagination," but by way of a technique called *heterodyning*. Heterodyning is a means of processing an audio signal (in this case, the vocalization of a bat) by combining it with another oscillator-generated signal of steady frequency; technology available to Pierce and Griffin in the late 1930s required careful tuning of the oscillator signal to render a third signal audible to the human ear.<sup>22</sup> Undoubtedly, a bat's ultrasonic utterances are more than simply "sounds that only a dog could hear"; dismissal of their presence or significance constitutes a premature foreclosure of knowl-



Donald R. Griffin

Donald R. Griffin with bat in hand and sound-detecting apparatus, ca.1960; photo courtesy of Harvard University Archives © Harvard

edge regarding the nonhuman animal. Against this conception of sound-as-audibility defined by Sterne, the significance of Pierce's vibrational paradigm extends beyond sound physics and ontology, carrying over, through Lucier, into a new realm of musical aesthetics and beyond. "One night," the composer wrote,

I had a vivid dream.... I saw humans—astronauts perhaps, I may have been one of them—exploring a dark space in an alien environment. They were beaming sound guns into darkened rooms, collecting information about those rooms and relaying it back to Earth. It was kind of a science fiction idea.<sup>23</sup>

Shortly after, while at work on *Vespers'* score, Lucier met a representative from a small company about to introduce a device to market called a *Sondol*; its name was derived from the words "sonar" and "dolphin", and described as "small, hand-held echolocation devices for boat owners, acoustic engineers, and the blind."<sup>24</sup> The *Sondol's* manufacturers designed it as an easy to use aid for exploiting "facial vision," the phenomena of human echolocation that some

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*The word sound itself is in its contemporary English usage a complex etymological convergence; one less frequent use as a transitive verb (derived from the Old French sonder) can signify an act of measuring depth in a body of water impenetrable to the eye, so performed by other means.*  
 .....

advocates believed could offer autonomous mobility for the blind;<sup>25</sup> Lucier recalled that,

I borrowed a prototype of a Sondol and turned it on. I adjusted the pulse rate—you couldn't adjust any other parameter—and immediately heard reflections off the surrounding environment. It was beautiful! When I beamed it at a wall I heard that the echoes that came back differed from the pulses that went out. If I aimed it at glass window I noticed that the echo was different from that which came from the wall. I visualized the sounds getting squashed on the impact... The echoes are beautiful outdoors; you can hear the leaves on trees.<sup>26</sup>

In devising his title for the new work, Lucier explained that “Vespers is one of the seven canonical hours the Catholic Church held in the late afternoon or early evening. Although I am not religious I thought of it as a ritual in some way.”<sup>27</sup> Included at the beginning of its text score is a dedication of sorts, and it reads:

For any number of players who would like to pay their respects to all living creatures who inhabit dark spaces and who, over the years, have developed acuity in the art of echolocation, that is, sounds used as messengers which, when sent out into the environment, return as echoes carrying information as to the shape, size, and substance of that environment and the objects in it. (1968)<sup>28</sup>

Much as in his dream, the score instructs its performers to “[p]lay in dark places, indoors, outdoors, or underwater; in dimly lit spaces wear dark glasses and in lighted spaces wear blindfolds.”<sup>29</sup> Here again, restricted vision is a performance requirement. Caroline Jones has described a recurrence throughout the history of western philosophy of what she has termed “volitional blindness,” most famously in Plato’s cave allegory. According to Jones, everyday vision for the cave’s prisoners amounts to an affliction by virtue of their confinement; the philosopher, in contrast, turns away from the spectacle- knowing that to move is to reflect, to advance to a place beyond appearance. Jones traces this motif as a recurrence in the works of William of Ockham and Denis Diderot, continuing closer to the present in the writings of Jacques Derrida and Paul DeMan. “The pathway from ignorant blindness to philosophical *insight*” Jones writes, “leads through the body: its turning and re-turning, its willed shift from retinal sight to mental image.”<sup>30</sup>

*Vespers* brings us back to our senses, or more precisely, senses no longer our own. Within the body of the score itself, another more fanciful directive encourages its performers to “[d]ive with whales, fly with certain nocturnal birds or bats (particularly the common bat of Europe and North America of the family Vespertilionidae), or seek the help of other experts in the art of echolocation.”<sup>31</sup> To be faithful to the spirit of the work, then, is to project oneself into an unaccustomed sensory frame. The ability to perform the piece (as well as for the blind subject to successfully navigate with a Sondol or other echolocatory techniques) raises a question as to the existence of vestigial senses within us and of the possibility



**Listening Incorporated**

Closeup of *Sondol*, manufactured by Listening Incorporated; photo by Jan Thoben. Photograph courtesy of Alvin Lucier

of their recovery. “The senses,” Jones continues, “both constitute our ‘sense’ of unmediated knowledge and are the first medium with which consciousness must contend”;<sup>32</sup> here, plainly stated, lies the fundamental error committed by Nagel’s “reductionist” contemporaries<sup>33</sup> whose analogies, he argued, were derived from a range of scientific disciplines ill-suited to the task of discerning “relation of mind to brain.”<sup>34</sup> Nagel, to his credit, did manage to identify the pre-conditional fact of sensory difference his colleagues somehow overlooked; Lucier, in turn, recognized something else that Nagel had failed to see: that what knowledge of “what it is like to be a bat” was there would only avail itself provisionally.

“Basic to my work is making audible that which is inaudible...”<sup>35</sup> Lucier made it clear via interviews and in the language of the scores themselves that emulation of particular sounds held little interest for him; instead, the phenomena that prompted a particular piece could be adopted to a range of performance settings and approached with a wide variety of materials and attitudes. With *Vespers*, he mused on the possibility of a version with runners on a track: “I would want to have runners of different styles and speeds—long distance runners, milers, sprinters.”<sup>36</sup>

*Vespers* grants its performers freedom in terms of time and movement; restraint follows from directives in the score itself, in

avoidance of obstacles, and self-awareness of audience presence. Players are instructed to maintain gradual pulse rate changes as a way of avoiding a default adherence to conventional musical values. Individuation of voices too helps to shape potential cacophony into more cohesive form:

The players have to stop playing every once in a while to allow each other a clear sound-image to follow. So silence is built into the performance. I didn't indicate when it should occur. Stops, starts, silences, density, and texture are built into the task of orienting oneself by means of echolocation. A performance of *Vespers* gives you an acoustic signature of the room, as if one were taking a slow sound photograph over a long period of time.<sup>37</sup>

With both the echolocation of bats and the guided missile systems developed by Norbert Wiener and his colleagues, we are faced with a peculiar twist to the basic underpinnings of what is today referred to as information theory<sup>38</sup>: the familiar dyad of *sender* and *receiver* has been rerouted as a closed loop. With the calls of insectivorous bats, these typically independent functions are that of a single agent.<sup>39</sup> A similar schema might well be applied to *Vespers*, and this then raises the question: what about the listener? When a closed circuit such as this is transposed to a musical setting, the audience finds its position as analogous to that of an eavesdropper. Roland Barthes struck a sympathetic note when, just two years after the first performance of *Vespers*, he wrote that,

[t]here are two musics (at least so I have always always thought): the music one listens to, the music one plays. These two musics are two totally different arts, each with its own history, its own sociology, its own aesthetics, its own erotic...<sup>40</sup>

For the skeptical listener, the music of *Vespers* may seem a type of residue, forensic evidence of a crime committed in the name of music. Even an ear as sympathetic as David Toop found certain Lucier compositions to be imbued with "an air of dry pseudo-science... almost as if they were lifted out of the gilt-edged pages of a late-Victorian acoustics textbook."<sup>41</sup> Such assessments hew insistently to a set of preexisting expectations, disregarding the possibility of something genuinely new; as Peter Szendy has pointed out, "the word *voyeur* has no auditory equivalent..."<sup>42</sup> While Toop was right (so far is *Vespers* is concerned) to identify a certain archaism, his mistake was in locating its source; Nicolas Collins, a former student of Lucier and now an innovative composer in his own right, reflected upon his own experience in performing the work:

In *Vespers*, Lucier reached back... to a pre-hominid time before the divarification of music from all other sound, and he invented something that re-connected music to physics, architecture, animal behavior and social interaction.... To perform *Vespers* is to experience sound as survival rather than as self-expression or mere entertainment. At the same time, in its engagement with fundamental acoustics, the piece evokes the kind of ineffable axiomatic musicality I as-

sociate with strict species counterpoint.<sup>43</sup>

Between the responses of Toop and Collins lies the very tension described by Barthes- but how in this instance might the respective erotics of which he speaks play out? Collins evokes a primal state of alert, when one's status as predator or prey remained as an open question; as Nietzsche once observed, "The ear, the organ of fear, could have evolved as greatly as it has only in the night and twilight of obscure caves and woods..."<sup>44</sup> Much of the discourse surrounding *Vespers* concerns questions of space, questions that might productively shift to include the model agents within it. And perhaps it is there to reimagine a new role, to eavesdrop oneself into an active current within the musical circuit.

.....  
*For the skeptical listener, the music of Vespers may seem a type of residue, forensic evidence of a crime committed in the name of music.*  
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### Perceiving Oneself Perceiving

The publisher's promotional blurb for his 2013 retrospective catalogue tells us that, "James Turrell is perpetually asking us to "go inside and greet the light"-evoking his Quaker upbringing."<sup>45</sup> In the copious writing on Turrell's work, such a coupling of light and spirituality has frequently been invoked;<sup>46</sup> perhaps just as common is reference to a sublime quality- most often in the adjectival sense, but occasionally too as famously codified by Edmund Burke. Without intending to discount its unquestionable beauty, I will pursue a different critical track, one that considers his work and its effects as a vector of technological mediation and, in addition, to view it through the other, less recognized aspect of Burke's formulation: "whatever is in any sort terrible, or is conversant about terrible objects, or operates in a manner analogous to terror, is a source of the sublime..."<sup>47</sup> Turrell's work is often cast as something akin to a Sonora Desert sunset conveniently transposed to the space of a gallery or museum; perhaps the other aspect of Burke's sublime is best accessed by way of an anecdote shared by the artist himself.

In a conversation with Craig Adcock, Turrell once recounted a night on which he flew his Helio Courier,<sup>48</sup> accompanied by two acquaintances, over the Pacific near Santa Barbara and made a field landing at a favorite location on Santa Rosa, one of the Channel Islands about 25 miles off the coast. There, they set up camp close to a cliff, built a fire, and made plans for an early morning departure. At around 2:00 AM that morning, Turrell was awoken by the sound of the wind, which had stirred up considerably; his first concern was for the plane, unsecured and vulnerable in those circumstances to being lifted into a pilot-less takeoff. When he climbed into the cockpit, the instrument panel confirmed that the wind was blowing at a speed of fifty miles per hour, well beyond the danger point for such a small aircraft. There was no choice but to stay in the cockpit, manning the controls just to keep the wheels on the ground. Despite his best efforts to maintain alertness—listening to weather reports over the radio, setting an alarm should he fall asleep—Turrell was unable to fight off fatigue; after briefly drifting off, he was jolted awake to find himself airborne in total darkness, further disoriented by the contradictory indications of his flight instruments. Without a single visual referent, he surmised himself, based on the incredible roar heard around him, as aloft at the mercy of high winds. "When I woke up in those horrible circumstances," Turrell recounted, "I had wanted the reality to be the dream, because the actual situation was

so bad."<sup>49</sup> Once the weather died down, he discovered the plane had been lifted alright- but no more than just a few feet off the ground; the sound of the surf below had convinced him he was airborne for an extended time. Looking back on the incident, he reflected that

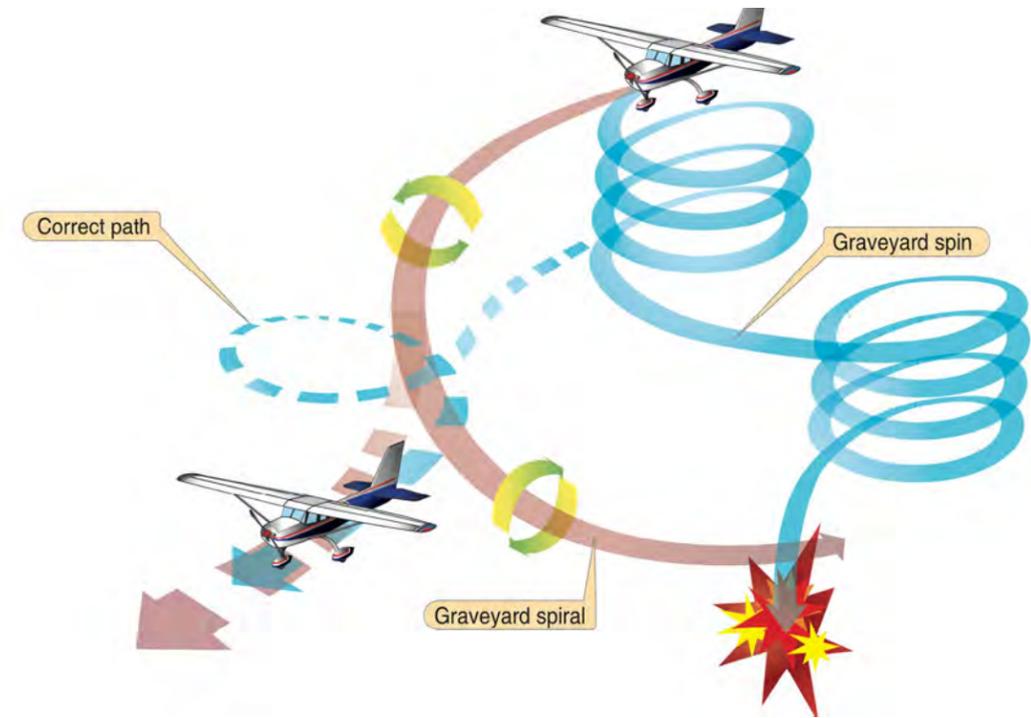
there was something there that was important, and I tried to hang onto it, that place between the awake and the dream state. That special quality of consciousness is what I'm really interested in. It's what I want to get into my art.<sup>50</sup>

Turrell's deep knowledge of aviation history is an indirect inheritance from his father, who had worked in his early years as an aeronautical engineer; after his death, the younger Turrell took on his father's extensive library devoted to aviation history and a collection of flight instruments which he later augmented with his own acquisitions. Adcock notes that, "he was interested in aircraft as components in the overall regime of flying and was equally concerned with such things as the techniques and instrumentation used in early navigation—what could be called "styles" of flight."<sup>51</sup> A pilot since age 16, Turrell later derived a key part of his income by restoring antique airplanes in the years leading up to commercial success through commissions and gallery sales. He also logged a great deal of flight time, particularly as a means of scouting sites on which to construct a more ambitious large-scale work; without this intimate connection to flying, the Roden Crater project is in a certain sense unthinkable. And yet the connection goes deeper than that: in the pages ahead, I will explore the ways in which aero- and astronautics have, both directly and obliquely, informed his art.

At the time Turrell was drawing up initial plans for his Roden Crater project, Vilem Flusser composed an essay in which he posited birds, flight, and freedom as historically determined phenomena forever changed by the advent of aviation and astronautics. Its simple language belies a densely enmeshed set of arguments; Flusser contended that,

We cannot experience their flight as our ancestors did: as an impossible desire.... such a modification of our attitude in relation to birds and to flight (provoked by aviation and astronautics) has a significant effect on our view of the world. We have lost one of the dimensions of the traditional ideal of 'freedom,' and we have lost the concrete aspect of the traditional vision of the 'sublime.'<sup>52</sup>

For Flusser, modern air travel was seen as a banal means of conveyance, forever severed from *the impossible*; "Jet flights from São Paulo to Paris overcome Leonardo's dream," he believed, "but they do not reach the 'freeing' dimension of the myth of flying."<sup>53</sup> Flusser's notion of dimensionality, so important to understanding his broader body of work, can be partially summarized (for how it applies here) as follows: the common understanding of human existence in three-dimensional space is illusory; terrestrially bound, we are, as he described elsewhere, "prisoners of bi-dimensionality."<sup>54</sup> While humans exist in a putatively three-dimensional world,

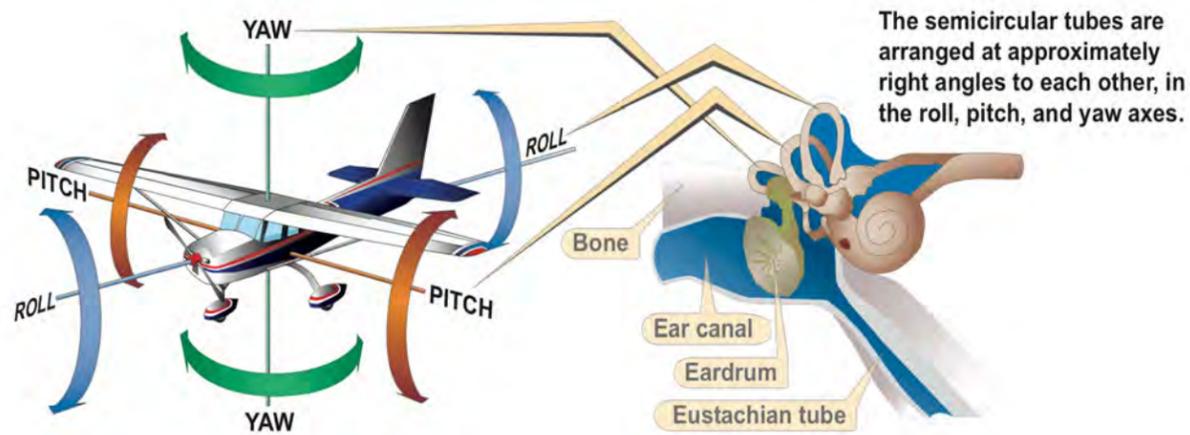


**Instrumental Flying Handbook**

*Graveyard Spiral*; Fig. 3-7 from Instrument Flying Handbook, U.S. Department of Transportation/FAA, 2012. Public Domain

the 'third' dimension is nothing more than a series of epicycles superimposed over a plane.... And the senses, more specifically vision, are organs that collect information that come from the three dimensions over a point on the plane. For terrestrial animals, including man, space is an ocean that bathes the flat island they inhabit.<sup>55</sup>

Flying, so far as humans are concerned, is a profoundly unnatural act. To state this is not to argue against it—futile as that would be—but to merely acknowledge the degree to which we are altered by it- in our dreams and idealism (as Flusser so eloquently emphasized), but just as powerfully, in our bodies and longevity. While Flusser makes it a point to highlight individual traits in the flight of different birds (citing "the hawk, the humming-bird, and the swallow")<sup>56</sup> as a step within his argument, his thesis is otherwise limited by its exclusive focus on jet travel; his perspective, that of the passenger, ignores the airplanes' inherent danger (such as that highlighted in Turrell's anecdote.) To describe flight as a passive, automatist function of contemporary life is to ignore the pilot, vigilant against the aviatational nightmares of *black hole approach*, *spiral dive*, and *graveyard stall*. Flusser's insights shine in the parsing of relationships between human, bird, and angel, and the disruption—both practical and mythic—that aviation brought about. Turrell's work,



### Instrumental Flying Handbook

Angular acceleration and the semicircular tubes. Fig. 3-4 from Instrument Flying Handbook, U.S. Department of Transportation/FAA, 2012. Public Domain

unlike Lucier's, makes little if any explicit reference to animality- nor could we (as Flusser shows) argue for a simple equivalence between airplane and bird. Rather, it is through considering the "styles of flight" practiced by Turrell, the flight instruments he has collected, and the ways they are reflected in his work, that we can speak here of a nonhuman relation.

The proper function of our vestibular system, necessary in maintaining a sense of balance and orientation, consists in humans of the tiny otolithic organs and the semicircular canals, both located in the inner ear. A related system exists in most creatures, though the variability of its functional details and thresholds of motion tolerance stand in a direct relationship to that creature's range of movement. The divergence of aviatic possibility from human biological fact is concretized as a set of technical objects that comprise the gyroscopic system included with the standard flight instruments found on any aircraft; the number and type of instruments are in direct correlation to the particular aircraft in question. Each instrument (*artificial horizon, directional gyro, turn-and-slip indicator*) corresponds both to a single necessary function within the vestibular system and as an indicator of safety thresholds for the proper functioning of the aircraft itself. The ability to fly, having brought upon the body new and violent types of movement, contains within its history a kind of feedback loop in which that violence is partially mitigated by the invention of instruments that could act as real-time warning systems; this symbiosis of aircraft, instrument, and pilot is both crucial and conceptually complex, mediating successful performance of the "unnatural act" of flight.

Clearly, the nature of Turrell's work—or any artist working in a gallery context—is a far cry from eliciting the bodily stress felt in even the most placid of aeronautical experiences. For the pilot, potential encounters with "false sensations" are precisely what the instrument panel is intended to guard against. Turrell understands the risk of dissonance between visual cues and vestibular performance, as well as the contradictory tensions that can take place within visual cognition itself- these would be utilized as a potentiality uniquely his own. These potentials were fully unlocked after meeting Robert

Irwin in 1968- for both artists, a momentous occasion in itself, as well as for the once-in-a-lifetime opportunity that would soon come before them- though eventually—and sadly—between them; nine months into the project, Turrell abruptly withdrew. Although their planned environment was never built, it is worth retracing their process for the insights it provides for his subsequent work.

Maurice Tuchman, the Los Angeles County Museum's curator and initiator of the Art and Technology project, first approached Irwin early in 1968 and, despite the artist's initial misgivings, the two embarked on a series of preliminary discussions; Irwin was determined to use the opportunity to create (unlike many of the other artist-participants) something far beyond a scaled-up version of his then-current work. In August, they toured Lockheed's research center with several other E.A.T.-affiliated artists and support staff. Concurrent with these on-the-record meetings, Irwin was separately engaged in informal conversations with Turrell, who at that point was becoming an active but unofficial contributor to many of the ideas discussed between Irwin and the E.A.T. staff. Irwin's curiosity proceeded from an intuitive engagement of eye and hand, an outgrowth of long, intensive hours in the studio.<sup>57</sup> Turrell's commitment was every bit as obsessive, with a studio practice augmented by his experience as a pilot and his formal studies in perceptual psychology as an undergraduate at Pomona College. Tuchman and members of the E.A.T. support staff were thrilled to see Irwin's engagement with questions—spurred on by Turrell—that artists don't ordinarily ask, perhaps best understood as a presentiment of that asked by Nagel: "what is it like to be an astronaut? As Craig Adcock described it,

*The ability to fly, having brought upon the body new and violent types of movement, contains within its history a kind of feedback loop in which that violence is partially mitigated by the invention of instruments that could act as real-time warning systems.*

"Both Turrell and Irwin were exploring perceptual matters in their own work, and they believed that the research being done by Lockheed's aerospace teams might be relevant to their art. In the weightlessness of outer space, what happened to things like knowing which way is up or down? In an orbiting vehicle or a capsule on its way to the moon, what did the astronauts have to do to maintain an earthlike environment?... They also asked a similar set of questions about vision. How was visual stimulation altered by space flight? In outer space, what was required for maintaining such basic functions as 'attention' and 'orientation'? How was space perceived?"<sup>58</sup>

Later that month, Irwin accompanied physicist Richard Feynman for a tour of IBM's San Jose facilities. Once Irwin's ideas had taken preliminary shape, he proposed a formal collaboration with Turrell. That November, Irwin and Turrell were given a tour of Garrett Aerospace Corporation, and it was there they met Dr. Ed Wortz, head of the Life Sciences laboratory there; the artists found Wortz's research to be remarkably sympathetic with theirs. Wortz's concerns were for the practical challenges to astronauts who were mere months away from their first steps on the moon; the curiosity of Irwin and Turrell was spurred on by a prospective collaborative outcome, but more than that, by a simple desire to know. Wortz referred to their initial meeting as "love at first sight,"<sup>59</sup> and from that point they convened on a regular basis; between the three men, the challenge was not a shortage of questions or ideas, but which were

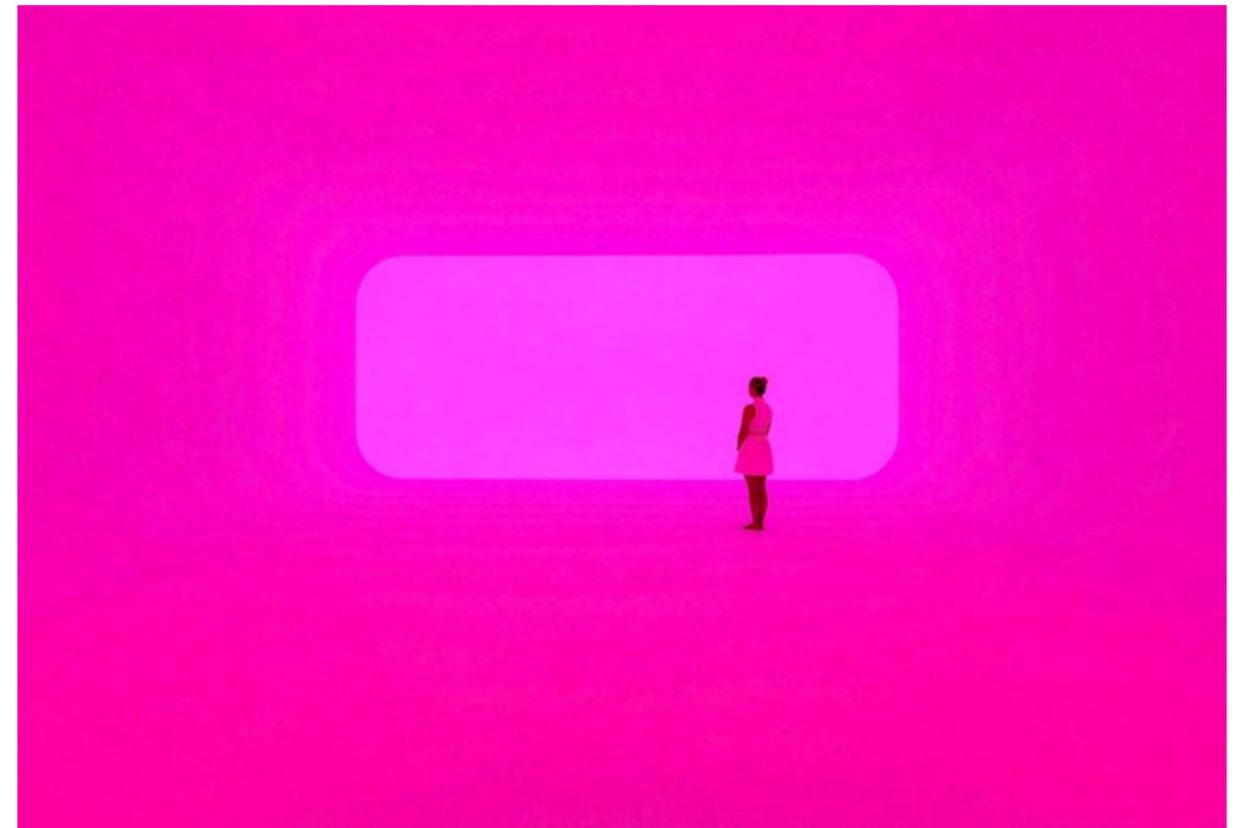
the most important, and how those ideas might take shape. Turrell documented their lengthy discussions and sadly, the highlights published in the E.A.T. catalog remain as amongst the only tangible by-products of their collaboration.

In reviewing the published project outlines presented in more or less weekly increments, we can trace the becomings of core ideas in their early evolution; what began with Irwin's inquiries to Lockheed about materials and techniques of space habitability would take shape over the coming months as the skin of a tripartite structure echoing the stages an astronaut moved from the Earth's environment to that beyond the upper atmosphere. The first part was described as a "queuing area," designed to accommodate two or three people at a time within a calm, sound-dampened interior; described as "museum-like," and its function that of a buffer between the museum's commotion preceding it and the inward encounter that lay ahead. In the notes of February 10, 1969, the word "conditioning" appears in the description; a use of language is also proposed, apparently spoken by attendants trained to

"...program people there using words to produce a thought-idea continuum which would have no literate context. The words can either be presented audibly or visually or combined somehow. They can start off as subliminally presented moving toward conscious presentation."<sup>60</sup>

The middle chamber was named as a space for "sensory deprivation" and later, simply as "anechoic chamber," (avoiding the former's vaguely sinister overtones.) Irwin had been introduced to such a space during his visit to Lockheed, and later the three collaborators found another at UCLA; there, they took turns in up to eight-hour intervals in the darkened soundproof chamber, observing both the effects of the time spent inside, and also amazed with its powerful impact upon sense perception after leaving it. Irwin recounted that, "the world did not look the same; it was very, very noticeably altered."<sup>61</sup> A few subtle light and sound effects were to be introduced just before moving into the third chamber, and these were a major focus of preliminary experiments; aside from them, the sensory stimulus experienced inside the chamber (approximately 12 feet in each direction) would be internally generated, such as the sounds of one's own breathing and circulatory system, or idioretinal images such as those studied by Goethe, Purkinje, and other 19th century physiologists. Turrell often referred to this in a broader sense as "perceiving yourself perceiving," a phrase he returns to again and again when discussing his work, and a state he sees as achievable without an anechoic chamber or related environment. However, this state is reached, it is closely entwined with various types of meditative states, something in which all three collaborators expressed fascination.<sup>62</sup>

An important component uniting the second and third chambers was a reclining chair mounted on a hydraulic lift; when the viewer would first enter the second (anechoic) chamber, s/he would be seated in a reclining position; when the time comes to move into the third chamber located directly above, the lift would be activated as the seat tilts into a full prone position and elevates into the next space. The viewer's supine position and enclosure in such unusual spaces would demand a certain level of trust, even surrender; the



James Turrell

*Virtuality squared, Ganzfeld, 2014, built space, LED lights 800 x 1400 x 1940.5 cm (overall). Collection James Turrell © Turrell*

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*The exhilarating and illusionistic effect of these spaces (and others like it), as Turrell would later learn, comes with its own perils: at a Whitney Museum show in 1980, two viewers filed separate lawsuits against the museum and Turrell for personal injuries suffered in mishaps while viewing his City of Arhirit.*  
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more recent felt necessity for "open MRIs" points to the potentially strong negative response to confinement over an extended time. The collaborative team understood this, though as Turrell later told Alex Bacon in a 2013 interview, "Related to the issue of theatricality is that of submission, which I also don't mind. When you go to the doctor's office, you disrobe, or sit back in a dentist's chair and open wide..."<sup>63</sup> Such limits on mobility recur throughout Turrell's work, raising questions to return to ahead.

This third and final chamber was conceived as a domed, cylindrical space with translucent walls lit from the outside. The light would be modulated, subtly changing color, with pulsating intervals amidst the duration of the individual's time inside the space. To maximize the light modulation's desired effects, the direction from which they originated was obscured- for this, they conceived of a plan to use tracking technology, so these changes were kept behind the viewer at all times. This undifferentiated field of light is referred to within the field of perceptual psychology as a *Ganzfeld*, a particular type of immersive environment that creates a dissolution of spatial boundaries and the feeling of indeterminate depth, without horizon or other planar cues that one is accustomed to in most any

landscape or architectural setting. As a concept, the Ganzfeld was first named (if not also theorized) by Wolfgang Metzger, a Gestalt psychologist working in Germany beginning in the 1930s; Metzger discovered that such environments could induce hypnagogic-like states in many of his test subjects.<sup>64</sup> Later researchers performing EEG monitoring within such environments also discovered a marked increase in alpha brain-wave activity (similar to those sought by Lucier in his *Music for Solo Performer*.)

Prior to his E.A.T. explorations, Irwin had experimented in his studio with a Ganzfeld-like concept with light effects and conventional building materials; dissatisfied with the results, however, he realized through re-approaching the problem with Turrell and Wortz that carefully backlit plexiglas was necessary for such an effect. Turrell's own curiosity about these environments dated back to his undergraduate years studying the work of James J. Gibson and other perceptual psychologists and were concretized in an extended series of works dating from the mid-1970s on through the late-1980s. The exhilarating and illusionistic effect of these spaces (and others like it), as Turrell would later learn, comes with its own perils: at a Whitney Museum show in 1980, two viewers filed separate lawsuits against the museum and Turrell for personal injuries suffered in mishaps while viewing his *City of Arhirit*; one suit charged that the plaintiff "became disoriented and confused," and was "violently precipitated to the floor"; she suffered a broken arm. "I'm accused of creating what was created," Turrell told Grace Glueck at the time; "I'm not responsible for how someone else takes care of his or her sense of bodily awareness."<sup>65</sup> More recently, Turrell reflected that,

It makes for interesting case law. The woman who fell, her testimony was that there was this wall and it didn't support her weight when she leaned on it. But, of course, it wasn't actually there, there never was a wall, it was just an illusion of the light.<sup>66</sup>

A Ganzfeld's disorienting effect hinges on reception of contradictory cues, between vestibular equilibrium—signaling all is well—and a horizonless visual field, suggesting the ground beneath one's feet is no longer there. Against a condition of stability that Herman Schone termed *primary orientation*, this dissolution of features within the surrounding environment resembles the fog a pilot faces during inclement weather- or, conversely, a bird. The same autumn that Turrell, Irwin, and Wortz ended their collaboration, Donald Griffin began research on the navigational ability of birds to fly through zero-visibility cloud cover; in his paper delivered at a 1970 NASA symposium on animal orientation and navigation, Griffin reported that he and his team "could not discern any consistent differences in the straightness of such tracks between overcast and clear nights."<sup>67</sup>

Limits to mobility are common throughout Turrell's oeuvre; sometimes they are subtle, sculptural considerations that limit the viewers' movement to certain areas of the exhibition space, maintaining the work's aesthetic effects. At other times safety considerations are of concern, as was clear following the mishaps at the Whitney. With the E.A.T. proposal and in later pieces, total immobilization acts as functional counterpart to the blindfolded performer in *Vespers*, but with a reversal of its effects: the viewer confronts dis-

orientation head-on, facing out at a void to paradoxically face oneself as a bipedal creature, "prisoner of bi-dimensionality" launched into an animal mobility for which our senses have yet to evolved.

Working on separate but parallel tracks, Alvin Lucier and James Turrell have pursued their common and complementary fascinations, stressing the importance of collaboration with individuals outside their fields. Their relationships with scientists and technical specialists willing to venture outside of standard laboratory exchange—particularly, with Edmond Dewan and Ed Wortz—made necessary the conception of both a "trading zone"<sup>68</sup> in which common interests are identified and worked through, and a "pidgin" to establish provisional language to bridge their disparate discursive frames. The inspiration, too, drawn from the research of Donald Griffin, James J. Gibson, and numerous others, extends beyond the content of particular experiments, embracing methodological approaches otherwise anomalous within the visual and sonic arts. Together, this intersection of artistic and scientific research exemplify what Siegfried Zielinski has referred to as *cultura experimentalis*, a state that expresses

a theory and praxis that is affected by science and technology and that is at least to a certain degree interested in them. When I write about science and its particular capability of experimenting, I have in mind a concept that is porous and curious about the theories and praxes of art. When we engage with the focal point of art, we do not need just any science, but a science that is able to think poetry and poetically. In such a system of coordinates, research could possibly take on the status of a third entity in the true sense of the word: it could be a medium; that is, the processual element that operates between the arts and the sciences.<sup>69</sup>

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## Endnotes

[1] Thomas Nagel, "What is it like to be a bat?" in *Mortal Questions* (Cambridge: Cambridge University Press, 1979), 165-180.

[2] I borrow this term, most commonly found in discussions of technology and cybernetic systems, fully aware of the overtones and attendant problems that emerge when transposed into a biological context.

[3] Nagel, "What is it like to be a bat?", 169.

[4] The fivefold sensory schema initially posited by Democritus was later elaborated by Aristotle.

[5] Burton, Maurice (1973) *The Sixth Sense of Animals*, (New York: Taplinger Publishing), 2.

[6] Schone, Herman (1984) *Spatial Orientation: The Spatial Control of Behavior in Animals and Man*. Translated by Camilla Strausfeld. (Princeton: Princeton University Press), 4.

[7] Griffin, Donald R. (1974) *Listening in the Dark: The Acoustic Orientation of Bats and Men* (New York: Dover Books), 297.

[8] Kim-Cohen, (2009) *In the Blink of an Ear: Towards a Non-Cochlear Sonic Art*, (New York: Continuum Books), 187.

[9] Alvin Lucier, (2005) *Reflections: Interviews, Scores, Writings 1965-1994* (Cologne: Edition MusikTexte), 30.

[10] Douglas Kahn includes an excellent account of their collaboration in his (2013) *Earth Sound Earth Signal* (Berkeley: University of California Press), 83-92.

[11] Lucier, *Reflections*, 32.

[12] Quoted in Kahn, *Earth Sound Earth Signal*, 99. Mumma, along with Lucier, Robert Ashley, and David Behrman, had together formed the Sonic Arts Union in 1966 as a kindred group of composers sharing labor and material resources.

[13] Nyman, (1974) *Experimental Music: Cage and Beyond* (New York: Schirmer Books), 14.

[14] Michel Chion defines the *acousmatic* as "Pertaining to sound one hears without seeing its source." In (1994) *Audio-Vision: Sound on Screen* (Translated and edited by Claudia Gorbman. New York: Columbia University Press), 221.

[15] Lucier, (2010) *Music 109: Notes on Experimental Music* (Middletown: Wesleyan University Press), 85.

[16] De Waal, (2017) *Are We Smart Enough to Know How Smart Animals Are?* (New York: W.W. Norton & Co.), 11.

[17] Helmreich, Stefan (2016) *Sounding the Limits of Life: Essays on the Anthropology of Biology and Beyond* (Princeton: Princeton University Press), x-xi.

[18] Wiener, Norbert (1954) *The Human Use of Human Beings: Cybernetics and Society* (New York: Houghton Mifflin & Co.), esp. Chapter 9, 137-162.

[19] It should be noted that Griffin’s discoveries were preceded by research conducted by Lazzaro Spallanzani, a noted 18th century Italian biologist who conducted an intensive series of experiments concluding that bats relied on their hearing for obstacle avoidance in flight; due to inaudibility of the bat’s vocalizations, however, his published findings were met with widespread skepticism by scientists unable to comprehend the possibility of such invisible, non-proximate forces. General consensus amongst scientists at the time (most notably, Charles Cuvier) ultimately rejected Spallanzani’s theory, and his bat research was soon largely forgotten. Griffin’s (1974) *Listening in the Dark: The Acoustic Orientation of Bats and Men* (Second Edition- New York: Dover Books), particularly Chapter 3, stands as a remarkable work of historical epistemology regarding Spallanzani and other subsequent research on this topic.

[20] George W. Pierce, *The Songs of Insects* (Cambridge: Harvard University Press, 1948), 8.

[21] Sterne, (2003) *The Audible Past: Cultural Origins of Sound Reproduction* (Durham: Duke University Press), 11.

[22] Not surprisingly, the responsiveness and portability of such technology has improved greatly, and the cost of bat detectors is low enough that they are now readily available on the consumer electronics market.

[23] Lucier, *Music 109*, 86.

[24] Lucier, *Reflections*, 78.

[25] Griffin, *Listening in the Dark*, 299-303.

[26] Lucier, *Music 109*, 85-86.

[27] Ibid, *109*, 87.

[28] Lucier, *Reflections*, 304.

[29] Ibid, 304.

[30] Caroline Jones, “Senses”, in (2010) *Critical Terms for Media Studies*, W.J.T. Mitchell and Mark B.N. Hansen, eds. (Chicago: University of Chicago Press), 88-90.

[31] Lucier, *Reflections*, 306.

[32] Jones, “Senses”, 88.

[33] Hilary Putnam, Daniel Dennett, Donald Davidson, and Saul Kripke are among those he names. Nagel, “What is it like to be a bat?”, 165.

[34] Nagel, “What is it like to be a bat?”, 166.

[35] Kahn, *Earth Sound Earth Signal*, 98.

[36] Lucier, *Reflections*, 74.

[37] Lucier, *Music 109*, 87.

[38] I refer here to the six-fold schema of Roman Jakobson, which was in turn derived from the Organon model of Karl Ludwig Buhler.

[39] To listen from outside this closed circuit—to intercept a signal—is to raise crucial questions as to the nature of both the signal itself, and the relationship between that circuit and what is outside and excluded from it. In his *Hermes II*, and later, with greater elaboration, in *The Parasite*, Michel Serres emended information theory’s fundamental communicative dyad by introducing a third term: the *parasite*, multivalent in its play on meanings particular to the French language, refers to both *noise* and, more commonly, a being or function deriving its existence at its host’s expense. For Serres, noise is not merely a gratuitous remainder but instead, a structurally integral component for any communicative act; the challenge then becomes that of identifying the “excluded third.” Serres shows that the identity of noise is never fixed but rather, determined relationally.

[40] Barthes, Roland (1977) “Musica Practica”, in *Image/Music/Text*, trans. Stephen Heath (London: Fontana Press), 149.

[41] Toop, David (1995) *Ocean of Sound: Ocean of Sound: Aether Talk, Ambient Sound and Imaginary Worlds* (London: Serpent’s Tail), 248.

[42] Szendy, Peter (2017) *All Ears: The Aesthetics of Espionage*, trans. Roland Vegso (New York: Fordham University Press), 23.

[43] Nicolas Collins, “Epiphanies,” *The Wire*, Issue 310 (February 2010): 98.

[44] Nietzsche, Friedrich (1997) *Daybreak*. Maudemarie Clark and Brian Leiter, eds. Translated by R.J. Hollingdale (Cambridge: Cambridge University Press), 253.

[45] “James Turrell by Michael Govan,” Penguin Random House, accessed November 8, 2018, <https://www.penguinrandomhouse.com/books/570928/james-turrell-by-michael-govan/9783791352633/>.

[46] To cite just two examples, see: Andrew Frost, “James Turrell: A Retrospective review – light and

colour reach for the sublime,” *The Guardian*, December 15, 2014, <https://www.theguardian.com/artanddesign/2014/dec/15/james-turrell-retrospective-review-light-and-colour-reach-for-the-sublime>; also, Colin Herd, “Perceptions of Light, James Turrell,” *Aesthetica Magazine*, November 17, 2014, <http://www.aestheticamagazine.com/perceptions-light-james-turrell-aesthetica-magazine>.

[47] Burke, Edmund (1990) *A Philosophical Enquiry Into the Origin of Our Ideas of the Sublime and the Beautiful* (Oxford: Oxford University Press), 137.

[48] A light utility aircraft first introduced into limited production in 1949, the cantilever high-wing design of the Helio Courier is distinctive for its ability to take off and land within tightly constrained settings such as the one Turrell describes; classed as a “bush/utility/sport-utility aircraft”, the manufacturer’s website boasts that “[i]f it had claws, it could land on a fencepost.” “Our Planes,” Helio Aircraft, accessed November 8, 2018, [http://www.helioaircraft.com/ourplanes\\_courier.htm](http://www.helioaircraft.com/ourplanes_courier.htm)

[49] Adcock, Craig (1990) *James Turrell: The Art of Light and Space* (Berkeley: University of California Press), xxiii.

[50] Though space constraints prevent us from including the incident in its entirety, Turrell’s full account of it is truly remarkable; see Adcock, *James Turrell: The Art of Light and Space*, xx-xxiii.

[51] Adcock, *James Turrell: The Art of Light and Space*, 3.

[52] Flusser, Vilem (2013) “Birds,” in *Natural: Mind*, trans. Rodrigo Maltez Novaes; ed. Siegfried Zielinski (Minneapolis: Univocal Press), 21.

[53] Flusser, “Birds,” 27.

[54] Ibid, 24-25.

[55] Ibid, 26.

[56] Ibid, 22.

[57] See Lawrence Weschler’s book on Irwin, *Seeing is Forgetting the Name of the Thing One Sees* (Berkeley: University of California Press, 1990), undoubtedly one of the best extended profiles ever written on an individual artist.

[58] Adcock, *James Turrell: The Art of Light and Space*, 62-63.

[59] Weschler, *Seeing is Forgetting the Name of the Thing One Sees*, 130.

[60] Ibid, 132.

[61] Ibid, 133.

[62] Ibid, 130-135.

[63] James Turrell, “James Turrell with Alex Bacon,” *The Brooklyn Rail*, September 2013, <https://brooklynrail.org/2013/09/art/james-turrell-with-alex-bacon>.

[64] Jiri Wackermann, Peter Putz, and Carsten Allefeld, “Ganzfeld-induced hallucinatory experience, its phenomenology and cerebral electrophysiology,” *Cortex* 44 (2008): 1364-1378.

[65] Grace Glueck, “Whitney Museum Sued Over 1980 ‘Light Show’,” *New York Times*, May 4, 1982, <https://www.nytimes.com/1982/05/04/arts/whitney-museum-sued-over-1980-light-show.html>.

[66] James Turrell, “James Turrell with Alex Bacon.”

[67] Donald R. Griffin, “Nocturnal Bird Migration in Opaque Clouds” in *Animal Orientation and Navigation*, ed. Sidney R. Galler, et al, (Science and Technical Information Office, NASA. Washington: 1972), 174.

[68] Galison, Peter (2010) “Trading With the Enemy.” In *Trading Zones and Interactional Expertise*, ed. Michael E. Gorman (Cambridge: MIT Press), 25-52.

[69] Zielinski, (2006) *Deep Time of the Media: Toward an Archaeology of Hearing and Seeing by Technical Means*, Trans. Gloria Custance (Cambridge: MIT Press), 162-163.

**Jim Supanick** is a videomaker and writer, born in Cleveland, OH and currently living in Brooklyn. He is currently at work on a dissertation about the laboratory and field investigations of nonhuman animal sensoria. His moving image work has been exhibited internationally, and his essays have appeared in *Film Comment*, *Millennium Film Journal*, *The Wire*, *Cineaste*, and *The Brooklyn Rail*, along with exhibition catalogs and DVD releases. He is the recipient of a Creative Capital Arts Writers Grant, NYSCA Media Production Grant, and a NYFA Grant for Nonfiction Literature. Jim is also a member of Synthumpers, a quasi-musical collaboration with Josh Solondz. He is an Advisory Board Member for UnionDocs, and currently teaches at City College of New York.



**Melissa Dubbin & Aaron S. Davidson**

*Vowels*, 2018 detail, Lodestones (magnetite), 113,904 ferrite core memory toroids, 35.56 x 30.48 x 15.24 cm / 14 x 12 x 6 inches. Courtesy of the artists © Dubbin/Davidson

## Metals Have Memory

*Recent works by artists Melissa Dubbin and Aaron S. Davidson engage computing, geology and methods of forming sound. Here they present some thoughts related to their inquiries into stones, metals and data infrastructures. Their experiments into recording sound with gemstones led them to geologist Violaine Sautter, with whom they collaborated on Making a Record (Diamond, Ruby, Sapphire, Emerald) (2009-2014) and Eclogitisation, or the strong process of amnesia (2016). Sautter's work continues to be a source of inspiration to their projects and their way of approaching the act of collaboration.*

text and images by **Melissa Dubbin & Aaron S. Davidson**

**M**etals have memory — they are a container for images, stresses, and bits. The repetitive flex of a wire is memory moving towards failure, a back and forth motion initiating a breakage, a splitting and halving simultaneously engineered against and for, dreaded and exploited.

The memory of metals is contained in the shape of a death mask and in the magnetic-core memory planes of a Cold War computer. Bits woven into Jacquard's successor as a matrix of stored north and south magnetic positions. Magnetic-core memory was designed to store magnetic states, to string bits into a byte, bytes into nybbles and nybbles into computational words. A process of accretion, manipulation and dissolution: computing as miniaturized polar expedition. A negotiation between the desires contained in the North and South Pole expeditions of Roald Amundsen, the shifting location of the magnetic pole and the non-dipole nature of the Earth's magnetic fields. The Earth as ferrite toroid with the computational storage of one static bit.

An ocean of liquid metal surrounds the solid metal core at the center of the earth. Earth's core is responsible for the generation of its magnetic field, an invisible force critical to maintaining the atmosphere to support life. In *Core (1 and 2)* (2017) stones exhibiting remanence, or the record of the Earth's magnetic field, simultaneously attract and corrupt thousands of bits of information previously stored on iron toroids used in early computer memory; both are fossils of things we cannot see.

The study of the deep Earth interior is a study of ourselves. The stones have made the journey to the center of the Earth on our behalf. We share attributes with stones, metals, water and phenomenological forces which emanate from the interior. Metals mined as ores surface containing the story of their origins. Geologists translate this language of stones, constructing narratives where economically important minerals play protagonists, antagonists and minor roles; fragments of dust transformed into a library of consonants and vowels. Like the tectonic plates, over time these stories shift, and new volumes are written. In the Anthropocene, storytelling implies that matter itself becomes an agent, your body a collection of extraordinary material stories.

A vowel is a component of language systems, a sound produced with no constriction in the vocal tract. Vowel-sounds can be described as frictionless continuous tones. When we learn to read there is a moment in which we understand letters as symbols for sounds. For *Vowels* (2018) we took count of all the vowels used in the text *Figure Out* (2018) by psychoanalysts Jamieson Webster and Marcus Coelen and extracted them. The number of toroids (113,904) used in *Vowels* refers to the amount of storage space needed to record these letters, an equivalent to the storage capacity of early computer memory materials, ferrite toroids. In *Woven Word* 32 bits of core memory store the abbreviated name of the exhibition. One toroid = 1 bit. A magnetic lodestone moves across the circuitry, corrupting the data stored in core memory causing the variations in sound and making audible the disruption of the magnetic fields. In *Pantograph*, iron now pulverized into dust is played with by a small robotic arm whose movements have been choreographed by a child. The child and robot draw together repeating an abstract form.

The deepest mineral found on Earth is diamond. While pure diamond might be valued by a gem collector, a geologist treasures the diamond containing inclusions — fragments of other minerals held within its structure which tell her when and where it came from. As carbon-based life-forms we have the potential to become diamond, eventually making the journey to the center of the Earth.



**Melissa Dubbin & Aaron S. Davidson**

*Core (1)*, 2017

Lodestone (magnetite), 40,000 ferrite core memory toroids, 20 x 13 x 12 cm / 7.8 x 5.1 x 4.75 in. Courtesy of the artists

© Dubbin/Davidson

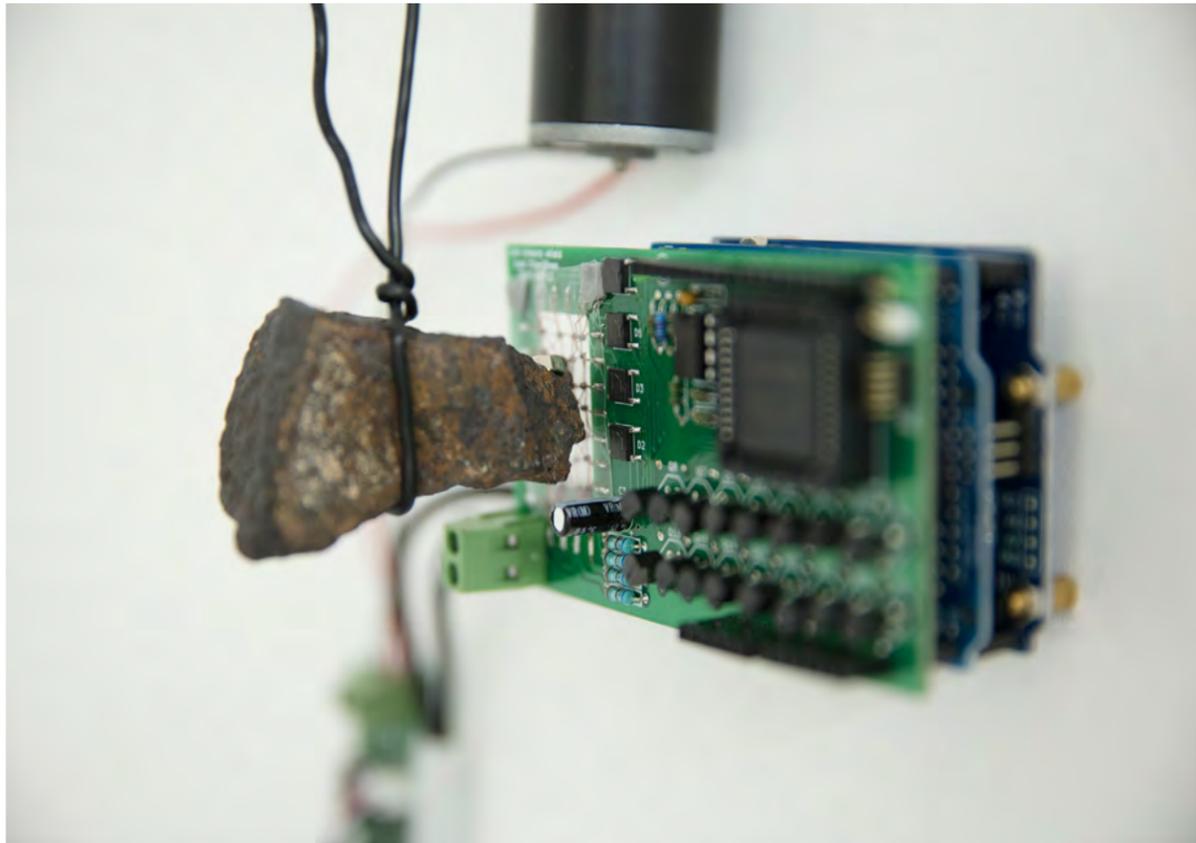


**Melissa Dubbin & Aaron S. Davidson**

*Core (2), 2017 Detail*

Lodestone (magnetite), 80,000 ferrite core memory toroids  
14 x 14 x 17 cm / 5.5 x 5.5 x 6.7 in. Courtesy of the artists

© Dubbin/Davidson



**Melissa Dubbin & Aaron S. Davidson**

*Woven word (Six Degrees of Freedom /6DOF), 2017* (above)

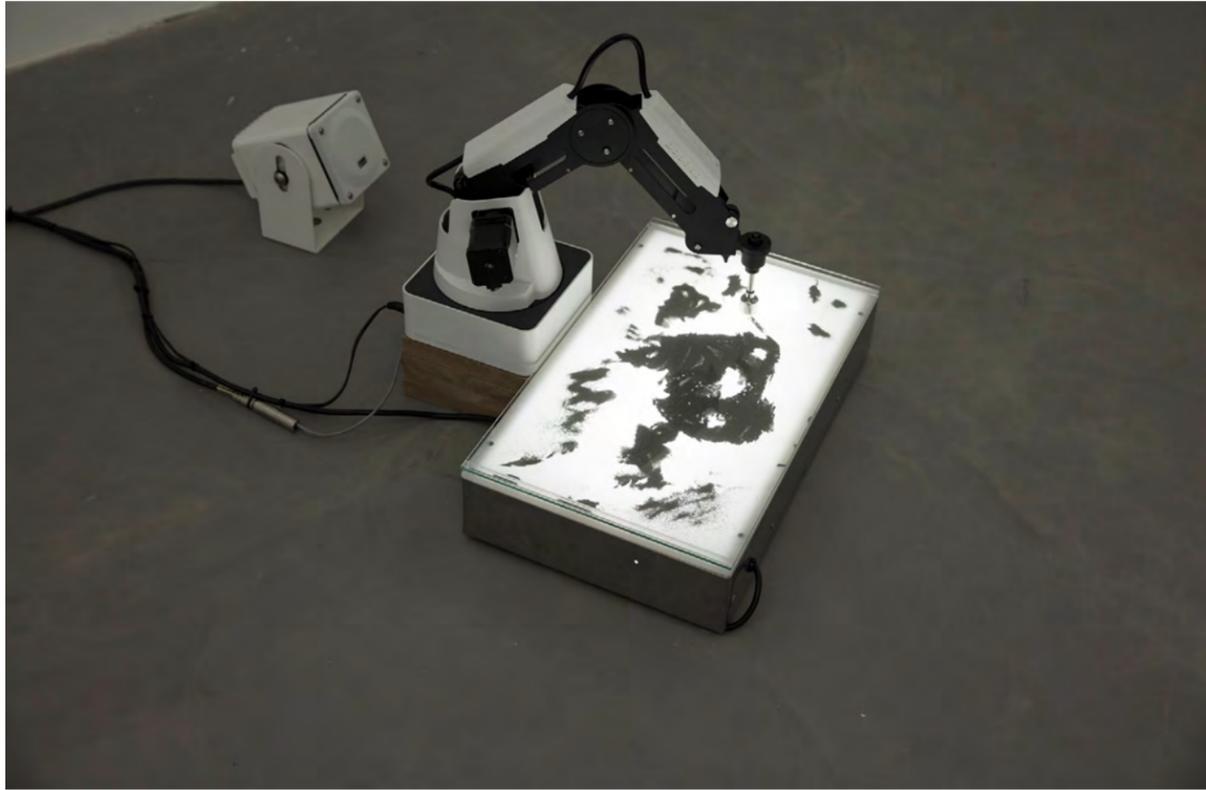
detail, (left) full view

Core memory shield by Jussi Kilpeläinen, arduino controller and code, tone library, piezo speaker shield, lodestone, motor, plastic, metal hardware, electricity.

30 x 36 x 10 cm / 11.8 x 14 x 3.9 in

Courtesy of the artists © Dubbin/Davidson





**Melissa Dubbin & Aaron S. Davidson**

*Pantograph*, 2017. Robotic arm choreographed by child's drawing, light box, glass, iron filings, magnet, contact microphone, amplifier, speaker, cables, electricity. 48 x 54 x 50 cm / 18.9 x 21.25 x 19.6 cm Courtesy of the artists. Photography: Ana Drittanti © Dubbin/Davidson



**Melissa Dubbin and Aaron S. Davidson** are artists based in Brooklyn, New York. Their work has been described as addressing "processes of transmission and reception, interference and transference" often seeking to materialize immaterial or ephemeral states of matter (sound, light, air, time). Together they have co-authored a body of works producing forms, objects, images and experiences incorporating the mediums of photography, video, sound, performance, sculpture and artists books. Recent solo exhibitions include *Six Degrees of Freedom* at Untilkthen, Paris (2017), *Poétique des sciences*, Le Fresnoy, Tourcoing, France (2017). In 2016 they were awarded the inaugural residency in the Pinault Collection artist residency program in France. Their work will be featured in the upcoming 2019 Okayama Art Summit in Japan.

# But you didn't come here to tell "stories"! (Yes, actually, I Did)

An artist reflects on research-based practice, the conception of a special committee Ph.D. in Interdisciplinary Arts and Science at the University of Wisconsin-Madison, and the privileges of working, learning and teaching at the intersections of disciplines.

text and images by **Helen J. Bullard**

***T**here is a person in this room who has decided to dedicate a significant chunk of their life to better understand the horseshoe crab. You might want to find out why.*

– William Cronon  
Eminent Environmental Historian, best Storyteller I ever met.

I was thrown a bone by Bill that day. And during the following week, I was more consistently asked about horseshoe crabs than ever before. But I don't recall anyone asking me *why*. It's just as well, because I think that question was mainly for me.

Three years earlier, I was standing in Rensselaer Polytechnic Institute (RPI) in Troy, New York. "Ah, yes," said a Dean, with a rolling laugh, "but, you didn't come here to tell 'stories!'" And I surprised myself with perhaps the frankest answer of my life: "Yes, actually, I did!"

At universities, we get used to justifying our research, our jobs, our funding. But I admire anyone who can answer these questions not only with literature reviews, statistics and compelling stories about "the problem," but also with the truth. Why are *you* choosing to do *this*? The honest answer I think is: because I know that no one else can do it quite like me. And I can't tell you it will make any difference at all, but I'm giving it everything I have. That is what I'm willing (and immensely lucky enough) to risk.

I always loved crabs. I didn't know that the horseshoe crab wasn't a true crab, but by the time I did I'd already fallen in love. The first living horseshoe crab I ever saw was a sad specimen in a museum in England. But the next several thousand were on the shores of the Delaware Bay, spawning in the high tides of the new moon at midnight. I still haven't fully processed that experience, even though it's one I've now attempted to replicate many times. The gushing waves, foam-tipped and certain. The soft knocking of carapaces, glittering in the black water and moonlight. The smell of salt. Persistent crabs, gathering around me, mistaking my booted feet for mates. It felt like a weighted blanket. It looked like the edge of the earth. There was such stillness. Such deep introspection. And for the crabs? There was an urgency that swelled in their silence. And that's when I fell in love, all over again. And every time since.

I'm a storyteller, and for the last five years (or seven, or maybe even 39), I've been learning about horseshoe crabs through

everything I've encountered. Through crayfish and birds-nests and deciduous trees. Through salt, and strata, and gold mines in the desert. Through sand in my hands and under my feet. The markers of time, the pendulums of life: mine, and everything else in the universe. And, during my doctoral years, those lessons have also come from labs and libraries, lecture halls and fieldwork. I have learned, in animated conversations and the records of human reflection, entomology, medicine, environmental history and the history of science, limnology, genetics, art history and ethics. We are all storytellers. I firmly believe that. And the key to finding your most powerful voice (where passion is already a given), is your medium. And by "medium" I don't mean your discipline. I mean your form.

My Ph.D. is in Interdisciplinary Arts and Science, with a certificate in Environmental History and the History of Science. And, I'm about to graduate. The University of Wisconsin-Madison had faith, from the beginning, that my Special Committee Degree was worth forming. There are no other programs quite like the one I was proposing. My committee is composed of two artists, two historians of science, and a medical entomologist. But that does little to explain these people or the project. Ph.D.s in the Arts, as anyone in the field knows, are fraught with contention. While they are now considered the terminal degree in much of Europe and Australia, the MFA is still enough to teach throughout much of the US. But getting a degree was never my reason for embarking upon it. I wanted to become a better thinker, a better researcher, a better teacher. A person, better equipped in our fractured world, to make any kind of positive difference at all.

I'm employing a Context Model for my doctoral work, which allows me not only to ask questions (as with the more traditional Research Question Model), and to reflect upon on my own work and that of others (as with a Commentary Model), but also to focus deeply on the various landscapes of horseshoe crab work, scattered across a multitude of disciplinary fields, and to sculpt all that I have learned into a new environment. A new conversation. And ultimately, a new polyvocal story. The aim is to ask more questions than I answer. To funnel outwards, rather than inwards. As Thom Van Dooren suggests, stories "hold open simultaneously a range of points of view, interpretations, temporalities, and possibilities," and that is exactly what those that I work with do best. They are extraordinary storytellers. The approach I have taken to my degree is absolutely fundamental, and a huge privilege. During the course of the last few years, I have taken classes in Entomology, Environmental Studies, Genetics, and the History of Natural History and Medicine. I have worked with scholars of ethics, performative theatre, environmental humanities, animal studies, model animals in medicine, and resilience. And, I have worked with those committed to hands-on change on the ground: the conservation workers, field researchers and volunteers using their own hands, words and money to better protect horseshoe crabs and the environments they depend upon so much.

Ultimately, the model of my Ph.D. challenges some long-standing institutional conceptions of what "doing" might be at the doctoral level (in the Arts, or otherwise), and what "doing" might be for. While I am working at the intersections of artistic and scientific knowledge, I expect my work to be primarily judged by the standards of the arts and humanities worlds, albeit with scientific scrutiny. That comes with its own problems because of conflicting

models, and existing anomalies within the Arts. I am by no means the first artist to confront these challenges. But despite a growing pool of methodological precedents for Ph.D.s in the Arts, most of us are still seen as "unconventional." For the most part the "doing" of a Ph.D. in any field (and often this "doing" is expected to turn around "the dissertation") is imagined as the precursor to publication, and a demonstration of ability to handle the academic rigors of "the field," often with the expectation of a book project or a series of articles. The Arts are anomalous because professional publication often doesn't translate to writing at all. While some artists certainly work in that way, it's more usual for standards of rigor, scholarship and knowledge to be demonstrated through creative work, peer-reviewed during public dissemination, where audience response is a part of the assessment itself. And yet, in most cases the expectation is still for a traditionally written dissertation (or at a minimum, an exegesis), in addition to a "Ph.D. Show," echoing what Milech and Schilo characterized in 2004 as "Solomonic" Ph.D.s: that the body of creative work as research is accompanied by an entirely separate traditional dissertation that does "not indicate how the baby might live as a whole." In most cases, both are judged to the highest rigorous standards, and usually concurrently completed. There is nothing wrong with this approach, so long as it reflects a careful intention, rather than a simple, ill-suited, expectation.

This has been the basis of exploratory and energized discussions with my committee over the course of the last few years. As Rob Nixon writes, stories matter, and the way in which they're told "can have profound imaginative, ethical, and political consequences." That's why I think form matters. My dissertation work is in two parts: 50% filmstory, 50% written (primarily in creative non-fiction form). It tells the story of horseshoe crabs through a deep and tumultuous past, through industrial use for fertilizer, for bait and medicine, and it questions a delicate and uncertain future. And throughout it all, there is a level of metanarrative that allows for literary analysis and methodological reflection. These kinds of works are important because they offer the opportunity not only for clean, well-crafted arguments, but also for those who engage the works to finish the answers for themselves; to pose their own new questions, to scratch their intellectual-and their most humanistic-itches.

"Wouldn't it be better to *do something*, instead of 'telling stories?'" asked a relative recently, whom I hadn't seen in twenty years. And in a strange way, his words liberated me. It was a redundant question, because everything we do is a form of storytelling. And while this way of understanding "doing" doesn't always reflect more traditional conceptions of achieving academic resolution, I think it's become a common experience to want (to need) to express a more resolved kind of complication through stories, in whichever form makes most sense. In my case, through live performance, writing, filmstory, hands-on fieldwork, public-facing talks, and teaching-possibly my greatest privilege. Perhaps, more than ever before, we need partnership and a flattening of the edges. We need affective stories, equipped with the tools to activate change and hope.

I grew up in the UK, so horseshoe crabs were physically absent from the first thirty-two years of my life. But they might still be my earliest project. Perhaps, this story started with the armored sea life in the rock pools of my childhood. But they are also my current project. And it's not done yet-of course-is it ever?

.....  
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instead of 'telling stories?'" asked a  
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.....

## Excerpt

These days when people ask me why, I don't know which story to start. I have tended to tell the short version: I was part of an art-science residency with a medical twist, and shortly thereafter was asked to make some work in response to a museum collection. It was there that I encountered my first horseshoe crab. But there's a much more honest version. A much longer story. I suppose, all good stories have multiple beginnings.

*In the beginning (my beginning),  
there was Cornwall  
and crabs and crayfish.*

*There were footsteps,  
running in the night—  
the staccato thump  
of blue lights in silence.  
And I would scramble to my feet  
as dad's siren screamed down "the bypass."*

*I wonder if he knew  
I was awake the whole time  
—every time—  
rooting for him.  
Rooting for the people he was saving.*

*In the beginning,  
there was patience.  
For the bread dough proving in the kitchen,  
for the seedlings,  
bedded in with fish blood and bone.*

*... if anyone was watching (which, they were not),  
they would have seen a small figure in the sky  
above that harbor with the seagulls,  
sitting atop a giant layer cake  
(more layers in those cliffs than I could possibly count).*

*From the hot rocks  
where standing still for too long burned my feet,  
I could see the offing.  
The Offing: that part of the ocean beyond the shore,  
beyond the shallows, beyond the dangers of running aground.  
That dark, mysterious belly of the sea that hung  
this side of the horizon but that side of the sand bars.*

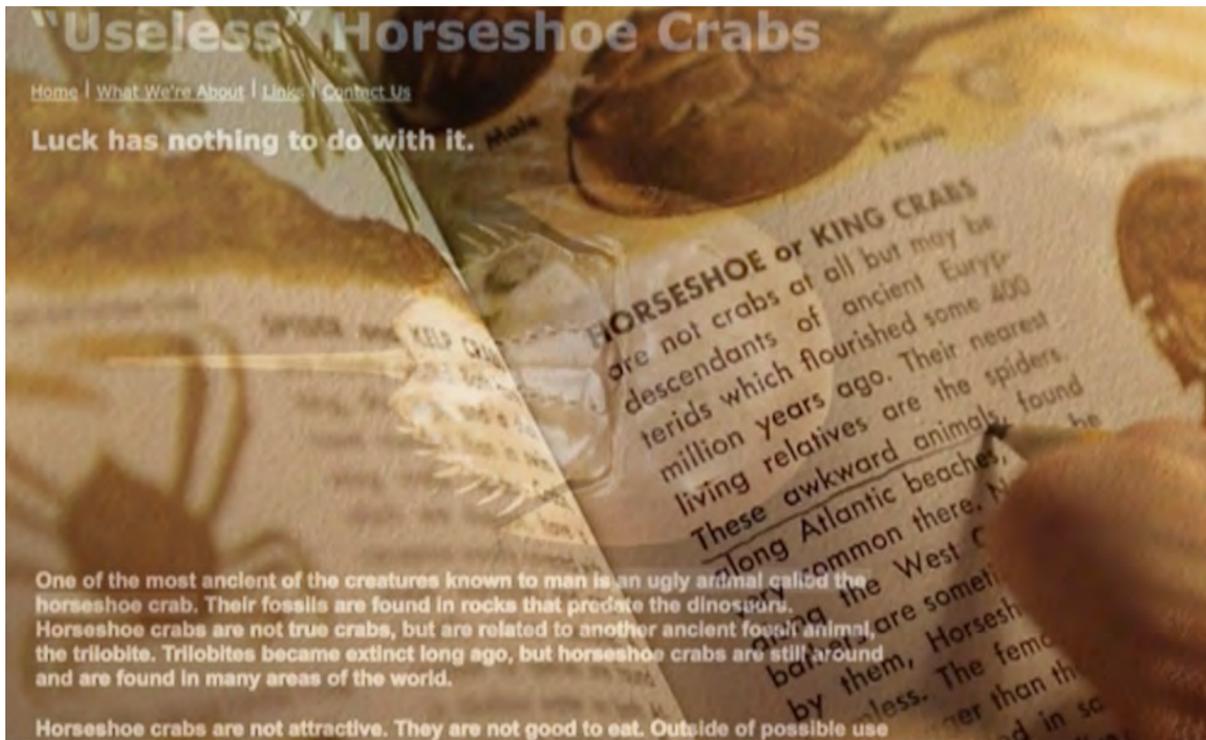
*... illusive,  
mysterious as the sea slaters,  
soft-bodied but plated,  
like little trilobites.*

*In the beginning,  
there was still time—  
we were going to Heal the World.*

*... if I could turn fast enough,  
I thought,  
I could catch that fleeting place  
(the one that's partly land and partly sea,  
partly calm and partly terror,  
partly death, but mostly always summer),  
and make it tangible forever.*

*Perhaps, I thought, it was visible only to me  
... one day, I will share it.  
One day, I will know the other creatures  
where the land flip-flops with the sea.*



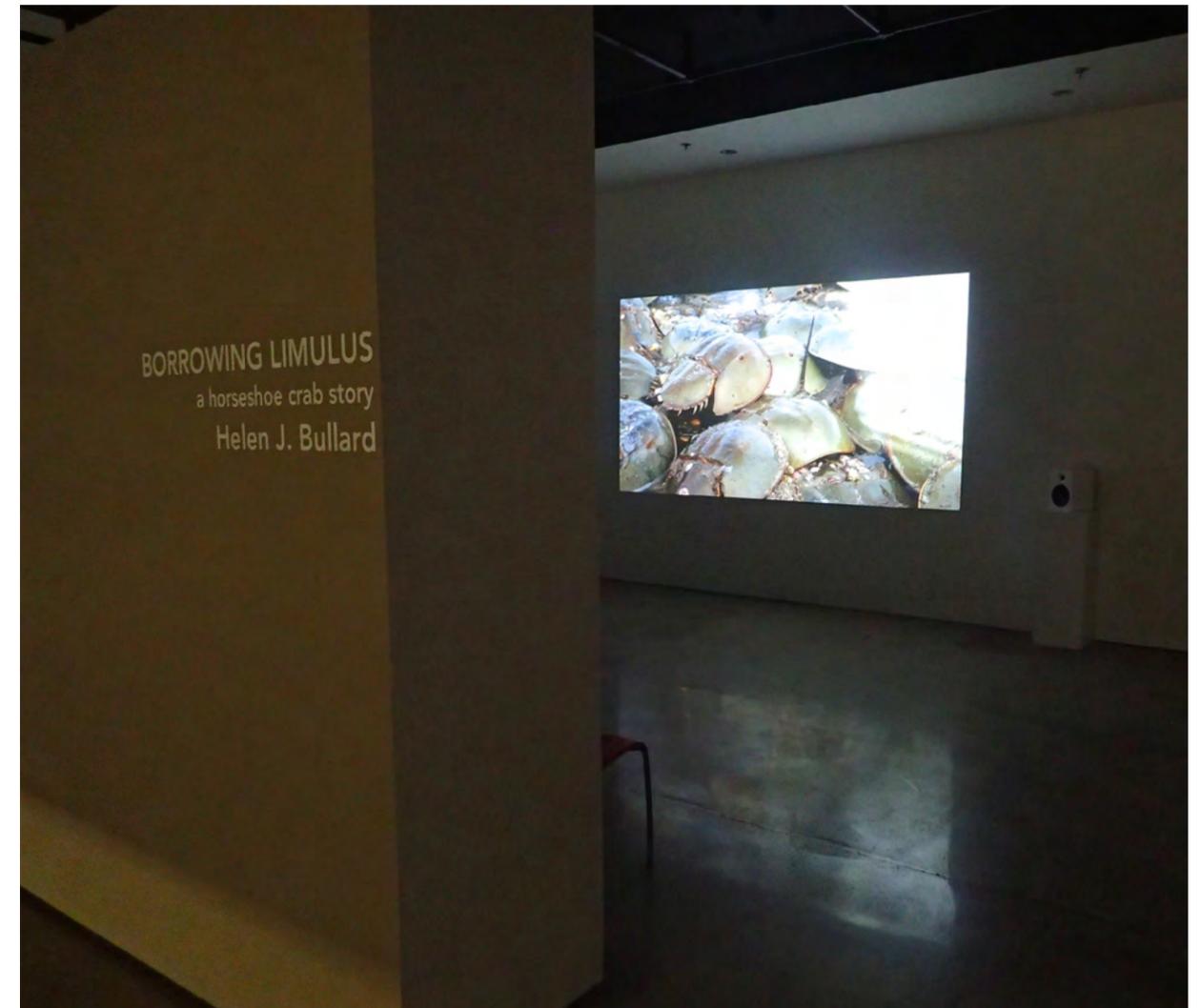


Helen J. Bullard

p. 105, top: Spawning horseshoe crabs, 2018; bottom: Rare Books Room, Marine Biological Laboratory Library, Woods Hole Massachusetts, 2015,

This page, top: Green Eggs & Sand, Teachers on the Estuary, DNREC Delaware, 2018; bottom: Borrowing limulus (film still), 2018.

All images © Helen J. Bullard



Helen J. Bullard

Borrowing limulus (installation shot), 2018 © Helen J. Bullard

Helen J. Bullard is a Research-based Storyteller, Educator, and Ph.D. Candidate about to graduate in Interdisciplinary Arts and Science from the University of Wisconsin-Madison, with a certificate in Environmental History, and the History of Science. She is also a Fellow of the Graduate School, the School of Education, and the Division of the Arts, and a Graduate Associate of the Center for Culture, History and Environment (CHE) in the Nelson Institute for Environmental Studies. Her work has been shown on five continents, and published in Europe and America. Previous teaching has included Art History and Contemporary Arts Practice, Biological Arts, Research Practice, Creativity and IT, Deep Listening, Listening to Animals, and Digital Film.

# Cooking Sex: Products and Porous Bodies

*Food connects us to our environment, our planet, our home. Quite simply - we are part of an environment and it is a part of us. The tale of food is a mirror reflecting back to us what we are and what we are becoming. Throughout history, culture has assigned gendered attributes and roles to food. Many foods also contain xenohormones that can alter sex hormone expression in humans, with a variety of outcomes. These xenohormones can be naturally occurring or the result of agricultural and industrial processes. In this interview, Byron Rich and Liz Flyntz, the collaborative artist duo responsible for Epicurean Endocrinology, discuss food, gender, sex, product design, environmental degradation, and communicating scientific knowledge to non-professional audiences.*

Interviewees: **Liz Flyntz and Byron Rich**

Interviewer: **Marnie Benney**

Since 2017 Byron Rich and Liz Flyntz have been working together on *Epicurean Endocrinology*, a project that uses cooking as a medium, citizen bio-science as a performance, and product design as activism.

*Epicurean Endocrinology* is concerned with how food is gendered and how it is sexed. Historically, food has taken on gendered attributes in its production, presentation, and consumption. In many cultural contexts, certain foods are associated with masculinity and virility or femininity and fecundity. These constellations of meanings function differently within specific spiritual and healing traditions. In the western capitalist tradition of food-as-product, foods are marketed to men (Burger King, Doritos) and women (salad, yogurt) with aspirational messages, promising to help consumers attain their culture's gender ideals.

While corporations honed this marketing strategy in the twentieth century, many new chemicals with hormone-mimicking properties wound up in the industrial food supply -- chemicals which endocrinologists now understand can alter sex-linked physical characteristics and reproduction on an ecosystem scale. Ironically, the gendered symbolism of food products and the sexual valence of their chemical contents often do not align, failing on a level that few consumers would notice to uphold the normative promises of commercial imagery. When the public does discover such disjoints, it's often the occasion for conservative outrage about the "unnaturalness" of modern life. *Epicurean Endocrinology* proposes that prying open the gap between consumer symbolism and the workings of our industrial food system is critical and empowering.

*Epicurean Endocrinology* encompasses a number of projects, presentations, and writing about food, gender, sex, ecology, and hormones. Past endeavors include phytohormone infused *Masculinizing and Feminizing Meals*, which presented meals containing as many plants and animal food-based estrogens and androgens as possible. *Down-Home Molecular Gastronomy* uses mutated tropes of haute-cuisine to investigate the intersections of class and the perception of food as entertainment or commodity.

.....  
*Epicurean Endocrinology is a vector for understanding the complex relationships between endocrine disruptors, biopolitics, corporate influence, and body autonomy.*  
.....

*Epicurean Endocrinology's* latest project, *Cooking Sex*, presents meal kit boxes in the style of Blue Apron, except these boxes allow the subscriber to test their food for the presence of endocrine disrupting compounds. These compounds may represent contamination -- or a hormonal inflection that the consumer desires. Using the popular model of the subscription-box to distribute their artwork allows Flyntz and Rich to consider a more distributed kind of participatory art, one that dissents through engagement with continuously morphing capitalist product development rather than static tactics of demurral.

In this interview, Liz Flyntz and Byron Rich discuss how this project came to be, as well as their influences and ideas and how they hope to alter the perception of food, art, and science.

**Marnie Benney:** When did you become interested in the interaction between endocrine disruptors, food systems, and ecological interference?

**Byron Rich:** For me, it was in graduate school when I first began work on *Open Source Estrogen* by trying to develop an *Open Source Birth Control Pill* by synthesizing the required components, namely progesterone, from cholesterol isolated from a chicken's egg.

**Marnie Benney:** Why did you choose to explore them in this work?

**Byron Rich:** I became fascinated with the biopolitical influence and biotechnical surveillance power that prescriptions can have.

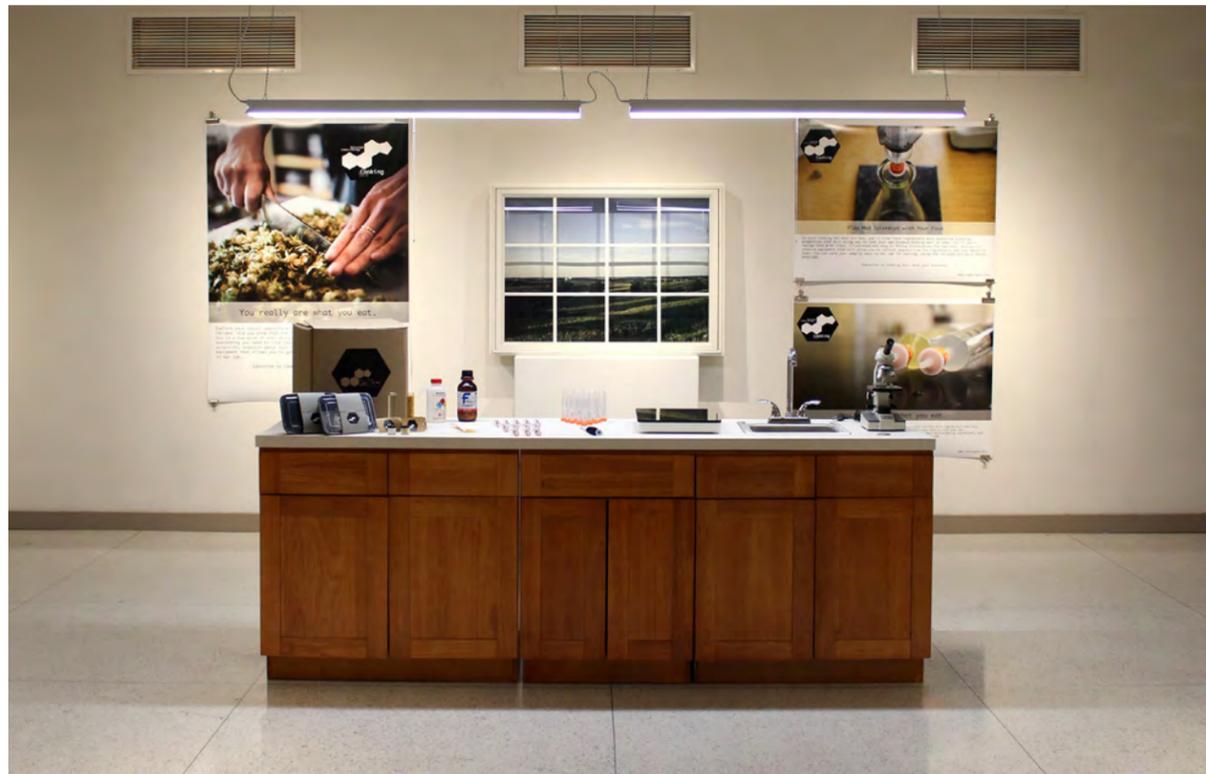
**Liz Flyntz:** Many of my friends have cycled on and off specialized diets for reasons having to do with chronic disease management, politics, athletic performance, and aesthetics. I was also in a vegan cooking co-op in college, where I learned to cook at scale and in earnest. Basically, cooking for people with a variety of needs made me interested in what food represents culturally, and how food can interact with and alter the body.

In my art and curatorial work, I've been interested in how humans engage, resist, and construct big systems - like agriculture in this instance.

**Benney:** Liz, in your work you try to "figure out how we got here from there, where we should go next, and how we can make the future more evenly distributed". Byron, you describe your artistic practice as techno-futility by creating work "that purposefully obfuscates boundaries of practicality, ethics, and sensibility".

How do you think this project embodies the motivations behind your work?

**Rich:** *Epicurean Endocrinology* is not designed to be a solution to access. By that I mean it won't and can't replace hormone therapy, or birth control, and kind of exists under the same dubious cloud of optimism that other non-FDA (Food and Drug Administration) approved health products do. EE instead is a vector for understanding the complex relationships between endocrine disruptors, biopolitics, corporate influence, and body autonomy. It is about contextualizing the relationships, more than a solution. The futility lies in trying to pry these spheres of influence apart to allow individuals greater autonomy over their physical self.



**Liz Flyntz & Byron Rich**

"We've Done The Research..." *Cooking Sex Ad*, digital image, dimensions variable, 2018. Photo by Byron Rich

© Liz Flyntz & Byron Rich

**Flyntz:** I second Byron's point – we are not trying to design a solution to the issues of an EDC contaminated food supply. In general, I think it is a mistake for artists to get lured into designing solutions to social ills or conducting publishable research. I understand the temptation because a lot of what we do encompasses design and involves research, but art is fundamentally about problematizing solutions, not solving problems.

Understanding "how we got here from there" is a crucial and often overlooked practice for everyone, not just artists. Over time, social constructs get embedded into the language and tools we use and reveal themselves in the ideas we have in the present. For instance, we have many of socially-received ideas about how the sex hormones, particularly estrogen and testosterone, are gendered and we project these ideas about chemical substances onto bodies and behaviors. In fact, we don't know a lot about how hormones influence behavior at all, let alone how they might influence what we call masculine or feminine attributes.

**Benney:** Can you describe the thought process that led to the format for this project? How you arrived at the different elements: the cooking show format, the Blue Apron style boxes, the public database of endocrine disruptors, and print version of the *Cooking Sex* cookbook?

*In general, I think it is a mistake for artists to get lured into designing solutions to social ills or conducting publishable research.*



**Liz Flyntz & Byron Rich**

"You Really Are What You Eat." *Cooking Sex Ad*, digital image, dimensions variable, 2018. Photo by Jeff Mertz

© Liz Flyntz & Byron Rich

**Flyntz:** I'm actually not 100% sure how we decided on all of these presentation elements – basically all of our ideas arise out of shared interests and ongoing conversations. We talked a lot about how food, a natural element of our ecosystem, is developed into salable products and often marketed using highly gendered language and design.

I think a lot about how products are constructed and distributed, there's a kind of black magic at work in entrancing people to assign value to an object and to identify themselves more strongly with one object over another. All of the different elements are media products of the food system or of scientific research.

**Rich:** I can't remember the specifics of how we came to this format exactly, but I think it largely arose out of Liz's interest in the marketing/packaging/aesthetics of food delivery systems. That kind of intersected with conversations that we were having around endocrine disruptor pervasiveness in water systems and in common food sources. We both are very curious as to how decisions regard



Explore your sexual appetite with our complete meals boxes and guided recipes. Did you know that the food you eat can alter your hormones? Cooking Sex is a new kind of meal delivery service. Each meal-kit box contains everything you need to cook your own hormone-hacking meal, accompanied by scientific research about each of the endocrine-disrupting ingredients, and equipment that allows you to gather samples of the ingredients for testing in our lab.

Subscribe to Cooking Sex. Hack your hormones.

**Liz Flyntz & Byron Rich**

"Hack Your Hormones." *Cooking Sex Ad*, digital image, dimensions variable, 2018. Photo by Josie Freeman.

© Liz Flynt & Byron Rich

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*The downside to freedom is a lack of deep knowledge in the biological sciences, and that makes even breaking through the esoteric language a barrier to succeeding.*  
 .....

ing the gendering of food products come about, and the cultural implications of making these associations part of advertising.

**Benney:** You both approach the interdisciplinary field of science and art from artistic backgrounds as opposed to formal scientific training. Can you talk about the pros and cons of this?

**Rich:** I studied Emerging Practices at The University of Buffalo with Paul Vanouse, and I was given ample opportunity to become familiar with the fundamentals of laboratory practice. At the same time, I was unburdened by scientific dogma and kind of given license to approach the biological as a tool of practice. The downside to freedom is a lack of deep knowledge in the biological sciences, and that makes even breaking through the esoteric language a barrier to succeeding. It's so time-consuming to just get up to speed on what I'm reading in a protocol or journal if I'm researching a very particular topic. For instance, when making *M-Ark*, or *Microbiome Ark*, I had to figure out how to freeze dry a sample, which is easy enough for someone trained, but outside the lab and working largely at home, it was a challenge...

**Flyntz:** I was also in the "Emerging Practices" program, though my MFA came from the Media Study department, rather than the Visual Studies department Byron was in. I worked closely with Tony Conrad, who was really interested in creating interventions into various media paradigms. He liked to deconstruct things he thought were overly constructed, or too baroque, like classical music, experimental filmmaking, or academic grading. At the same time, he was into re-constructing things that seemed to him to be underdeveloped or under-utilized. He used the local cable-access tv format to create some extremely poignant commentary about cities, democracy, education, and media - by doing simple on-the-street interviews or having kids do their homework on air. I think this interest in making a sort of DIY microcosm of the whole corporate food world, including the Cooking Channel, cookbooks, meal kit boxes, and so on comes from Tony's prankster-y "just show up/we can make our own version" ethos.

You asked about scientific background, of which I have none, though I do work with information technology, for a research institution. I spend a lot of time reading remedial basic biology in order to understand the material we are accessing. In all of my lines of work, I spend a lot of time thinking about how to convey complex and often technical information simply and accurately.

**Benney:** Immersive experiences like yours have often been used to expose people to difficult or complex topics that would otherwise be difficult to broach in everyday life. For example, telling someone that there are chemicals in their food can often be met with defensiveness or denial - and rarely incites change. Do you think a project like this can connect to audiences in a different way than traditional forms of communication? I mean knowing that you are going to be making something called a "Cheesy Taco Bake" is pretty disarming.

**Flyntz:** In a way, this is a "traditional" culture-jamming project. We are doing a sort of detournement - but instead of the target being entertainment or news media, the target is food products. Part of



Liz Flyntz & Byron Rich

*Feminizing Meal at Craigardan, digital image, dimensions variable, 2018. Photo by Jeff Mertz.*

© Liz Flyntz & Byron Rich

what we are doing is presenting this scare info about EDCs to our audience in a less intimidating, more engaging way. In another way what we're doing is interrogating the systems in order to better understand them ourselves.

The articles we're reading, often have titles like "Exposure to an anti-androgenic herbicide negatively impacts reproductive physiology and fertility in *Xenopus tropicalis*" (1). Is anyone besides an environmental biologist in a research setting going to read this article? No. Does it actually contain data that is important to human health in a real and immediate sense? Yes definitely. How can we make that connection?

The traditional method has been to produce "layman" science articles for publication in the mainstream press. However, these articles often over-simplify information or lead readers to believe that something has been "proven" or "disproven" by a single study, when that is just not how science works. Systems are complicated and a single study doesn't prove anything except that someone was interested enough in the subject to design and fund the study. Lots of things that are important don't get studied; the effect of phthalate plastic exposure is one.

**Rich:** I would add that there is a power to being able to get visibility in more mainstream platforms, and projects like this that obfuscate traditional boundaries between ethics, politics, science, and art have a particular level of resonance in pop-cultural modes of dissemi-

nation. Headlines Like "Birth Control Pills Turnings Frogs Female" can be seen in news outlets, but the broader cultural absorption of the implications doesn't extend much further. Academic journals are filled with studies showing the results of years of research, but, like the esoteric knowledge required to work with much of the hard science, esoteric language and knowledge is required to digest the true complexity of interaction. To further complicate the issue, the cultural implications are rarely discussed in scientific journals. *Epicurean Endocrinology* will hopefully act as a vector for bridging scientific understanding, even if cursory, with the cultural implications.

**Flyntz:** I think it is also important to take a critical look at the cultural implications of headlines like Newsweek's infamous "hermaphrodite suburban frogs" (2). Media representations like this use sensationalized sex-panic and misogyny to get attention which does a real disservice to the actual problem and its real-life effects. First off, the problem of xenoestrogens in municipal water supplies is real, but the primary cause is agricultural chemicals, not consumer level pharmaceutical birth control. Also, the problem is not that frogs are "turning female" it is that this fragile part of a living ecosystem is being destroyed. Just as the problem with EDCs in humans is not that humans are being "feminized" it is that we're being exposed to carcinogens that cause a wide range of negative health outcomes.

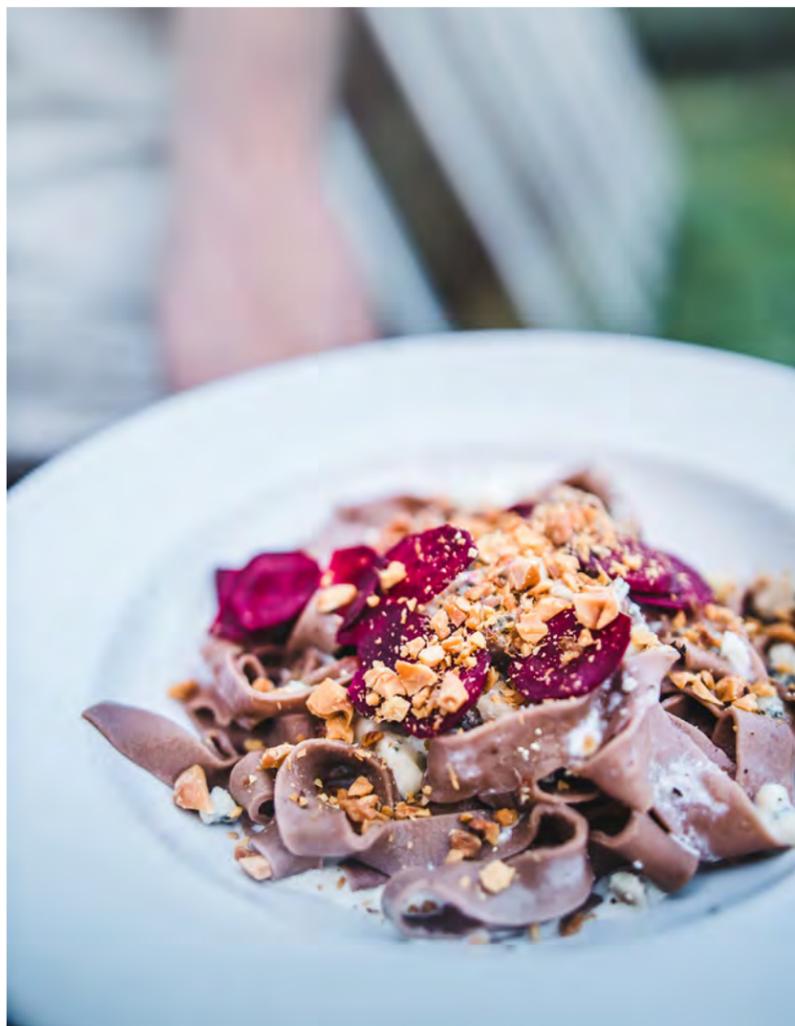
**Benney:** Truly impactful experiences often engage both cognition and emotion – thinking *and* feeling. Tell me about how you approached both sides of this coin in your work. For example, you gathered hard scientific data, and turned it into a relatable experience that could be seen, felt, touched and tasted. How did you approach melding these two seemingly disparate areas of focus – science and art?

**Rich:** Food is a natural meeting point as it is a culturally resonant act that invites collaboration and conversation. The dinner table is the site of debate and togetherness, and by using cooking and food production, we are inviting dialogue and meaningful interaction into the home. Furthermore, by capitalizing on the aesthetics and form of food delivery systems, we move beyond simply representing the interconnections between bodies, politics, science, and food systems, into an interactive examination of the pervasiveness of EDCs, ecosystems and human bodies.

I'll add that science and art are pretty intrinsically linked. Artists are adept at finding what I call 90-degree solutions to problems embedded in industry and science. Additionally, scientists are wildly creative, as their careers are based on discovering the unknown, and the only path towards that is through creatively approaching embedded notions, and ideas. Science is about proving itself and its beliefs wrong, and that takes courage and creativity. The first piece that comes to mind when discussing this is Tissue Culture Project's *Victimless Leather* where they created a small living leather jacket in vitro by growing culturing skin cells on a scaffold.

**Flyntz:** EDCs are difficult to research because they are everywhere, we rely on so many EDC-containing products in our lives and in our various industrial systems, they are very small and relatively hard to detect, and their negative effects on the body are very hard to trace

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*Artists are adept at finding what I call 90-degree solutions to problems embedded in industry and science. Additionally, scientists are wildly creative, as their careers are based on discovering the unknown, and the only path towards that is through creatively approaching embedded notions, and ideas.*  
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**Liz Flyntz & Byron Rich**

*Plated: Feminizing Meal at Craigardan, digital image, dimensions variable, 2018.*

*Photo by Jeff Mertz © Liz Flyntz & Byron Rich*

and pinpoint because exposure occurs on so many fronts and because the endocrine system itself is not well understood. No one knows that much about EDCs, in part because there is no political or economic will to seriously study their effects. These subjects – sex and gender expression, food, environmental degradation and contamination – are all so complex and so emotionally fraught, especially in our current political climate, that we needed a pretty broad and flexible platform to explore them. Really, food is a location where art and science meet in everyday homes all the time. Chemistry, biology, and ecology come together when we cook and eat a meal, but that meal equally draws on culture, design, history, and art.

**Benney:** How have participants been responding to the project? Have they been able to make the food? Test it? What seems to be the favorite meal?



**Liz Flyntz & Byron Rich**

*Cooking Sex: Meal Kit box prototype, mixed media, dimensions variable, 2018, Photo by Byron Rich © Liz Flyntz & Byron Rich*

**Flyntz:** People loved the *Masculinizing and Feminizing Meals*. The food served during the meals was definitely good and people were into it. *Down Home Molecular Gastronomy: Cheesy Taco Bake* on the other hand just looked super disgusting and neither Byron nor I could bring ourselves to actually eat it.

**Rich:** I'll speak to the lab portion. Participants in our lab-based workshops are massively receptive as they can physically see just how pervasive EDCs actually are. The ease with which our approach allows them to detect and extract demystifies the complex science while maintaining scientific credibility as a process. The lab and the kitchen are so similar: they're highly gendered, they're experimental, and they rest upon the recombination of constituent components in finding new outcomes. The lab/kitchen hybrid embodies profound interconnection between politics, science and human bodies, and works to breakdown the bifurcation of the arts and sciences as distinct disciplines.

**Benney:** You make a point to use local recipes to explore your subject matter. Why was it important to do this?

**Flyntz:** We were interested in the connection between vernacular cooking and agriculture. We chose recipes that reflected a particular region and the kinds of crops that are often grown there. Of course,

everyone everywhere in the US can get corn anytime now, but it retains a sort of conceptual affiliation with the corn belt of Illinois, Iowa, Nebraska, and Kansas. That's also where we see really high rates of atrazine use, which is an endocrine disrupting herbicide.

**Rich:** I find the political gymnastics that middle America is willing to do absolutely fascinating. In the pursuit of higher yields and profits in the production of specific crops, corporations and the individuals governing them are willing to overlook the politics in headlines about "Intersex" frogs for instance in pursuit of higher profits. It seems that the "traditional values" – which is inherently profoundly problematic as a term in its latent heteronormative connotations – seems at odds with the ramifications of the use of EDC-rich compounds aimed at increasing yields.

**Benney:** Viewers are active participants in your project. They are learning how to create these meals and also learning how to become citizen scientists. Why did you choose to structure your project in this manner?

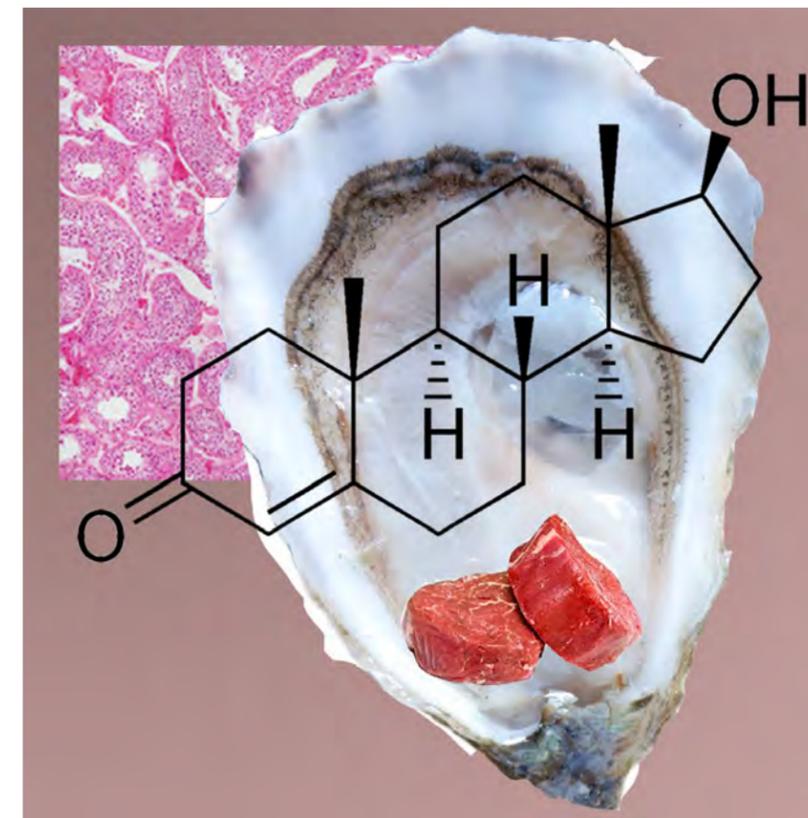
**Flyntz:** We wanted other people to make the art for us. Just kidding! We were really interested in this product-design model of selling a semi-assembled product like the meal kit. We were talking about that design concept and realized that what was really being sold to people was "not grocery shopping" and "not deciding what's for dinner". And you see that concept being sold a lot! "Not shopping in the store" is basically Amazon's whole business model.

**Rich:** Citizen science *could/can* be a dangerous concept, so instead, I prefer to frame it as building scientific literacy and increasing individual's belief that they can participate in the discourse around EDCs. I also think it is important to give people laboratory experiences to hopefully inspire impassioned and self-aware scientific pursuit. It's all about interconnection and drawing lines between the science and politics that affect bodies - human or other.

**Benney :** I love that the average participant/consumer is able to take back some power and really understand what they are putting into their bodies. Through the meal creation/testing process, they build their scientific literacy, understanding and then controlling their food/hormone intake. That's such an empowering thing. What do you hope participants walk away with after engaging with your project?

**Flyntz:** I hope people will learn a bit about the discourse that's happening about endocrine disruptors in the food and water systems and consider what the implications are, how we got to this stage and what could be done about it. I also hope people think a little bit about the nature of food itself. We are literally made of food! Food and eating are the points at which our bodies intersect with the environment around us in a conscious, constant way.

**Rich:** I just want to build scientific literacy, and a more profound understanding of the interconnectedness between political systems, industrial food production, and human bodies. Science and technology are immensely powerful tools, obviously, and drawing



**Liz Flyntz & Byron Rich**

p. 118-119: *Down Home Molecular Gastronomy Recipe Card*, digital image, dimensions variable, 2018 Photo by Byron Rich © Liz Flyntz & Byron Rich  
*Masculinizing Collage*, digital image, dimensions variable, 2018. Found image collage by Liz Flyntz © Liz Flyntz & Byron Rich

connections between their outputs and their cultural dispersion are vital to best utilize them for cultural good.

**Benney:** How will you keep participants engaged after their initial participation?

**Flyntz:** Well we are hoping people will want to check out the site after they submit their samples to see if their food does indeed contain EDCs!

**Rich:** I hope that if we are able to build this into a sustainable, and ongoing model, people will continue to order kits and build their awareness of just how prevalent EDCs are. I think there will be an ongoing connection to the project, as food consumption is a part of everyone's lives. Hopefully, people won't look at food and food products the same way long-term.

**Benney:** What is next for this project? What is your future vision?

**Flyntz:** We are planning to do a beta test round of the *Cooking Sex Meal Kit* boxes. We'll have about 20 participants in this first test round and then we'll figure out if it would be possible or desirable to scale that part of the project. We also hope to do some video pro-

duction of cooking and science demos - we want to do everything Blue Apron does only like way smaller scale, and you know... against the food industrial capitalist time suck gender fascist culture.

**Benney:** Which artists and theorists have influenced this exhibition?

**Flintz:** When we were first researching and working on this project I came across Cassils's work and was really fascinated by their process in *Cuts: A Traditional Sculpture* of altering their body into a more "masculine" presentation as an art project. I wondered how much we are all altering our gender presentation through the foods we eat and the culture we engage with. I also love Ryan Hammond's work, especially a *Queer History of Hormones*, which was published in the *Addivist Cookbook*.

Byron and I both spent some time with Paul Preciado's *Testo Junkie* and the *Futurist Cookbook*. I'm also really interested in the food product/art collective Nonfood, started by Sean Raspit, one of the flavor scientists who worked on Soylent. I just read *Sex, Science, Self: A Social History of Estrogen, Testosterone, and Identity* by Bob Ostertag which was an extremely illuminating look at the historical development and present usage of hormones and hormonal intervention from the pharmaceutical side. We're obviously both Donna Haraway fans.

**Rich:** I will add that Critical Art Ensemble, especially their project *Free Range Grain*, and Paul Vanouse's *Suspect Inversion Center* definitely played a role in terms of aesthetics and approach to the cultural dispersion of scientific principles that are not adequately understood.

**Flintz:** On the editorial side, I recommend anything coming out of the Center for a Livable Future, here at my institution the Johns Hopkins School of Public Health. The CLF developed the "Meatless Monday" campaign which is a successful public health and awareness raising campaign dealing with the intersection of food consumption habits and the environment in a very approachable way. Also, the journal *The New Food Economy* has excellent, approachable issues relating to food systems, the environment, and economic issues.

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# In Pursuit of Variegation: Art as Research-based Collaboration

*This article situates the process of artistic enquiry within the realm of molecular biology and new biotechnological practices. Using a research-based format, the artist investigates how variegation is produced in plants and bacterium, and asks if natural biological processes can be artistically echoed, interfered with, and synthetically designed. The projects described search out the parameters of collaboration and look for new definitions of "artwork" within a laboratory setting. This piece ultimately questions how our personal sense of "wanting" and desire control what it is we conjure and manipulate. It asks what role aesthetic bio-synthetic artistic input may play in our evolutionary futures.*

text and images by **Carolyn Angleton**

In the age of synthetic biology, what determines our sense of "wanting" in our creation of novel biological characteristics? Can we mitigate our presence as hierarchical manipulators who imbue our "creations" with self-reflexive fictions and desires that impose a foreign aesthetic on the environment and the organisms within it? By what means do biological organism themselves create desirous color and pattern, and for what reasons?

In flower petals, color acts as a signaling device. As carotenoids and anthocyanin accumulate and change color, a visual display communicates the plant's developmental cycles. Flowers also trigger an intense sense of desire in humans, and as such, human's botanical longings become as much at issue as the plants' features themselves.

In my research-based artwork, I have focused on mapping the variegation of camellia flowers, and how patterns of red, white and pink congregate, break, stipple, blotch and margin to create a color scheme that can show evidence of mutations and changes in gene regulation.

Camellias are a naturally genetically unstable plant. All camellia species can and will mutate. When a camellia bud shows variegation, even only a single small streak of color, it serves as an indicator. It makes known that the plant, at some time in the future, will form a "sport," a branch which has differentiated from the rest of the bush. When a change in a flower's color is genetically induced, it indicates the turning on or silencing of a specific color gene. It may indicate the presence of a chimera, two differentiated cell lines growing side by side. When virally induced, this change indicates the presence of a pathogen.<sup>1</sup> Variegation can be understood as a type of biological assay, one that provides visual evidence of alterations in DNA sequence (e.g. mutation).

I first became smitten with camellias when I moved to northern California. There, in a garden shop, I saw a poster featuring images of 30-40 different camellia varieties. All related, similar forms, but each one a nuance, a slight deviation and modification from the next. What neuroticism, what beauty! What on earth would lead someone to create a collection, a biological treasure trove, of

Melissa Dubbin and Aaron S. Davidson are artists based in Brooklyn, New York. Their work has been described as addressing "processes of transmission and reception, interference and transference" often seeking to materialize immaterial or ephemeral states of matter (sound, light, air, time). Together they have co-authored a body of works producing forms, objects, images and experiences incorporating the mediums of photography, video, sound, performance, sculpture and artists books.

Recent solo exhibitions include *Six Degrees of Freedom at Untilthen*, Paris (2017), *Poétique des sciences*, Le Fresnoy, Tourcoing, France (2017). In 2016 they were awarded the inaugural residency in the Pinault Collection artist residency program in France. Their work will be featured in the upcoming 2019 Okayama Art Summit in Japan.



Carolyn Angleton

*Camellia Sport*, photograph, from the historic capital grove in Sacramento, CA. 2017 © SacBioArts

so many slightly different, systematically developed forms and colors? And then my next thought: I want to plant one of each. The transition from a feeling of immediate visual pleasure and delight, to amazement and intrigue, to wanting to own and propagate the entirety of possibilities was instant. And years later, aspiring to better grasp the genetic mechanisms and learn how to manipulate cultivars as a form of artwork. My response was one of appreciation, longing, possessiveness, envy, and dominion. It was a very strong, complex set of emotions.

What was it about desire, specifically the desire to cultivate, to entice to grow and control form, to manipulate biologically, that formulated in my mind and allowed me to interpret it as a possible framework for an artistic practice?

Luckily, due to budget restrictions, increasing drought, and

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*But there's also is another sentiment that circulates through our botanical desire. That of exoticism, of the dark "other." This is best represented in Edward Said's coining of the term "Orientalism".*  
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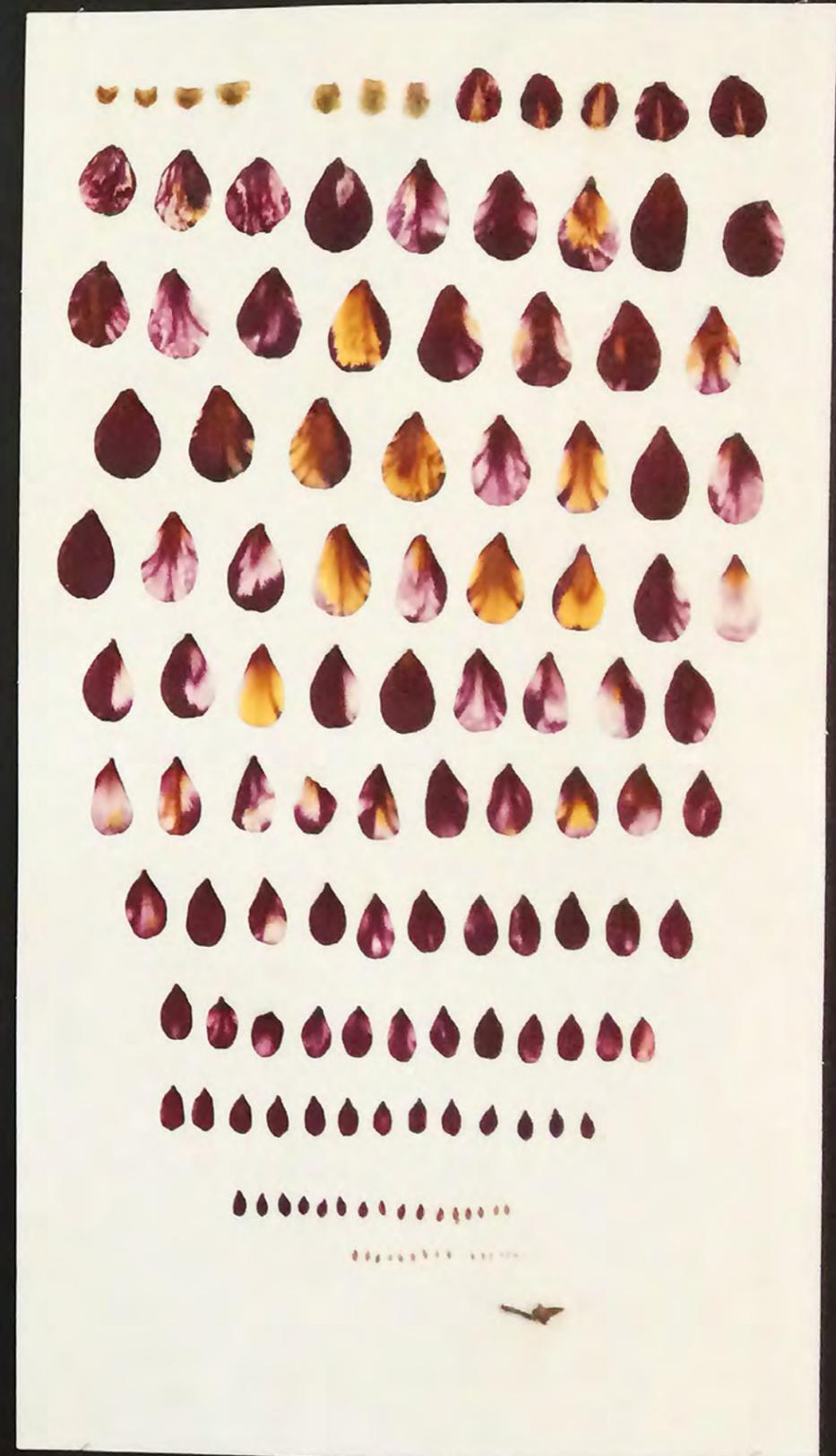
limited space I only planted a few cultivars of camellia. Meanwhile, I became aware of a large garden on the grounds of Sacramento's State Capital Building, that had a historic camellia grove, and also discovered the annual (now in its 92nd year) "Sacramento Camellia Show."<sup>2</sup> Soon afterwards, I used samples from both of these sources to begin an extensive herbarium and photographic cataloging of the species that had been brought into the western United States as a sort of imperial "prize" garden. Notably, there is nothing native about camellias in California. The first cultivars were brought over from China and Japan, and initially thrived in greenhouses kept by people with means on the East coast. The bushes were grown inside in pots during winter, then brought outside and carefully watered in summer. Eventually it was found that camellias could survive in Georgia and the south too, and later they were brought to the west coast. Plants, and our ardent passion for them, have a way of following our migrations, our distribution of wealth, and our desire to culturally conquest new territories.

This sense of "aesthetic wanting" in biological plant terms, has numerous historical roots. The red and white variegated patterns of camellias immediately bring to mind the phenomena of "Tulipomania" that took place in the Netherlands during the 17th century. The discovery of a tulip whose solid color could be broken by a lighter sector, first as a single streak, indicated that a particular bulb might potentially produce a flower with magnificent variegation, a striking pattern of on-again, off-again color. It was valued because it was beautiful, it was rare, and one could not predict its development. An initial light streak gave a hint, but it was a gamble as to what would emerge. Additionally, there was a fatalistic flaw. The variegation was due to the deadly mosaic virus- a potyvirus (the oldest recorded plant virus) carried by aphids that infected the bulb- and it would eventually kill the lineage.<sup>3</sup> All the makings of molecular high drama!

But there's also is another sentiment that circulates through our botanical desire. That of exoticism, of the dark "other." This is best represented in Edward Said's coining of the term "Orientalism," which he used to describe the way Westerners viewed the East, from a perspective of a hierarchically structured differentiation, and as having a forbidden, erotic appeal.<sup>4</sup>

These two tenets, unusual rarity and eroticization, can still be seen today in modern flower breeding, where intense depth of color, and high contrast are two of the most sought-after traits. Our breeding for visual pleasure in decorative flower cultivars tends to move a plant away from its original "organismal" use of color, which it uses to attract pollinators or indicate when fruit is ready for seed dispersal.

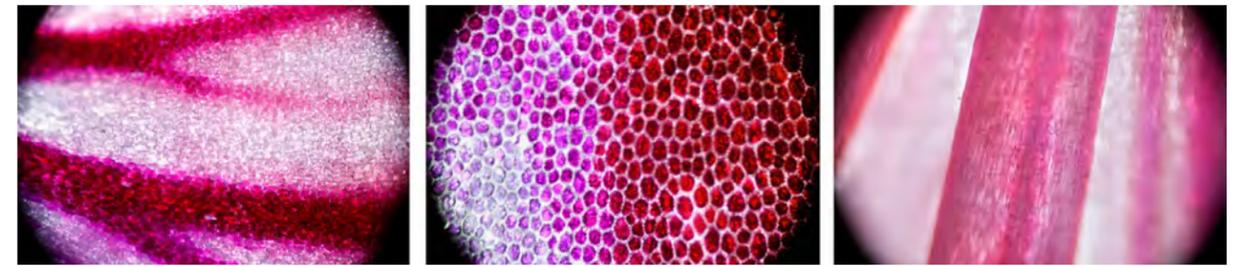
The path of a bio artist not infrequently starts within an observing/ depicting/ collecting modality. A probable next step is to begin engaging with the tools of science as a means of seeing in un-conventional terms. I wanted to see what variegation looked like on the molecular level. I had the fortune to take part in several residencies at the School of Visual Arts, NYC, where Bio Art pioneer and dean of undergraduate programs Suzanne Anker had developed the first full-spectrum wetlab within an art school.<sup>5</sup> There, I began to learn the lighting and photographing techniques of microscopy, the stacking of images and portraying different types of form as they emerged with each change in magnification; all skills traditionally



Carolyn Angleton

Herbarium Collection of Variegated Camellia Flowers from the historic "Pioneer Capital Grove", Sacramento, CA.,

Acid free mat board and petal tissue. 2016 © SacBioArts



**Carolyn Angleton**

*Molecular Geraniums*, microscopy photographs of variegated geranium petals, 2016 © SacBioArts

used in medical and scientific inquiry of biological samples.

I broadened my botanical selection to look at other species that had been bred for intense color and variegation, and searched for ways to depict that information artistically. When working between art and science, the challenge is to develop one's own language, a visual voice that is situated between two different realms, at once searching for underlying commonalities and articulating polarities. It's both poetic and iterative, a sometimes irreverent endeavor. It's located in the physical as well as metaphorical understanding of matter. I often feel like I'm working on the margins of non-sense, something that doesn't hold legitimacy in either field.

It's also a form of art making where confusion lies in the collaboration. What belongs to the organism's own creation, and what is the result of an artistic manipulation or interference? One must ask who the creator is when an artist and scientist collaborate. What's "real" knowledge vs. artistic supposition? Is there a "valid" way of describing a scientific reality and who determines this? I wanted to go beyond depicting nature. I sought to enter the realm of co-creating, or even taking control of the biological formation on the cellular level. Then, I also had to ask myself what ethical boundaries lay between artist and organism.

In this borderline territory there are more questions than answers. The artist/scientist is cast in the realm of the inventor, experimenter, and trespasser. Artists are involved in the practice of envisioning, bringing forth a "thought experiment" that didn't exist before. I conceive this process is a type of rumination that unwittingly, though strategically, ties together buried remnants of the past, current political positioning, and hopes for a modified future.

Meanwhile, still pursuing variegation and biological coloring, I began looking for other organism that developed variable color. I also became more interested in learning the mechanisms involved with biological formation of pattern and how to artistically interact with its formation. The next species I turned to was the bacterium *Serratia marcescens*.

I worked with this bacterium in several settings. One was in a 300-year-old farm house at a residency led by bio artist Marta de Menezes at 'Cultivamos Cultura', in Sao Luis, Portugal.<sup>6</sup> There, we constructed a color range of pinks and oranges by heating the bacteria to different temperatures. From this palette, I created a series

**Carolyn Angleton**

*Left: Petal List*, photographs of systematically dissected and arranged individual variegated camellia flowers, part of a series of 30 photographs, 2016-17 © SacBioArts

of “breast plates,” consisting of bacteria/fungi sampled from within the farmhouse, and shades of *S. marcescens* inoculated onto milk agar in petri dishes. While this species of bacteria can be an opportunistic pathogen, it’s also one of the more versatile and strikingly colorful micro-organism. It occurs naturally in soils and moist places and is found commonly in household settings such as at the edge of a shower. *The Breast Plates* piece was a collaboration of bacterial process, artistic intent, and the digestion of casein. It spoke to issues of inoculation, infection and intergenerational immunity.

My next artwork developed at the School of Visual Arts, NYC, with support from Tarah Rhoda, artist/head technician of the school’s wetlab. With Tarah’s assistance, we formulated a procedure that would allow me to structure a collaboration between different bacteria to see if I could transfer the patterning of camellia-like variegation into another organism’s growth pattern, thus attempting a “cross-species” dialogue of simulated design. Interaction between bacteria is competitive, as bacteria try to exceed each other for resources, so species-pairing and placement is critical. I inoculated black agar with 3 species of different bacteria, which I had selected for their structural qualities, growth patterns, and color subtleties in an attempt to create a reformulation of one of the camellia *Petal Lists* photographs.

This project enabled me to further prod the parameters of collaboration. It conjugated and diverged between the biologically driven patterns of variegation in the original camellia petals, the particular species of bacteria selected and their genetically determined color and growth forms, and the parameters I, the artist, set through my inoculation patterns. The piece developed under controlled growth conditions of temperature, moisture and light. In this sense, collaboration meant a transfer of knowledge, process and form, engaging each element on multi-faceted levels.

Eventually, while pursuing this type of plant-bacterial experimental artwork, I decided to enroll in an official biotechnology program. I wanted to move beyond the “artistic interpreting of science” and develop some “hard core” laboratory skills and knowledge. As I live in Northern California, home to the West Coast hub of biotechnology companies, I found the best access to training lay in the local community college’s biotechnology workforce training program. There I first met Dr. Ken Kubo, who was the faculty leader of the North Valley Biotechnology Center at American River College.<sup>7</sup> I was fortunate in getting to know a professor and researcher who had the capacity to see value in interdisciplinary learning and crazy artistic ideas. I explained to him my search to biologically investigate the process of variegation. Soon, we set off on an experiment to produce “sectored” bacteria.

By exposing the afore mentioned strain of bacteria, *S. marcescens*, to U.V. light, we could mutate some cell-lines within a sample. This was a different kind of artistic manipulation, one that involved following a “protocol” and initiating an intervention in the bacteria’s natural life cycle. As the artist/scientist, I could delineate an “independent variable,” i.e. the length of time of U.V. exposure, but the art work itself ultimately resided as the experiments “dependent variable”- a pattern created by changes in level of gene expression. Variegation was formed by colonies growing from differentiated cell-lines. Those whose genes had been altered produced a white lineage of cells, those that had not remained the characteristic red



**Carolyn Angleton**

*Culture/Re-culture*, Inoculation of bacteria and fungi onto agar in pattern of historic Portuguese tile; Historic farmhouse window frame, agar, glass, paint, wrought iron. 2014 © SacBioArts

.....  
**When does the laboratory itself  
 cease to be a purely research-based  
 space and when does it become a  
 poetic manifestation?**  
 .....

color of *S. marcescens*. The terminology used for this motif of biological growth is “sectoring.” It occurs where two types of chimeric cells grow side by side, expanding outward into colony formation. Chance and genetic manipulation became the tools for creating epigenetic changes which designed the “artwork”.<sup>8</sup>

I have deliberately used the word “artwork” in parentheses since, at this point, my definition of “artmaking” had continued to morph to the point where the lines between artistic output and biological research were fundamentally blurred. What constitutes an art project? How does it have to be portrayed in order to be such? Is creating a manipulated biological product an artwork in and of itself? Does its status depend on context? Or can it exist as such on a laboratory bench, as a novel species or mutated form? When does the laboratory itself cease to be a purely research-based space and when does it become a poetic manifestation?

Could artist and bacteria create a new interspecies form of aesthetic autopoiesis when no one was looking? If bacteria grew in an incubator into a novel inter-species-artistically-directed performance and there was no NYC art-scene critic there to comment on it, could it ever be called socially relevant art? I was really beginning to like this! I began integrating the techniques of biotechnology, and the vocabulary of scientific inquiry, deeper into my art practice. I was out of



Carolyn Angleton

Breast Plates, Milk agar, petri dishes, mutated *Serratia marcescens* bacteria, local fungi gathered from farmhouse. 2015 © SacBioArts



Carolyn Angleton

Post-Species Variegation, Petri dishes, agar, charcoal, camellia petal photograph, 2017 © SacBioArts

my element, over my head, enrolling in highly technical science classes, and doing really well. Some of my intrapersonal, philosophical questions, which have curtailed my wanting to make art in the last several years (centering around “why make art in the midst of the Anthropocene and global climate demise”) were put on hold—slightly, at least for a moment.

The next question /artwork /thought experiment I wanted to research/perform was how to characterize the difference between red vs. white petal tissue on a molecular level. I designed a project called *Red/White Dahlia*.

This type of bicolored dahlia was the first flower I grew as a child. My mom allotted me a small spot in her vegetable garden and said I could grow anything. I chose the bicolored Dahlia, “Duet,” created by hybridization and registered in 1955. In my young mind, this flower contained extreme beauty and great significance, of what I didn’t know or care. But my desire for that particular flower resounded deeply within me. I still grow a number of varieties of red/white dahlias each year. This aspect of growing experimental gardens has emerged as a sustaining aspect of my art practice. It’s an evocative process to plant, cultivate and experiment in a framework based within my own backyard perimeter. In this way, my art working has become a DIY, biohacking approach to a unique type of investigating and creating of knowledge for my own purposes and prompts.

My association with the American River College’s science department has allowed me to form advanced level collaborations

with biotechnology experts. The piece I am currently working on is a joint effort with two of the college’s molecular biologists, Dr. Ken Kubo and Dr. Adam Telleen. I have been able to expand my knowledge of biotechnological techniques, while continuing my pursuit of examining biologically produced color, and how to manipulate it.

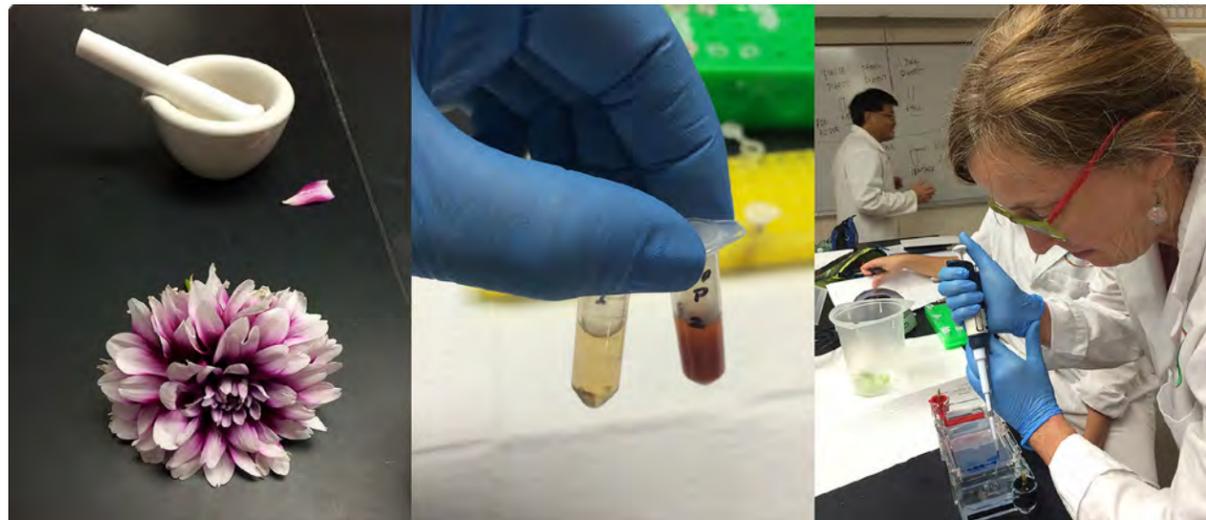
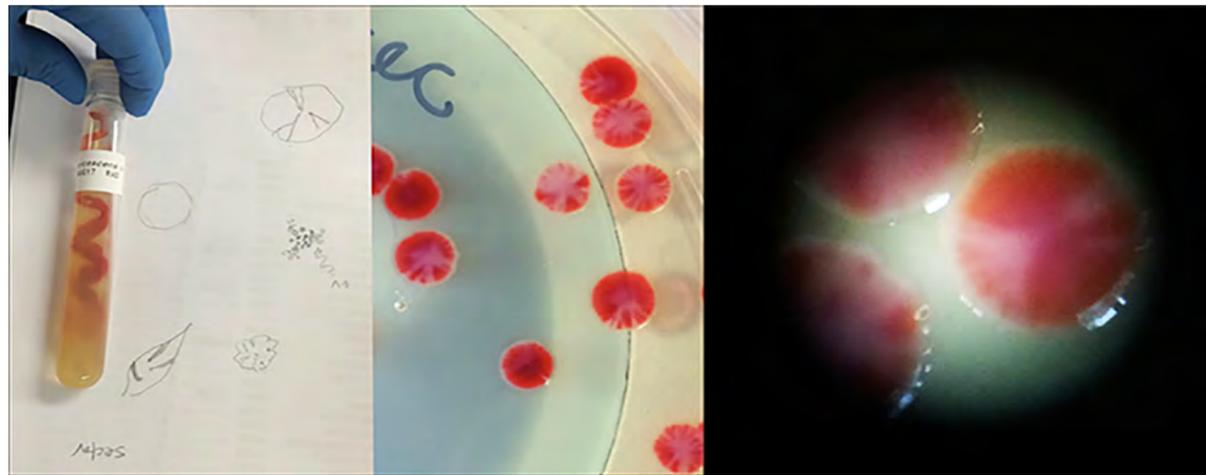
As a team we formulated an idea to synthetically construct a biological pathway to express color transformation, based on a naturally occurring process found in plants. Our project, titled “Rendering a Biosynthetic Carotenoid Pathway” is funded by a grant from “Biohack the Planet,” a conference that occurs in Oakland, California each year and brings together bio artist, scientists, bioethicist and the DIY biohacking community.

This experimental work links artistic ideas to biological concepts regarding the transformation of color, and to the notion of color as a means of signaling or communicating biological change. The goal is to demonstrate how biosynthetic pathways operate and how gene expression can be regulated. The studio work, now in its beginning phase, was initiated by designing primers and assembling small, circular bits of DNA that serve as cloning vectors for inserting new genes into bacteria.

These genetically engineered plasmids are used to “transform” a host cell, which forces it to produce the protein that the newly introduced DNA codes for. The *E. coli* cells will then be plated out on differential media to express a sequential development of colors ranging from white, pink, and orange.

The construction method being used is “Gibson Assembly”,

.....  
*This experimental work links artistic ideas to biological concepts regarding the transformation of color, and to the notion of color as a means of signaling or communicating biological change.*  
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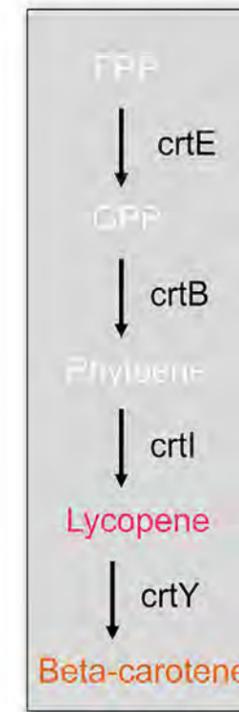
Carolyn Angleton

Sectoring Patterns in *Serratia marcescens* as a Result of UV Light Exposure, photographs, petri dishes, red/white mutated *Serratia* © SacBioArts  
 Red/White Dahlia, bicolored dahlia tissue, scissors, mortar and pestle, elution buffer and spin column, micro tubes, pipette, EZ dye, agar gel and electrophoresis apparatus, written protocol. Biotechnical leadership by Dr. Ken Kubo. 2018 © SacBioArts

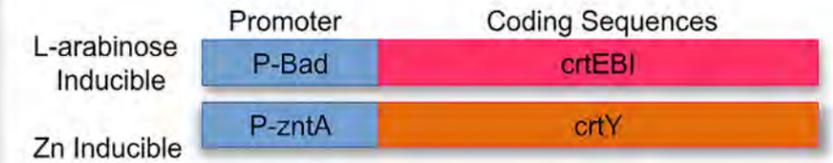
a molecular cloning technique which can join multiple DNA fragments in a single, isothermal reaction.<sup>9</sup> Rather than traditional artist tools, we use micropipettes, PCR amplification, genomic elution buffer and spin columns, and gel electrophoresis as production methodologies. The “rendering” in this case, will be done on the molecular level, then grown out and given form through *E. coli* bacteria in a petri dish.

This project is based on the emerging area of research called “synthetic biology”, a field which appropriates engineering principles and applies them to biological systems. Genetic engineering can be used to create novel biological parts, insert DNA from one organism into another, or redesign naturally occurring biological systems and entities.<sup>10</sup> The most commonly referenced method is a system called CRISPR, which utilizes bacteria’s natural immune defense system as

### Biosynthetic Pathway



*E. coli* containing plasmids with constructs shown below:



### Media Supplemented with:

Arabinose	Zn	Color
-	-	White
+	-	Pink
-	+	White
+	+	Orange

Dr. Adam Tellen

Gene Design and Diagram by Dr. Adam Telleen, American River Biotechnology Department, 2018  
 © Adam Telleen

a way of cutting and pasting genomic code. It has the potential to speed up evolution, and ultimately, to redesign nature according to the “insights” (read “desires”) of the designer.

This brings us back full circle to the initial subject of human desire, camellia breeding and biologically produced color. Selective breeding, such as that used to produce all those varieties of camellias that I first saw in a garden shop in Fresno, California, has long been used by humans to produce unique cultivars with desirable features. Botanically, hybridization is achieved by controlling cross-breeding, and gradually producing successive generations of plants with traits increasingly matching one’s envisioned “design.”

Evolution itself is the “original author” of successive genetic alteration. Evolution creates change through “natural selection,” a process in which individuals with the highest degree of fitness sur-

vive to produce the greatest number of offspring. In the case of natural selection, what's deemed to be most "fit" is determined by the immediate, local environmental conditions the organism lives in. Natural selection can also only "select" from what is already present; it is derivative, adaptive, unable to select from something not there. Mutation is an ongoing natural phenomenon that can change the available gene pool from which evolution can proceed, creating divergences and new species.

Genetic engineering changes the game-plan. We can now "selectively" design novel plants, biological pathways, cells, and devices that we deem important, that fit our model of the "greatest good," or our sensations of desirability. A particular combination of traits isn't limited by what existed before, but is able to be created via the expression of "novel" proteins. This technology has applications in the medical field, in drug development, in crop and livestock innovation.

Genetic engineering also has application in an aesthetic and artistic field. We have the ability to produce selected/selective novel proteins, and to patent and "own" the DNA mechanisms and genetic code of other organisms and individuals. As such, the element of genetic design straddles a scientific, artistic, and ethical realm.

Understanding variegation is a way of tracing certain historical aspects in the field of synthetic biology. Variegation represents the expression, or the silencing of the expression, of a structural gene in the flavonoid biosynthetic pathway (a biological mechanism responsible for producing color in flower petals). A process called RNAi, or RNA interference, is a type of cellular silencing mechanism that uses the gene's own DNA sequence, in the form of a messenger RNA, to turn the gene off. The process of RNAi was discovered in 1990 when researchers (Jorgensen et al.) were trying to create a darker purple petunia by injecting a trans gene encoding for chalcone synthase, which is responsible for the purple coloring, into the plant's genome. In addition to a darker flower, their experiment also yielded an all white flower and a variegated one. The white tissue resulted from the inserted chalcone "trans" gene and the endogenous, original purple gene cancelling each other out. Jorgensen termed this the "co-suppression" of genes.<sup>11, 12</sup>

In 2017, synthetic biologists at the University of Tsukuba and Yokohama City University, Japan produced the first "knock out" white petunia. They used CRISPR to target a single gene, dihydroflavonol-4-reductase-B, encoding an anthocyanin biosynthesis enzyme, to change flower color. The ability to silence, or knock-out, a gene so that it no longer functions has become a cornerstone of genetic research. By having the technology to turn genes on and off, scientists can observe the resulting molecular or phenotypical changes and thereby determine the function of a gene. The University of Tsukuba's experiment was also a "proof of concept" for the accuracy of CRISPR. In the petunia plant, there are two similar genes sitting on either side of the target gene. The researchers were able to demonstrate that they could change a closely related gene in the middle of two similar genes, without effecting the gene on either side.<sup>13</sup>

Much earlier, in 1862, Charles Darwin learned of the existence of the Madagascar Star Orchid, a flower that has a nectar spur reaching over 12 inches long. He predicted a pollinator moth with a proboscis of comparable length.<sup>14</sup> Flowers have co-evolved with

.....  
*By having the technology to turn genes on and turn off, scientists can observe the resulting molecular or phenotypical changes and thereby determine the function of a gene.*  
 .....



**Carolyn Angleton**

*Monitoring Small Batch Fermentation of Synthetic Proteins, Solano College, photograph, 2018*

© SacBioArts

pollinators, and if either the plant's characteristics or the pollinators abilities didn't match, a species would need to adapt a different reproductive strategy, or it would perish. Darwin's prediction of such a moth's existence was seen as an impossibility by his contemporary colleagues, and he was often ridiculed on this subject. Twenty years after his death, such a species was eventually discovered. It was a hawk moth, with a curled proboscis that could uncoil and reach into the depths of the orchid's nectary, transferring pollen from nearby flowers to fertilize the plant. Darwin's type of scientific "envisioning" is one that artists in the lab can elicit and bring forth. It involves a putting together of disparate parts and dreaming of what is not yet recognized as perceivable/conceivable reality. Darwin's thinking also integrated cause and consequence. It was anticipatory. And this is critical.

Can we envision and create novel synthetic formulations beyond our own neurotic desires for pleasure and gratification? This is the dilemma that haunts modern biological innovation. Technology is not going to "march backwards," although political values may continue to regress. What lessons do we need to learn now about artistically collaborating with organisms? Are we capable of "radical listening," learning to hear and respond to the codes, vibrations and chemical signaling of other species?

It's fair to question the legitimacy of an artist participating in the manipulation of nature. Yet from another point of view, we may need to learn the language and skills of genetic engineering such that a variety of viewpoints, including ones potentially not aimed at monetary profit or biosecurity, can engage in a dialogue about our genomic futures.

The idea of an artist as an evolutionary agent of biological matter, is a predictable conjoining of the theory and methods of scientific and artistic disciplines. The element of aesthetic desire, of determining

a function or non-function, of simultaneously utilizing the technological and artistic processes of creation, of bringing into being something which has not yet existed, all combine to transpire within an ethical, theological, and ecological realm. Artistic research of this sort raises “impertinent” questions that would not be asked in quite the same way in any other single discipline. The quandaries that emerge out of this research pathway lead the way to a new artistic discourse, or critical theory, about the nature, limits and purposes of biological invention/intervention.

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**Carolyn Angleton** is a bioartist, researcher and experimental gardener. She holds a MFA from Rhode Island School of Design, a BFA from Colorado State University and is currently pursuing a degree in biotechnology. She is retired from a professorship at Sierra College in Rocklin, California, and has taught art, critical theory and feminist studies at California State University, Fresno and CSU Stanislaus, both in the central valley of California. She is the founder of SacBioArts, an art/science studio, and co-founder of ARC-BAC, a synthetic biology collaborative at American River College in Sacramento, California. Her artwork has been shown throughout California and internationally, including venues at the Yerba Buena Center for the Arts, Ca, the Crocker Art Museum, Ca, the National Museum for Women and the Arts, Washington D.C. and the Japan Media Festival. She is a recipient of a Djerassi residency award. As an active participant in the biohacking community, she serves on the organizing committee for the MIT Biosummit, and has received project funding from “BioHack the Planet” in Oakland, California for her research project “Rendering a Biosynthetic Carotenoid Pathway”. She speaks internationally at conferences on the topic of artistic desire and CRISPR technology.

# Smallpox Syndrome

Pei-Ying Lin is the founder of the Taiwanese Bio Art Community and of ‘Ouroboros: Organic Organism of O’. Her main research focuses on the combination of science and human society through artistic methods. She is particularly interested in building a common discussion ground for different cultural perspective regarding elements that construct our individual perception of the world.

text and images by **Pei-Ying Lin**

## 2012 - 2014

Smallpox has been one of the most deadly virus with a mortality rate of 30 - 50%. In Asia, such effort has been put into fighting the virus as early as 15th century. It was at around this time that doctors started the practice of applying tissue collected from the pus of an infected individual to healthy people in order to vaccinate them. There is no way to treat smallpox except vaccination. Smallpox has been declared eradicated by World Health Organization in 1979, and the very last case known was reported in Somalia. Although eradicated, the virus is still being preserved in many labs, mostly in the United States of America. Right after the events of 9/11, many feared that smallpox could become part of bioterrorist plans. The U.S. government has, for a while, been taking precautions for a possible outbreak.

Meanwhile, Synthetic Biology Scientists have developed a whole new smallpox vaccination technique. By modifying the *Variola* virus and manipulating the scar formation, the vaccine can not only induce antibodies to protect the subject from smallpox, but also create a desired pattern on the subject's skin. Later on, the scientists even started a new cosmetic company named VaccineBeauty. All their products can function as vaccines as well as cosmetics for fashionable people.

## 2015

A new research published by *The Royal Society Publishing Interface* in 2014 claims that infectious diseases have recently been on the rise (Smith et. al., 2014). This has prompted scientists to research new techniques to monitor emerging infectious diseases through metagenomics. (Mokili et. al., 2012) Recent outbreaks of Ebola, MERS, and measles has prompted the World Health Organization to look for alternative methods that might prevent epidemics.

## 2020

As more and more superbugs appears, the world engages is at war with pathogens. The fast reproductive speed of pathogens is forcing us to be one step ahead of the game in order to survive. Humans have to protect themselves with vaccines before any outbreaks instead of waiting for outbreaks to develop vaccines. However, the unpredictable nature of diseases has made it harder and harder to detect healthy carriers, thus making social interactions more and more dangerous.

## 2025

Scientists engineer a new vaccination method that entails the production of visible, but aesthetically desirable smallpox-like bumps. Asian teenagers are swept up in a frenzy and the vaccination becomes a fashion trend. Meanwhile, as the political, cultural, and economic power of Europe continues to decline, new discussions on bioethics based on eastern medicine and philosophy gain strength among scientists. The focus is now shifting towards enhancing the human immune system to combat unpredictable infectious diseases.

## 2030

The VaccineBeauty company is established. Combining vaccines with makeup, this company is changing the ways in which we have always conceived aesthetic notions of health and sickness. The visible markers of a vaccinated individual state "my body is safe from infectious diseases". Meanwhile, new smallpox research is published the book *The Smallpox Chronicle*: the very first book in history written from the perspective of co-evolution between smallpox and humanity.





# VaccineBeauty

Stay Beautiful, Stay Safe

Report 2036/03/04

## How do we work?

VaccineBeauty was established in year 2020, throughout the past 10 years we have managed to set up roughly 30,000 surveillance spots around the world for realtime potential viral genomic fragments detection using metagenomics. Every time a newly evolved viral genetic fragment has been detected, the data will immediately enter our world-wide simulation system to seek for viral risk factors for our customers each individually. The information will then be used to produce personalised vaccine and mailed to our customers within 12 hours. VaccineBeauty aims to advance our vaccines as fast as the viruses evolves. We believe only if human beings can use technologies to keep up with the evolution clock of viruses can we arm ourselves in this daily more competitive world against worldwide pandemics.

## Smallpox aesthetics

We have borrowed the symbols from smallpox, but in a much cleaner styles, to be the encryption code of our vaccines. Historically, the first vaccine was invented combating smallpox, which in fact word 'vaccine' was derived from the 'smallpox of cow' - Variolae vaccinae - for which Cowpox was inoculated prevent the person from contracting smallpox. For this historical reason, we use the aesthetics and biological mechanism of cowpox pustules as the ground element of our vaccination nomenclature. When you confront a new acquaintance, whether the person is up-to-date with the latest vaccine can be easily tell through reading the nomenclature on his body. All you need is to learn how to decode the nomenclature as in the instruction.

## How do we design for you?

Once you've subscribed to our service, we will do a full genomic profile for you. Your genomic profile will be stored in our VaccineBeauty system. Using the genomic information we create a simulation of your genetic phenotype, whenever a new viral risk factors appears in our system we will simulation how the viral risk factor is going to affect your body and design a correspondent vaccine for you.

Our vaccine, unlike the vaccine in 20th century that was applied as injection or tablets. Our new technology allows you to apply the vaccine like makeup at the location you like. The vaccine not only updates your inner immune system but also creating beautiful patterns on your skin signifying your body is protected from the newest viral threats. The vaccine will react with your immune system within 24 hours to keep your body's viral database up-to-date.

## Personalised Beauty

For our premier customer, we also provide the personalised beauty serum tailor to your genome. Now, you can vaccinate yourself while having the best ageing protection for your skin too.

## Immediate Update

After a short winter season of quietness with only 4 patches needed since the beginning of year 2036, we have an alarming news for the upcoming spring season of North Hemisphere. According to the report on 2036/03/04, a new strand of Influenza A/Paris/9/2036 (H5N7) was discovered in Paris, proving that Influenza is having a 5% evolution rate increase. We have also discovered a potential new folding of Ebola virus on the coast of Southern China, and a new semi dengue-fever structure genome at the surprisingly cold area of Quebec. The large scale immigration of urban foxes in London also cause the potential outbreak of the once contained London Respiratory Syndrome, naming LORS, within the high-rise banking district and its satellite residential areas. This immediate update guarantees to protect you with all the above mentioned viral threats. Please be aware of the people with aged vaccines for they could be the vector of transmission.

## Nomenclature



## Numbering System

The pustules consist of the following two different forms:

	Single pustule		Double pustule
One = 1		Six = 2*2 + 2	
	Two = 2		Seven = 1*2*2 + 1*2 + 1
	Three = 1*2 + 1		Eight = 1*2*2 + 1*2 + 2
	Four = 1*2 + 2		Nine = 1*2*2 + 2*2 + 1
	Five = 2*2 + 1		Ten = 1*2*2 + 2*2 + 2*2



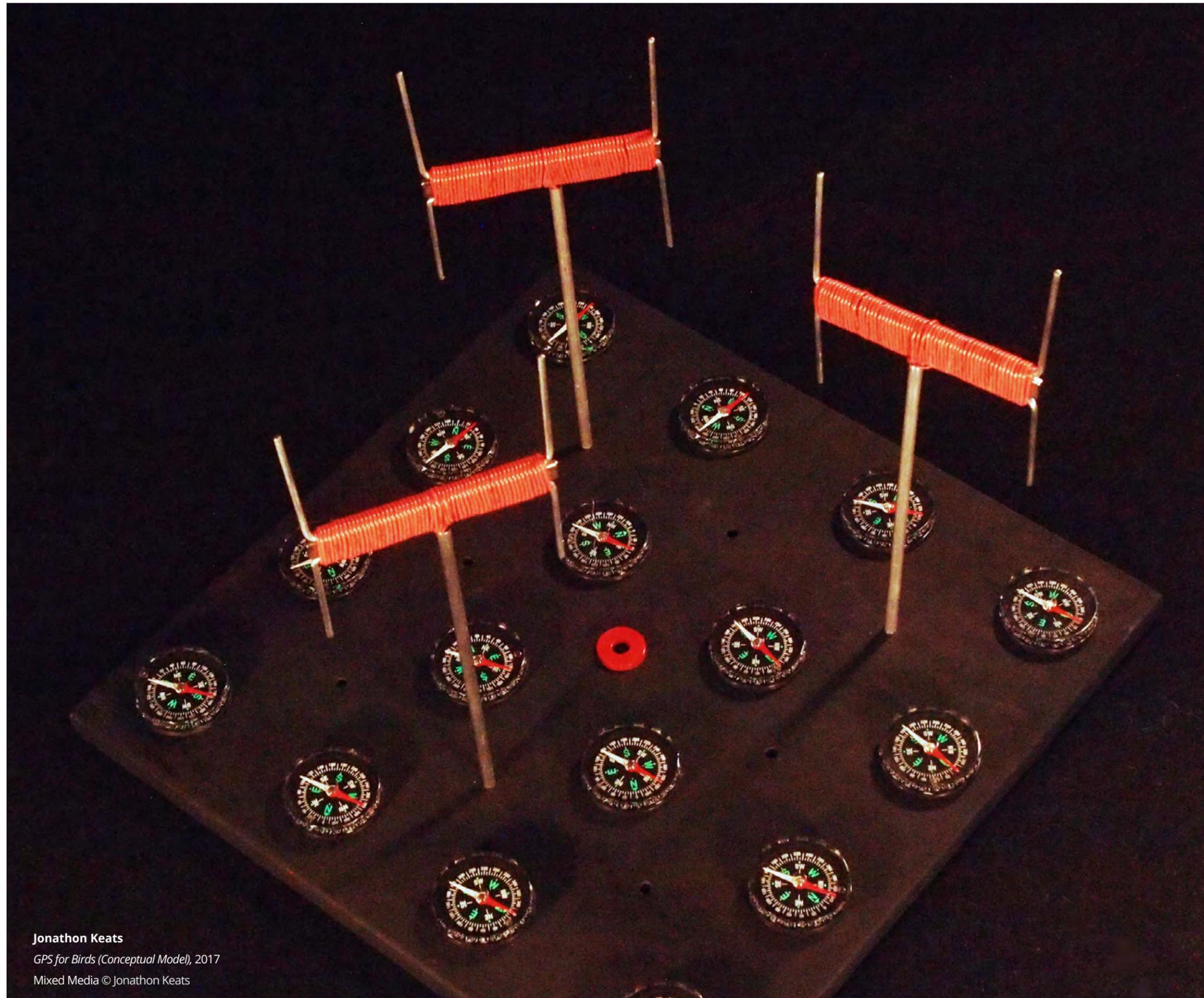
### Pei-Ying Lin

Page 140 and 143 (top): *Smallpox Syndrome - Vaccine Beauty Advertisement*, C-Type Print, 2012 - 2014 © Pei-Ying Lin

Above: *Smallpox Syndrome - Vaccine Beauty Set*, C-Type Print, 2012 - 2014 © Pei-Ying Lin

Bottom right, page 143: *Smallpox Syndrome - Smallpox Chronicle*, book, 2012 - 2014 © Pei-Ying Lin

Pei-Ying Lin is an artist/designer from Taiwan and currently based in Eindhoven, the Netherlands. Her main focus is on the intermingling of science and human society through artistic methods. She is particularly interested in building an open discussion involving different cultural perspective about our individual perception of the world. Recently Pei-Ying Lin has been focusing on manipulating the boundaries between the invisible/visible, living/non-living and finding ways in which to build tools and methods that facilitate such explorations. She has won the Honorary Mention in "Hybrid Arts Category" of Ars Electronica 2015, "Professional Runner Up" in Speculative Concepts of Core 77 Awards 2015, Bio Art and Design Award 2016, and was part of the first group of Taiwanese artists in residence of the program of Accelerate@CERN. Her project PSX Consultancy is in the permanent collection of Museum of Architecture and Design, Slovenia.



**Jonathon Keats**  
*GPS for Birds (Conceptual Model), 2017*  
Mixed Media © Jonathon Keats

## Reciprocal Biomimicry

*In recent years, engineers have designed body armors based on beetle shells and applied the aerodynamics of kingfisher beaks to bullet trains. Biomimicry is the buzzword, and the principle has served us well, but biomimicry rarely benefits the organisms whose innovations we appropriate. To compensate, experimental philosopher Jonathon Keats has founded the Reciprocal Biomimicry Initiative, a program dedicated to systematically adapting human technologies to benefit other organisms.*

text and images: **Jonathon Keats**  
interviewer: **Giovanni Aloï**

Returning from a hunting trip in 1941, a Swiss engineer named George de Mestral spent hours picking burrs from his Irish pointer's fur. Curious about how they stuck, he put one under a microscope. The pod was clad with miniature hooks.

Given his profession, de Mestral couldn't help but admire the ingenuity of the adaptation, which allows burdock plants to spread their seed by exploiting animal locomotion. Nor could he resist the temptation to emulate the natural invention. He artificially recreated the burdock hook in nylon, fashioning a fastener he dubbed "Velcro" and touting it as a zipperless zipper.

Velcro is hardly the only example of biomimicry, the practice of using the innovations of other species to solve human problems. For instance, early designers of gliders learned about lift and thrust by observing birds in flight. More recently, birds have provided solutions to problems in airplane stability and have shown Japanese engineers how to improve ground transportation.

When Shinkansen bullet trains pass through tunnels, they encounter changes in air resistance that can produce sound waves that are audible more than a quarter mile away. In physical terms, the phenomenon is equivalent to the ripples surrounding a body hitting water. For a Shinkansen engineer who happened also to be a birdwatcher, the problem called to mind the kingfisher, a bird capable of diving in pursuit of prey without making waves. Japanese bullet trains were redesigned accordingly, their nose cones shaped like a kingfisher's beak.

It was an ingenious solution, and the Japan Railways Group received kudos for being sensitive to nature. But did the natural world benefit in any meaningful way? Was the kingfisher compensated? No more than the burdock, which wasn't even mentioned in the Velcro patent.

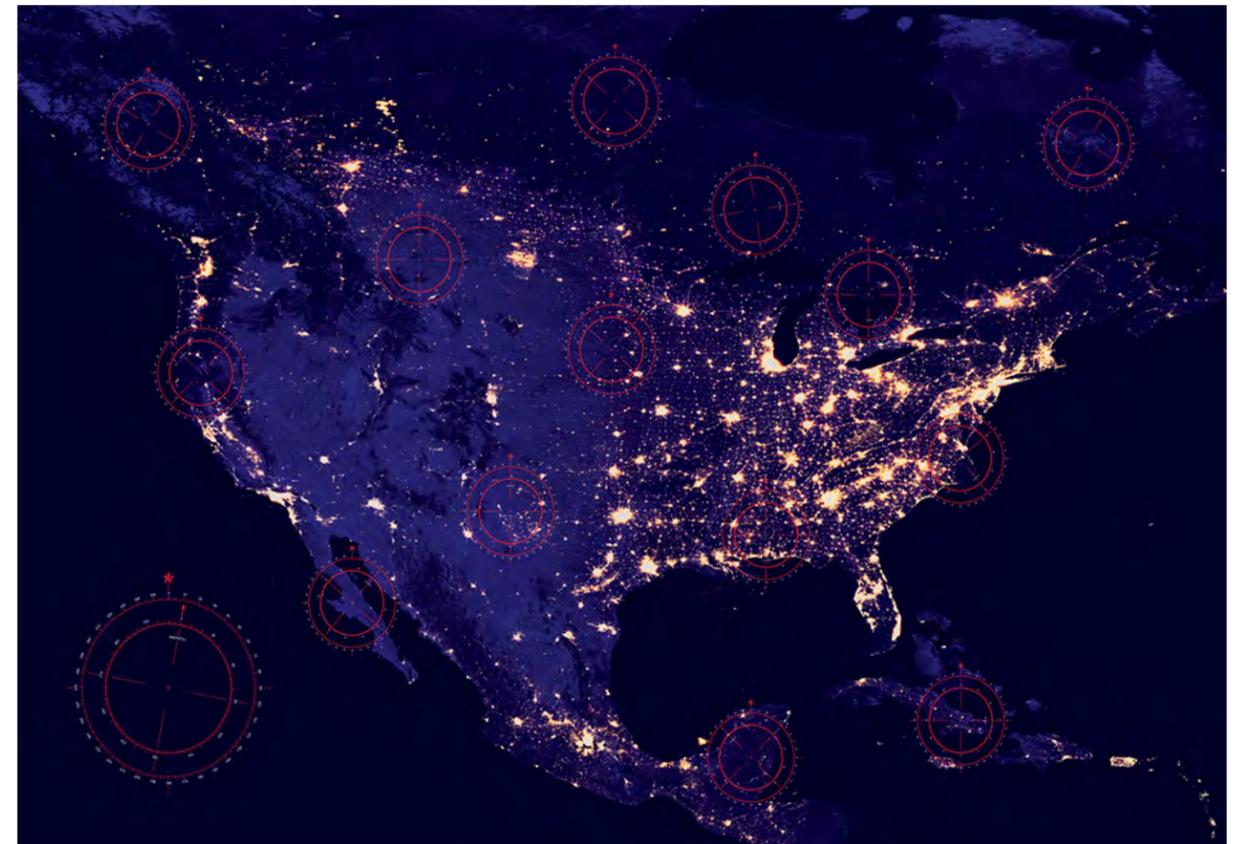
Biomimicry is now widespread. Frogs' feet have inspired tire treads. TV screens exploit the structural colors of butterfly pigments. Industrial cements emulate the adhesives in mussel beds. A recent Point Loma Nazarene University report estimates that biomimicry will be a \$1.6 trillion industry by 2030 – the same year that Harvard biologist Edward O. Wilson predicts 20 percent of species could disappear as humans drive the planet toward a sixth mass extinction.

Aided by biomimicry, we are only becoming more ecologically predominant, and more destructive to the organisms whose innovations we plunder. In fairness to all species, humans need to give back. We need to let other organisms exploit our innovations for their own benefit.

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I have founded the *Reciprocal Biomimicry Initiative* to facilitate the transfer of technology in this alternative direction. The initiative is broad in scope, and dedicated to redistributing all human intellectual property according to need. Since the most pressing crises faced by most species are caused by us, the initial focus is on technologically compensating imperiled animals and plants for our destructive impact on their habitats.

Consider the plight of birds. Migratory species sometimes travel to the wrong places, or arrive at the wrong time, as climate change wreaks havoc on their nesting sites as well as their internal



Jonathon Keats

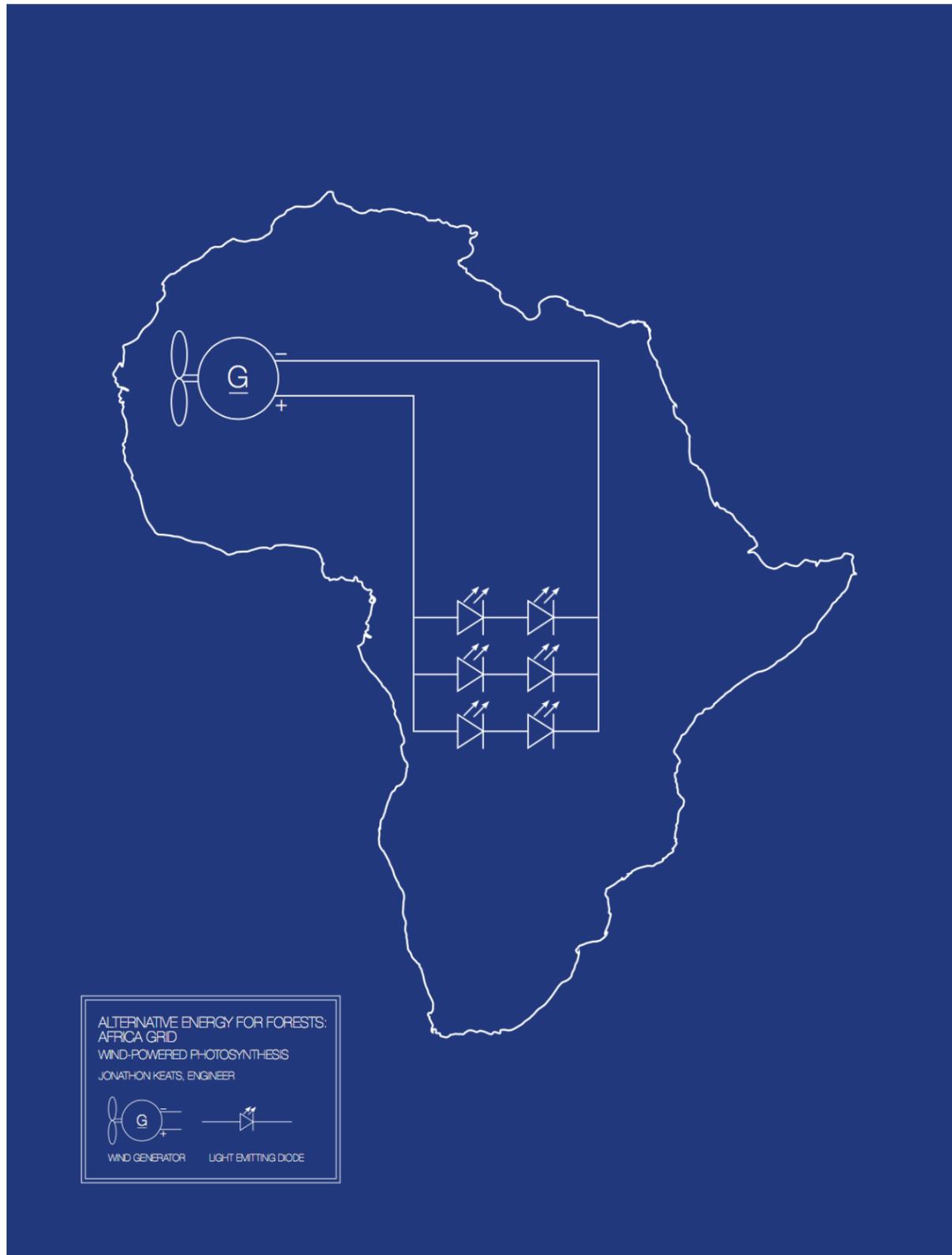
*Air Traffic Control Towers for Birds (National Grid), 2017, Inkjet. Print Base Map Courtesy of NASA Earth Observatory © Jonathon Keats*

clocks. The evolution of their instinctual behavior is not occurring fast enough to keep up with the rate of global warming. Advanced technologies are needed to inform their migratory decisions. Fortunately, ground sensors are now ubiquitous. Unfortunately, birds have no natural way to access them in order to identify ideal migration routes.

Electromagnets can help fill the communications gap. Birds naturally fly by sensing Earth's magnetic field. Helmholtz coils can cancel out geomagnetism, and powerful solenoids can superimpose an artificial north and south. In other words, electromagnetism can provide an interface for reorienting birds' internal compasses.

The Helmholtz coils and solenoids could be attached to drones that fly with flocks, their flight routes informed by real-time data from an environmental sensor network. A more ambitious plan would entail the construction of air traffic control towers for birds. Placed along flightways, these electromagnetic towers would broadly reshape the geomagnetic field, warping compass lines to guide birds toward the most advantageous destinations. The towers could also adjust birds' timing by putting them in holding patterns. And many accidents could be averted by navigating birds around big cities.

Climate change impacts other organisms in other ways. For corals, one problem is that oceans have become more turbid, di-



**Jonathon Keats**  
*Alternative Energy for Forests (Africa Grid), 2017 © Jonathon Keats*



**Jonathon Keats**  
*Alternative Energy for Forests (South America Grid), 2017 © Jonathon Keats*

minishing the light they need to perform photosynthesis. An obvious workaround would be to outfit coral reefs with fiber optic cables.

Conveying light efficiently regardless of surrounding water clarity, the fibers could be illuminated in myriad ways. The most direct method would entail running cable from the reef to the ocean surface, where sunlight could be concentrated with a parabolic mirror. Alternately the ocean surface could support photovoltaic cells or wave energy generators, with electrical wires powering lighting units on the sea floor. In that case, optical fibers would subdivide the light, efficiently distributing photons to the reef's photosynthetic algae.

Alternative energy sources would not only benefit corals. They could also provide a lifeline to forests impacted by air pollution or cloud cover. For instance, a wind farm could be established in the Sahara Desert, and the electricity could be carried to the Congo Basin. The current would be sufficient to illuminate a vast array of light emitting diodes covering the forest canopy, finally ending trees' dependency on sunlight.

Having energy alternatives is important in a time of climate change because climate phenomena are increasingly unpredictable, and alternative energy sources can bolster systemic resilience. The *Reciprocal Biomimicry Initiative*, therefore, seeks to provide all species with access to all forms of energy, from solar and wind to nuclear.

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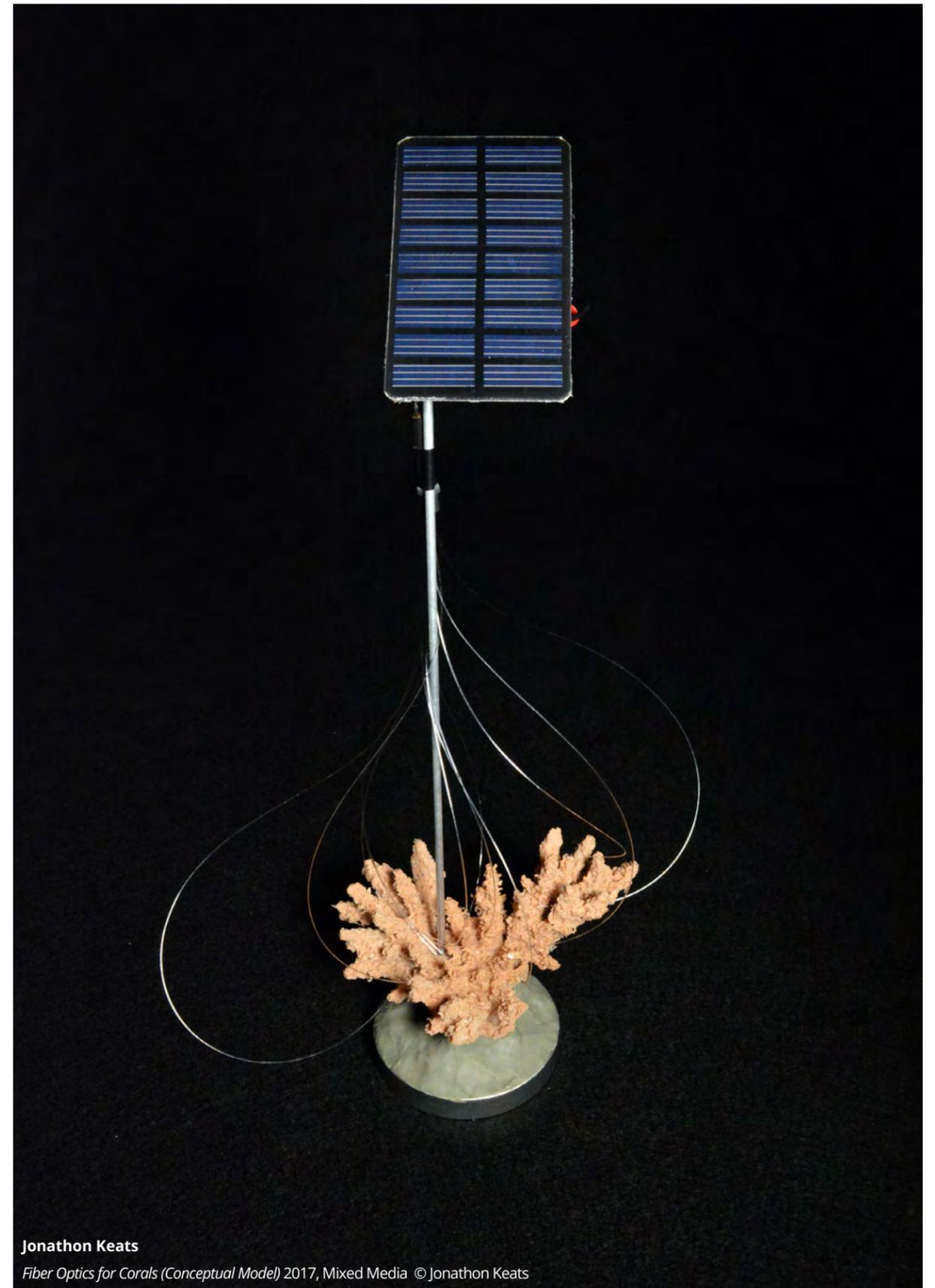
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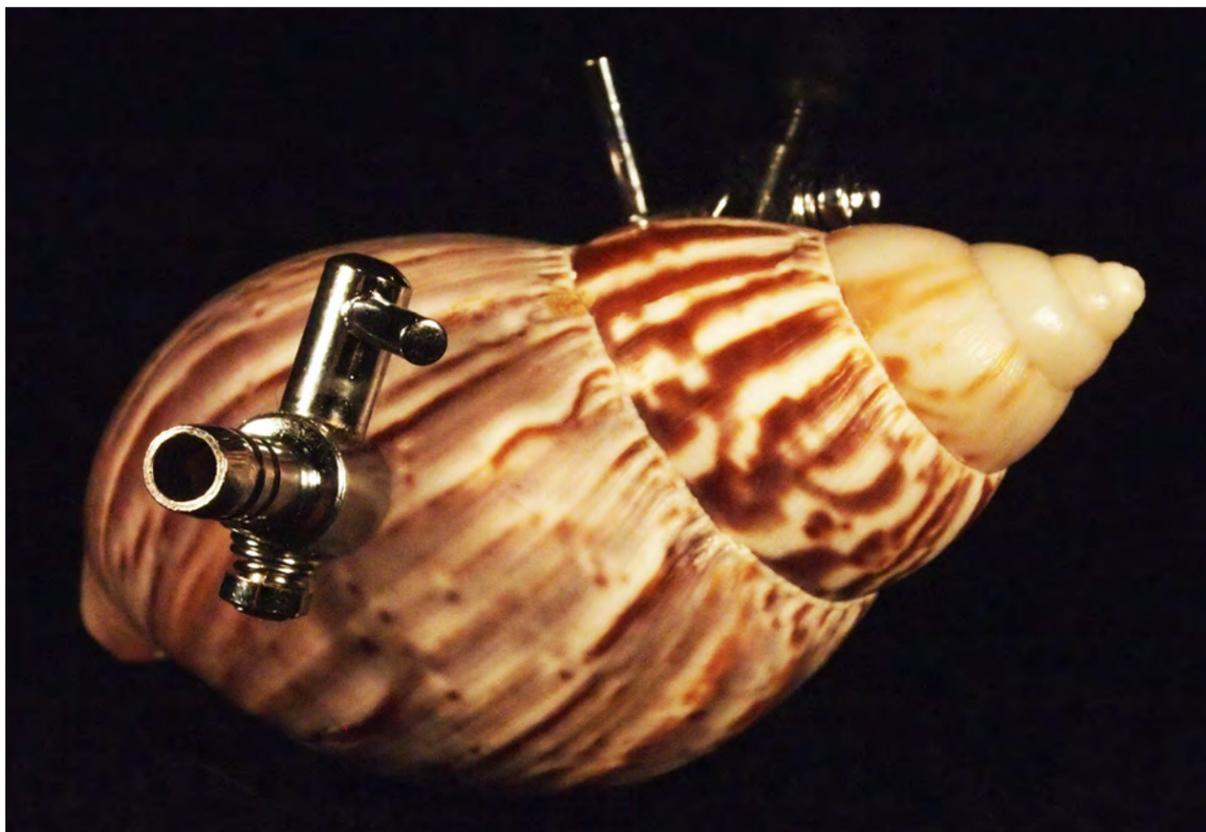
This pages present some of the many opportunities for reciprocal biomimicry. The drawings, models, and prototypes cover not only alternative energy schemes and navigational mechanisms, but also technological fixes for problems ranging from colony collapse disorder to ocean acidification to urban sprawl. For instance, as cities encroach on the habitats of reptiles, natural camouflage may no longer be effective. The *Reciprocal Biomimicry Initiative*, therefore, seeks to outfit turtles and tortoises with military camouflage designed for urban warfare.

And yet, for all the remarkable ideas we have to give, we need to acknowledge our limitations. We are but one species, and a relatively new one at that. Our braininess is no match for the evolved intelligence of life in totality. We tacitly acknowledge this fact every time we plunder ideas from other species.

Beyond reciprocal biomimicry, we can provide compensation to non-humans by legally recognizing the inventors of technologies inspired by nature. It may be too late to reassign the Velcro patent to the burdock plant, but future patent applications can formally name animals or plants or bacteria as inventors. The licensing fees they receive from industry can be spent to conserve their habitats or to lobby on their behalf. In that way all species can be enfranchised into the economic and political systems heretofore monopolized by humans.

Yet we must strive simultaneously to become better mimics. What makes biomimicry succeed is the process of generalization. For centuries humans strove to fly by flapping artificial wings, succeeding only when the essential actions of lift and thrust were decoupled and recombined in a form suitable for engineering. The





**Jonathon Keats**

*Breathing Apparatus for Mollusks, 2017, mixed media © Jonathon Keats*

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*My formal training is in philosophy.  
 I studied logic and epistemology  
 and aesthetics. These all provided  
 good training for rigorous thinking,  
 but philosophy seemed lacking to  
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 and who it reached.*  
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formula worked for the first gliders and still applies to 747s. Applicability broadens with an increase in generalization, and the potential for generalization increases with the gamut of observations. Therefore the ultimate act of biomimicry, which could apply to all human technology, would naturally derive from life in its entirety.

One key generalization is that non-human species use technology only reluctantly. Birds and tortoises and corals and trees are all luddites *avant la lettre*.

That may make them tough customers for reciprocal biomimicry. Their take-up of our technologies may be fleeting, contingent on our commitment to manufacturing and servicing these devices for them. There is no clear evolutionary path for rainforests to work out the steps for manufacturing wind turbines and LEDs.

However if humans can integrate the reluctance of other species into our research and development cycles – and into our consumption habits as well – we might just find our way to a more sustainable future amenable to all species. If biomimicry lives up to its potential, reciprocal biomimicry may not be required after all.

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**Jonathon Keats**

*Urban Camouflage for Reptiles, 2015-17, mixed media © Jonathon Keats*

**Giovanni Aloï:** In 2000, you sat in a chair and thought for 24 hours while a female model posed nude in the gallery. Your thoughts were then sold to patrons as art, at a price determined by dividing their annual income down to the minute. What was the background for this project? Which works by other artists informed the making of this piece?

**Jonathon Keats:** My formal training is in philosophy. I studied logic and epistemology and aesthetics. These all provided good training for rigorous thinking, but philosophy seemed lacking to me in terms of how it was practiced and who it reached.

I found the practice to be unnecessarily restricted to argumentation, generally at a high level of abstraction. When natural philosophy became science, the philosophers who remained, turned their back on the observational and experimental dimensions of thought. Philosophy transitioned from a mode of discovery to a sort of intellectual bookkeeping at best, and at worst an excuse for unsubstantiated bluster. My primary reason for becoming a philosopher was my curiosity about everything. I wanted to explore ideas, not to persuade people of my opinions.

And that brings me to the second limitation: that philoso-

phy reaches only a very small and self-selecting audience. Very few people participate in the discussion, which is highly technical, and loaded with foreboding jargon.

Art has its own jargon and bluster but nevertheless seemed to me to afford an opportunity to do philosophy in public. Partly I was inspired by conceptual artists such as Sol LeWitt, who were asking questions that were as provocative as any I was encountering in academia. I was equally inspired by what was missing in art: a restrictive tradition. Ever since Marcel Duchamp broke with art history by presenting readymade objects as art, artistic practice has been wide open. Much of this freedom has been squandered in my opinion, especially by art that is solely self-referential, self-consciously recapitulating the revolution achieved by Duchamp a century ago.

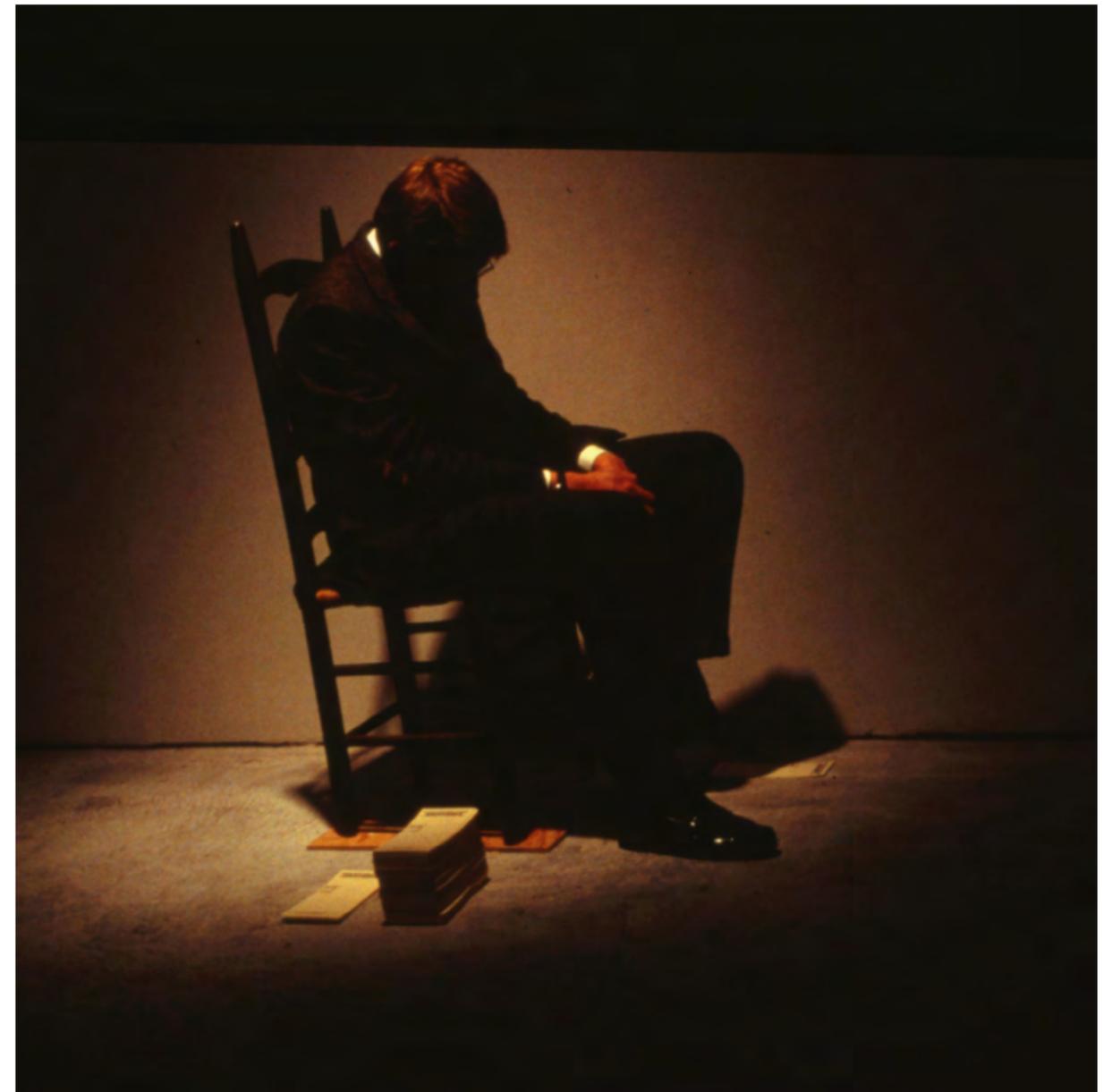
But the lack of professional standards has made art a counterforce to the specialization that has driven fields including philosophy increasingly in the direction of narrowmindedness and obscurity. Not needing to train as a painter or sculptor, I realized I could become an artist and make art on my own terms, using the art world as a platform for doing philosophy.

My first works were actually too artistic, at least by my current standards. They were too much about art, too closely aligned with Duchamp and LeWitt and what I'd studied in aesthetics. *Twenty Four Hour Cogito*, my first gallery work, falls into that category. I was concerned with the definition of art, which has been debated for millennia. My idea was that we could discover the essence not by constructing necessary and sufficient conditions but rather by *reductio ad absurdum*. To achieve that, I sought to reduce art to nothing but thought, contextualizing my thinking process with artistic clichés. So, I had a model posing nude, alternating with a still-life bowl of fruit. I also aspired to investigate the art market, which is why I put my thoughts up for sale, where a minute of my thought cost whatever the client made per minute in his or her chosen career. I used a factory timeclock to track my thoughts and to certify them as work.

All of this sounds very complicated in retrospect, and I suspect it was confusing to people at the time. However, the confusion turned out to be beneficial because people interpreted the work in ways I'd never have imagined. For instance, some saw it as a reflection of labor and value in the burgeoning dotcom culture of San Francisco. That made me realize that I needed to strive for greater clarity in my work, and also made me recognize that the work could explore any phenomenon at all – potentially even phenomena I didn't set out to explore. This open-endedness perfectly fit my curiosity. Philosophy led me to make art, but it was through art that I learned how to do philosophy.

**Aloi:** When did you begin to focus on “thought experiments” as a form of conceptual art?

**Keats:** I believe that every project I've ever done has been a thought experiment, though I probably didn't start using the term until around 2004, when I enlisted a laboratory at UC Berkeley to work with me on a literal experiment: an attempt to genetically engineer God. My motivation was to address the schism between faith and reason by applying religion to science and science to religion. Of course, my thought experiments bear little resemblance to traditio-



Jonathon Keats

*Twenty Four Hour Cogito*, mixed media Installation, 2000 © Jonathon Keats

nal philosophical techniques. Conventionally the thought experiment is a sort of rhetorical trick: You coerce somebody to agree with you by presenting them with a counterfactual situation and showing how that counterfactual leads to an absurdity. Since I don't have a position I'm arguing, I've made my thought experiments genuinely experimental in the sense of not knowing in advance what the outcome will be. Even outside the laboratory, I create scenarios in which anything can happen. That said, my experiments are carefully structured and based on hypotheses. They're designed to encour-

age certain kinds of interaction that I believe will be conducive to collective exploration and discussion.

An experiment can take us in directions that we might otherwise not consider. By initiating a thought experiment, and allowing it to run its course in public, I open myself up to ideas and questions that might otherwise might never have occurred to me. I measure success partly based on the extent that the results are unexpectedly interesting.

**Aloi:** Some of your early works are concerned with the law, challenging the law, and notions of identity as conceived by the law. I am specifically thinking of *Every Entity Is Identical to Itself* (2002), or the copyrighting of your mind, that took place in 2003 with *Brain Trust*. You've subsequently often delved into economics. What's so fascinating about the law and economics, and which philosophical references have informed these bodies of work?

**Keats:** I want to explore the underlying operating systems that shape the world in which we live. So I often focus my attention on topics such as economics and law. In the former category, I've frequently experimented with money and banking. For instance, in 2013 at Rockefeller Center, I founded a bank that put money into a quantum superposition, such that everyone on the planet could withdraw whatever funds anyone deposited. Money is central to almost every human interaction, yet even economists struggle to understand the flow of cash. The situation isn't exactly analogous to quantum physics – the interactions between subatomic particles that are fundamental to our universe yet elude deep scientific explanation – but there are parallels in terms of our tolerance for black-box systems that are inexplicably functional. By setting up an experimental economic system predicated on scientific theory that researchers use every day yet cannot fully fathom, I want to encourage the public to confront the known and unknown unknowns in both economics and physics.

In the case of law, I've probed both the legislative process and the implications of our present legal code. Petitioning for a law of logic – which couldn't be broken even if desired – was in many ways akin to my approach to artistic creation in *Twenty Four Hour Cogito*. It was a strategy to confront the limits of law – to reckon with self-determination and free will – through a form of *reductio ad absurdum*.

In contrast, *Brain Trust* was an effort to see the implications of the laws we live by. I exploited what I perceived as a loophole in the Copyright Act to press my way toward immortality. Copyright law provides intellectual property protection on an artwork for seventy years beyond the lifespan of the artist. By copyrighting my mind as a sculpture and licensing neural networks to others, I sought a way to subsist for seven decades beyond my own death – at least according to the logic of *cogito ergo sum*.

On one level, *Brain Trust* poses questions adjacent to those motivating *Every Entity Is Identical to Itself*. I'm investigating the limits of legal action by attempting to overcome death by legal means. On another level, *Brain Trust* uses the dubious prospect of immortality to investigate the assumptions of intellectual property, especially in a time when companies such as Disney are doing all they can to make intellectual property eternal. The persistence of intellectual

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*I very much hope that the copyright on my brain will be challenged after I die. In a sense, all that I've done so far is setting up that possibility. The court case will be the most telling thought experiment.*  
.....



**Jonathon Keats**

*The Quantum Bank*, mixed media Installation, 2013 © Jonathon Keats

property poses deep challenges to the future of creativity because it keeps control over ideas in the past, a situation that becomes more extreme as the length of copyright is extended.

I very much hope that the copyright on my brain will be challenged after I die. In a sense, all that I've done so far is setting up that possibility. The court case will be the most telling thought experiment.

**Aloi:** Often, your work is concerned with ontology; it aims to subvert the “presumed naturalness” of categories. Your ideas are usually big, to some they might even appear outlandish, and yet their hypothetical applications are very real and potentially world-changing. How important is accessibility in your practice?

**Keats:** I believe the ideal artwork would be accessible to everybody and could change everything. I don't say that out of megalomania, nor do I claim to have even approached this ideal. I set out these standards because I see art as uniquely suited to the task of asking *what if?* The societal operating systems I mentioned earlier are deeply entrenched. They're extremely powerful and usually imperceptible to the public. As a result, the decisions we make as individuals and as a society tend to be limited in ways we might not even realize. I want to see past the assumptions that I unconsciously make and that are made on my behalf – to consider what I really want for civilization and the planet – and I'd like to encourage the same in everyone else. Philosophy provides some of the intellectual apparatus for self-examination and meta-analysis, but not in ways that are broadly intelligible or appealing. Artistic expression can draw philosophy out of academia and into society.

The question, then, is how to express these philosophical mechanisms artistically. I often do so by taking up a specific issue and instantiating a hypothetical future distant enough from present reality to make space for possibility. For example, in 2015 I proposed to resolve geopolitical conflicts by taking charge of plate tectonics. The premise was quite simple: Much of the animosity in the world today is a result of nationalism and xenophobia. Our physical separation brings out our differences, leading not only to bloody conflict but also to a loss of common purpose in addressing global issues such as climate change. I wanted to literally bring people together by creating a new supercontinent akin to Pangaea, but arranged specifically to counteract present-day divisions. I called it *Pangaea Optima*, and I did everything I could to figure out how to bring it about practically. My primary method was to redistribute heat in Earth's mantle. I developed subcrustal power plants and other technologies to facilitate this grand feat of political geoengineering.

Projects like this *are* outlandish, even if their presentation is totally straightforward and potentially actionable. The outlandishness not only gets attention but also widens the realm of intermediate options. A radical proposition affords many degrees of freedom. At the same time, feasibility gives it traction. Because it could really happen, we can't be passive about it. It carries both promise and risk and all the more so given how dramatically the world could change as a result. I refer to this practice as *prototyping tomorrow*.

And I don't wish to be the only one doing it. My imagination is limited, as is my ability to engage other people's attention. We need as many practitioners as possible. In fact, prototyping tomorrow needs to become a habit for everyone. The movement between the imminent and the outlandish generates possibilities. If everyone acts as an artist, we can all be philosophers.

**Aloi:** In the mid-2000s, your focus started to more consistently shift towards the non-human. In 2006, you enabled 50 Leyland cypresses to make art. The same year, you choreographed a ballet for bees. The year after, you staged the first pornographic cinematic experience for plants, and a few years later, you gave plants the opportunity to experience the glow of the Italian sky through film. In early 2011, you turned your attention to flora once more, opening a "photosynthetic restaurant" where plants could enjoy "gourmet sunlight", and just a couple years ago, in 2017, you developed an alternative energy system for trees. What has motivated this non-



Jonathon Keats

*Pangaea Optima*, mixed media Installation, 2015 © Jonathon Keats

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*I believe the ideal artwork would be accessible to everybody and could change everything. I don't say that out of megalomania, nor do I claim to have even approached this ideal. I set out these standards because I see art as uniquely suited to the task of asking what if?*  
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human turn? And why have you focussed specifically on plants?

**Keats:** I don't have a special interest in plants, at least not to a greater extent than my interest in other life on this planet including my own species. But I often work with plants, or for them, in order to better understand humans in relation to other organisms. Because plants seem so unlike us, they can attune us to what all life has in common and also to the peculiarities of *Homo sapiens*.

When I gave cypress trees the means to make art, and exhibited their work in a gallery, I was especially interested in examining human chauvinism, challenging some of the standards we use to claim special privileges. Most humans think that art is something humans alone can make, and are especially certain that the requisite intelligence and creativity cannot be found in trees. But if you consider the distribution of branches and leaves, for instance, you find a remarkable level of intelligence. The branching serves the purpose of maximizing photosynthesis, a complex problem that has been systematically addressed through evolution. The evolutionary process also looks to be creative, in the sense that random mutation allows each individual tree to solve the photosynthetic problem uniquely. The distribution of branches is non-obvious but also not arbitrary.



**Jonathon Keats**  
*Agrifolk Art*, mixed media Installation, 2006 © Jonathon Keats

When humans create paintings and drawings, we enlist evolved traits toward ends for which they weren't intended. By tying pencils to the branches of cypresses and placing easels in front of them, I provided trees with an equivalent diversion from evolved function, directing the intelligence and creativity of their branching toward mark-making. The drawings they made by the movement of their limbs in the breeze were arguably as artistically rich as the Mona Lisa. By framing them and putting them on the wall of an art gallery, I simply provided a context for people to appreciate them as art, and by extension to appreciate the trees in terms we ordinarily reserve for one another. For some people, that may be humbling. For me, it was exhilarating to find how much more artistic creativity there is on the planet than I'd been led to believe.

My photosynthetic restaurant and my movies for plants – which I continue to make today – take the opposite approach. The plants are not the creators, but rather the consumers of distinctively human cultural products. In the case of the pornography, for in

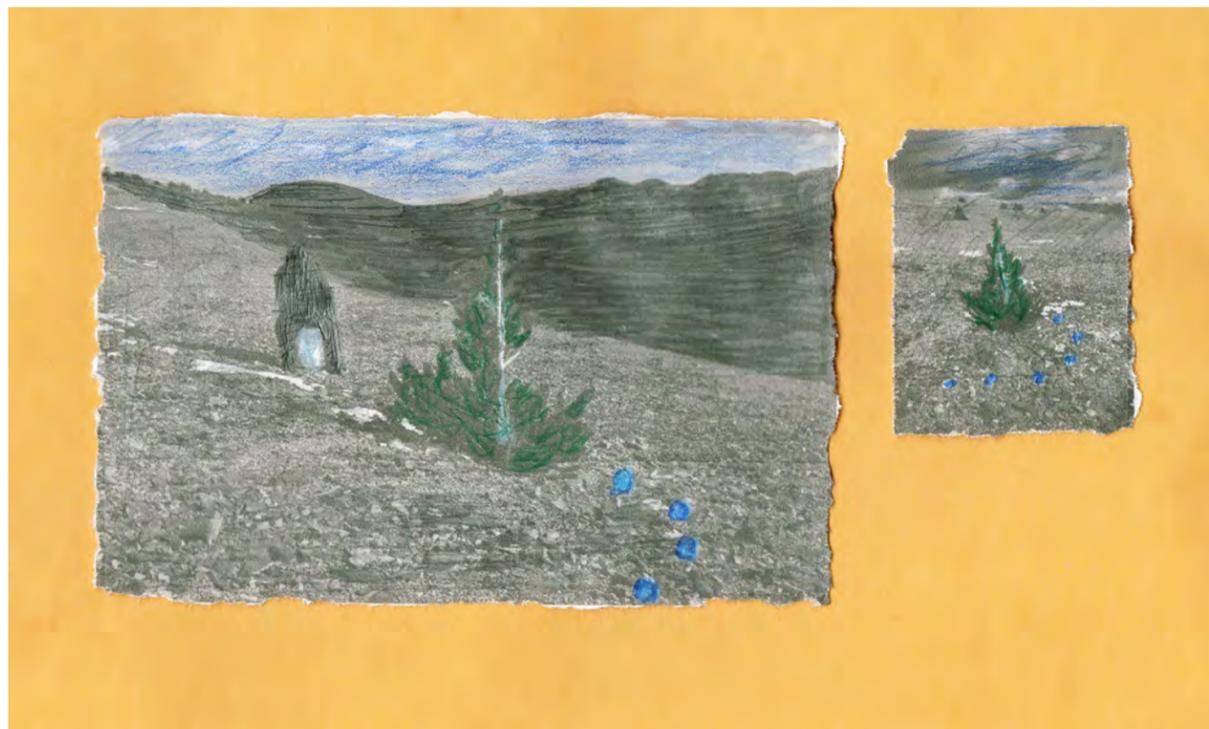


**Jonathon Keats**  
*Pollinated*, mixed media Installation, 2007 © Jonathon Keats

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*Of course, the plant porn also asks fundamental questions about human experience, and the artwork by cypresses puts us in a position of more closely considering our own masterpieces and what we might see in them that was not intended by the artist.*  
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stance, I took a favorite human movie genre and translated it into terms a plant could enjoy: I filmed honeybees pollinating flowers in the wild, and projected the footage directly onto the foliage of indoor plants so that they could vicariously experience the thrill of sex through the play of light. Beyond the benefits to my botanical audience, I believe this film can help us to see our own cultural practices from the outside. So much of our experience is indirect, encountered on-screen. Sometimes we barely notice or remember the source. Watching plants watching movies, we can gain perspective on what we lose and gain through our viewing habits.

Of course, the plant porn also asks fundamental questions about human experience, and the artwork by cypresses puts us in a position of more closely considering our own masterpieces and what we might see in them that was not intended by the artist. These projects can be interpreted in myriad ways, engaging audiences based on their interests. The pornography and easel drawing projects are philosophically connected and connect to my alternative energy schemes for plants.



**Jonathon Keats**

*Centuries of the Bristlecone*, mixed media, 2017-21 © Jonathon Keats

The idea of providing plants with means of exploiting wind and water and nuclear power came out of my conviction that biomimicry is unfair. We're constantly plundering the intellectual property of other species to build human technologies, without compensating them in any way. (When is the last time a thistle got royalties on Velcro?) In collaboration with Bucknell University's Center for Sustainability and the Environment, I set out to compensate for biomimetic exploitation by making human technologies available to other species.

I exhibited prototypes and plans for nearly a dozen technological adaptations at the Samek Art Museum. Many of them are ready for production, such as the wind power device, a turbine that turns mechanical energy into light sequences of our past engineering. Might we learn other strategies of survival from other species? Might that be a better approach to biomimicry – better for all species?

**Aloi:** What are you currently working on?

**Keats:** I'm currently developing a new kind of calendar, calibrated by trees. The basic idea is to enlist the varying thickness of annual ring growth so that the timekeeping is erratic by atomic clock standards, but reflects the ground conditions of life as lived on our planet.

The calendar will be monumental, built on Mt. Washington

in Eastern Nevada, on a stretch of land owned by the Long Now Foundation. Spirals of titanium markers will be set around bristlecone pine trees, which have an expected lifespan of 5,000 years. The markers will be regularly spaced based on the estimate girth of the trees in 100 years, 500 years and more – *if* the future growth rate is consistent with the present. As growth varies with climate change, the arboreal calendar will deviate from Gregorian time. People will be challenged to decide whether the time kept by the trees is ultimately more valid: whether to live on bristlecone time.

Since the titanium spirals on Mt. Washington will be remote and hard to reach, bristlecone time will also be measured by a device known as a dendrometer. Data will be relayed to a monumental electromechanical calendar at the Nevada Museum of Art in Reno, and the signal will also be accessible to the public as a new time protocol to calibrate municipal clocks, corporate scheduling systems, and personal smartphones and watches.

I'm simultaneously starting to develop other calendrical systems based on other natural phenomena that vary with the climate. In Alaska, working with the Anchorage Museum, I'm exploring calendrical systems calibrated by the accretion and ablation of glaciers. And in the Ticino region of Switzerland, I'm developing a timekeeping mechanism driven by the flow of a river.

I believe that the time kept by atomic clocks gives us the false illusion of control: being able to manage the present and predict the future. In arboreal and glacial and fluvial calendars, time is alive with contingencies. We experience the complexity of the global environment, especially as these calendars begin to drift away from Gregorian time and from one another. We come to terms with where planning and prediction fail us: the limitations of what we can know about the future – and the threat of hubris.

Acclaimed as a "poet of ideas" by *The New Yorker* and a "multimedia philosopher-prophet" by *The Atlantic*, **Jonathon Keats** is an experimental philosopher, artist and writer based in the United States and Italy. Over the past two decades, his conceptually-driven interdisciplinary art projects have been hosted by institutions ranging from Arizona State University to the Los Angeles County Museum of Art, which awarded him a 2015-16 Art + Technology Lab Grant. Keats is the author of six books, most recently *You Belong to the Universe: Buckminster Fuller and the Future*, published by Oxford University Press, and a recipient of the American Library Association's Sophie Brody Medal for his fiction. He was recently the Black Mountain College Legacy Fellow at the University of North Carolina - Asheville, and is currently a Research Fellow at the Nevada Museum of Art's Center for Art + Environment, a Polar Lab Artist at the Anchorage Museum, and an Artist-in-Residence at both the Fraunhofer Institutes in Germany and UC Berkeley's Sagehen Creek Field Station in California. Keats is represented by Modernism Gallery, San Francisco.

# Eugenia Cheng: The Art of Logic

Dr. Eugenia Cheng is Associate Professor at the School of the Art Institute of Chicago. She won tenure in Pure Mathematics at the University of Sheffield, UK, where she is now Honorary Fellow. She has previously taught at the Universities of Cambridge, Chicago, and Nice and holds a Ph.D. in pure mathematics from the University of Cambridge. Alongside her research in Category Theory and undergraduate teaching, her aim is to rid the world of “math phobia”.

Interviewer: **Giovanni Aloï**

Interviewee: **Eugenia Cheng**

**E**ugenia Cheng’s first popular math book, *How to Bake Pi*, was published by Basic Books in 2015 to widespread acclaim in *from the New York Times, National Geographic, Scientific American*. Eugenia has been interviewed around the world including on the BBC, NPR and *The Late Show with Stephen Colbert*. Her second book, *Beyond Infinity* was published in 2017 and was shortlisted for the Royal Society Insight Investment ScienceBook Prize. Her most recent book, *The Art of Logic in an Illogical World*, was published in 2018 and was praised in *The Guardian*.

Cheng was a pioneer of math on YouTube, and her most viewed video, about math and bagels, has been viewed more than 18 million times to date. She has also assisted with mathematics in elementary schools and high schools for 20 years. Cheng writes the “Everyday Math” column for the *Wall Street Journal*, is a concert pianist and founded the Liederstube, a not-for-profit organization in Chicago bringing classical music to a wider audience. In 2017 she completed her first mathematical art commission, for Hotel EMC2 in Chicago; her second was installed in 2018 in the Living Architecture exhibit at 6018 North.

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*I hope to show people that mathematics is not what they always thought it was, that it’s not just about numbers, equations and problem-solving. I hope to reach people who “fell off” the math train at some point in the past, and show them that math can be fun and beautiful, not that awful hated subject in high school.*  
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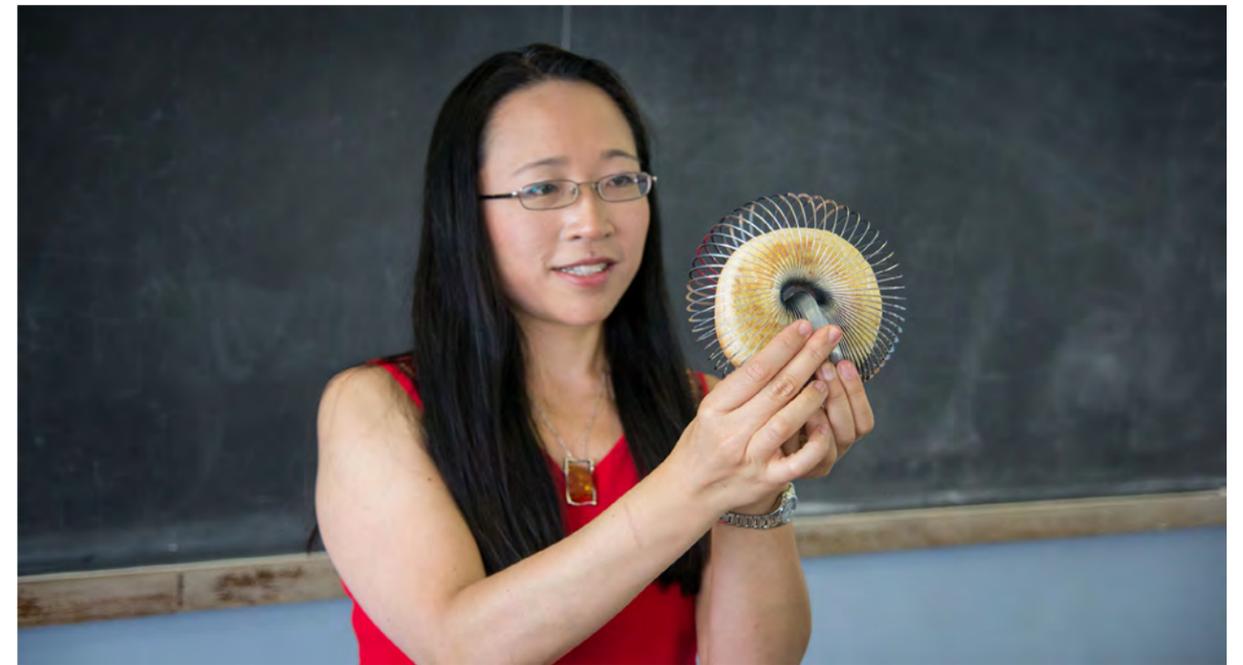
**Giovanni Aloï:** What was Eugenia Cheng interested in as a child?

**Eugenia Cheng:** Math, music, reading, writing, making things (out of household items like empty toilet paper rolls, yoghurt pots, egg cartons...).

**Aloï:** How did you become interested in Pure Mathematics, and can you explain to us what it is?

**Cheng:** I think I never stopped being the toddler who keeps asking the question “Why?” until all the adults are fed up with them! For me, pure mathematics provides the most satisfying and irrefutable answers to the question “Why?” at the end of a long string of Whys.

In 2015 you published a book titled *How to Bake Pi: An Edible Exploration of the Mathematics of Mathematics*. Each chapter of the book begins with a recipe for a dessert, to illustrate the methods and principles of mathematics and how they relate to one another.



**Eugenia Cheng**

Eugenia Cheng uses a Slinky toy and a bagel to demonstrate the concept of a torus, the geometric shape of a bagel. A torus can be cut into a Möbius strip. Photograph: University of Sheffield

The book is an explanation of the foundations and architecture of Category theory. Category theory is a branch of mathematics that formalizes mathematical structure and its concepts.

**Aloï:** Can you talk to us about the importance of accessibility in your work?

**Cheng:** I hope to show people that mathematics is not what they always thought it was, that it’s not just about numbers, equations and problem-solving. I hope to reach people who “fell off” the math train at some point in the past, and show them that math can be fun and beautiful, not that awful hated subject in high school. I hope to show that math is there to be illuminating, not just to answer questions and provide answers, and that it’s everywhere, all around us connecting things together whether we know it’s there or not.

Many people are put off by math because of the way it is forced on you at school with a series of looming (boring) tests as hurdles you have to leap over in order to move onto the next phase. The thing about a hurdle is that once you’ve got over it you can just forget about it, and many people think you don’t really need math in your daily life. Well it’s true, you don’t, but math is about thinking more clearly, and wouldn’t it be better if more people in the world could think more clearly, especially these days? That’s why I want to share my love of math as widely as possible.

**Aloï:** More specifically, how did the idea for *How to Bake Pi* come about and how did the metaphorical analogy between mathematics

and baking emerge? Or is it more than a metaphor?

**Cheng:** I love food and I love maths, but unfortunately most people love food more than maths. I have always liked telling unexpected stories to give more character and “flavour” to maths, and I realised that the ones involving food were particularly popular with my students, especially when it involved a demonstration. I enjoyed it too as I secretly always wanted to be on a cooking show. And if I enjoy my explanations that’s a good start - if I find my own explanations boring then I have no hope of interesting anyone else.

The idea for the book grew organically, starting from my undergraduate lectures at the University of Sheffield. I began with a few demonstrations, and then each time I taught the same course I found myself adding some more. Once there was a plate of Oreo cookies on the front desk and nobody knew what it was doing there. A student said, “Explain some maths with it!” so I did, and then I found that I could explain almost any mathematical concept with a food analogy.

**Aloi:** To promote the book, you were invited to demonstrate the power of exponentials on the Late Show with Stephen Colbert. The five minutes sketch is hilarious and yet informative. How much of what we saw there is representative of your approach to teaching?

**Cheng:** I do try to be hilarious and informative at the same time. It’s not that hard to be hilarious while teaching math because most people are expecting it to be so boring, alas! The baseline expectation is low. But at SAIC I’ve found it’s possibly more important to be relevant than hilarious, and so I make sure that I’m bringing in discussion of social and political issues wherever I can.

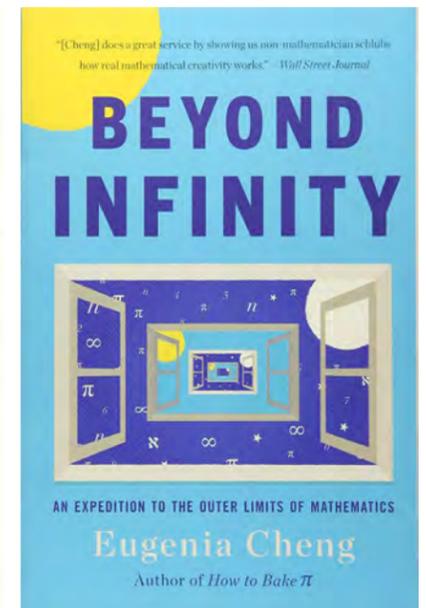
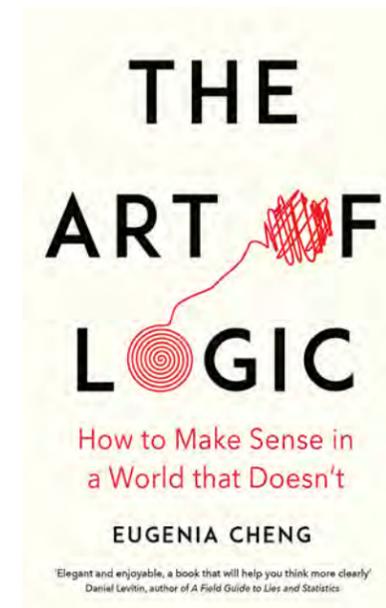
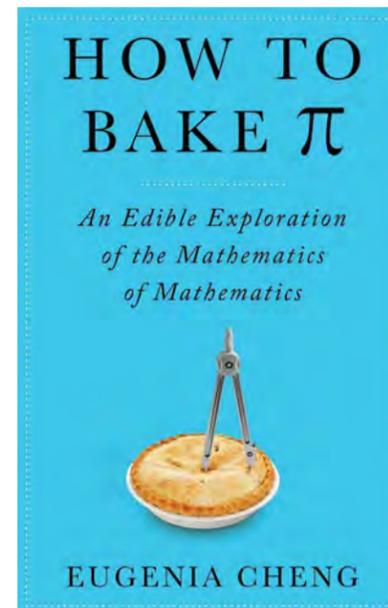
**Aloi:** Before arriving here at the School of the Art Institute of Chicago, you have worked at Sheffield University, Cambridge, University of Chicago, and Nice. Is SAIC your first experience working with art students?

**Cheng:** Yes.

**Aloi:** How has your teaching practice changed in order to better suit the needs of “young artists in the making” and what challenges have you encountered?

**Cheng:** The biggest challenge I’ve faced in the past was the fact that certain demographics tend to dominate conversation, typically white men even though they’re in an extreme minority in my classes with art students. I’ve dealt with that by writing everyone’s names on popsicle sticks and pulling them out at random to contribute to the discussion. I also remove the risk of contributing by making sure everyone knows their contribution is valid and there are no right and wrong answers. This has neutralised the effect of social dominance on the class dynamic.

It’s really a great pleasure teaching art students. In the past with math majors the challenge has been that they all arrive thinking they will be the best in the class, and then they get sad because most of them are not. With art students it’s the opposite - many of them arrive thinking they will be the worst in the class, and they’re



**Eugenia Cheng**

A selection of the author’s most recent books.

happy to discover they’re not (because they can’t all be... well actually there’s no concept of “worst” in my classes). Sometimes with math majors I found them so focused on getting an A and moving onto the next thing that I really had to work hard to persuade them to think, whereas I find that art students really love thinking.

**Aloi:** Who are your favourite artists?

**Cheng:** I don’t really do favourites. But if pushed I’d say I love Vermeer, Caravaggio, and, when I am there, I love popping into the National Gallery in London to see Lake Keitele by Akseli Gallen-Kallela although admittedly I know none of the rest of his work.

**Aloi:** Can you give us an example of a teaching topic/demonstration/experiment you particularly enjoy?

**Cheng:** I do an exploration of the relationships between factors of numbers in which we put them into geometric shapes, and they become things like cubes stacked up on each other. There’s then a plot twist and the same structure shows us relationships between different types of privilege (eg. straight, white, male, cisgendered).

**Aloi:** Higher education, at least on the surface, is thoroughly invested in the concept of multidisciplinary and collaboration. What’s your take on the subject and what challenges have you encountered working in a multidisciplinary context?

**Cheng:** I don’t really like thinking of it as multidisciplinary, because



**Eugenia Cheng**

The Liederstube. Photograph: Paul Chrisanti, PhotoGetGo

I dislike the whole idea of separate disciplines. It seems odd to me to put down contrived boundaries between things and then express surprise that some things work across those contrived boundaries. I think of all thinking as part of the same discipline: the discipline of thinking.

The challenges I faced were really all from earlier in my career, when I wasn't working in what we might call a "multidisciplinary" context. It didn't make any sense to me to do just one thing, but I tried for a while and became progressively more unhappy. Now that I don't try to pigeonhole myself anymore, I am much happier, more productive, and also making a better contribution to the world, I think.

**Aloi:** In your most recent book, *The Art of Logic: How to Make Sense in a World that Doesn't*, you apply black-and-white logic to some of the most urgent issues we are currently experiencing, from Black Lives Matter and Brexit to other thorny political questions. The book shows how mathematical logic can help us see things more clearly. How did the idea for the book come about?

**Cheng:** My previous books focussed on showing that maths can be

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*I hope to show that math is there to be illuminating, not just to answer questions and provide answers, and that it's everywhere, all around us connecting things together whether we know it's there or not.*  
 .....

fun, creative and open-ended. But then came various political developments in the last couple of years, the rise in the prominence of "fake news", and the continued swerve towards clickbait headlines, simplistic memes, soundbites and short social-media-style attention spans. There have always been people manipulating the news, manipulating statistics, and having futile divisive arguments, but the political developments made me feel very urgently that I should do something.

**Cheng:** It has been very gratifyingly well received. I thought I would receive a lot of hate mail but it's only been about the same amount as usual. (There's a certain level of hate mail that I think any woman receives if they have a public profile at all, even if they don't talk about anything particularly controversial.)

**Aloi:** What's the difference between mathematics and philosophy?

**Cheng:** I think that math and philosophy both use logical techniques, but philosophy is seeking to answer much more human questions, whereas math is only trying to answer abstract questions. That's why I think philosophy is harder (for me).

**Aloi:** In 2013, you founded Liederstube, an oasis for art song in downtown Chicago. Liederstube's mission is to present and enjoy classical music in an intimate and informal setting. A relaxed environment for musicians to enjoy sharing music they love, and for audiences to enjoy classical music without the formality so often associated with it are key to the success of this format. Can you tell us what brought you to develop this initiative?

**Cheng:** I think you just answered it in your description! I like the idea of sharing music rather than performing it, and intimacy rather than formality, and the atmosphere of a party, and an emphasis on spirit rather than "perfection", and inclusivity rather than exclusivity.

**Aloi:** Do you have a favourite composer?

**Cheng:** If pushed, I suppose I'd say Bach, and then people would roll their eyes and say "Of course, you're a mathematician". People just love dismissing other people's tastes! I also love Wagner, Debussy, Brahms, Schubert, Mahler, Janacek, Britten...

**Aloi:** Are you working on a new book?

**Cheng:** Three actually.

Eugenia Cheng is Honorary Fellow in Pure Mathematics at the University of Sheffield and Scientist in Residence at the School of the Art Institute of Chicago. She was educated at the University of Cambridge and did post-doctoral work at the Universities of Cambridge, Chicago and Nice. Since 2007 her YouTube lectures and videos have been viewed over a million times. A concert pianist, she also speaks French, English and Cantonese, and her mission in life is to rid the world of maths phobia.



**Christine and Margaret Wertheim**

*The Toxic Reef at the Smithsonian* - from the *Crochet Coral Reef* project by Margaret and Christine Wertheim and the Institute For Figuring, featuring corals by Siew Chu Kerk, Clare O'Calaghan and Evelyn Hardin.

Plastic, videotape, cable ties, New York Times wrappers and other detritus, 2007-2009 © Institute For Figuring, by Christine Wertheim

## Crochet Coral Reef

*Crochet Coral Reef is the brainchild of Christine and Margaret Wertheim. A unique nexus of art, science, geometry, and environmental reflection, Crochet Coral Reef is an ever-evolving archipelago of woolen installations that not only emulates the structures of natural reefs but also enacts the evolutionary processes by which living things evolve. Just as life on earth is underpinned by the code of DNA, so these fiber forms are material incarnations of a symbolic code – the stitch patterns of crochet.*

interviewer: **Margaret Wertheim**

interviewer: **Giovanni Aloï**

Since the dawn of life nature has utilized algorithmic techniques to generate mathematical forms such as the hyperbolic surfaces of corals. Craft practices too are algorithmic – the original “digital” technologies – and through the medium of yarn intricate emulations of living reefs can be brought into being.

*Crochet Coral Reef* by Australian-born twin-sisters Christine and Margaret Wertheim is a meditation on the interplay between nature, mathematics and iterative construction, and also a response to the decimation of actual reefs by global warming.

In a communal dimension of the project, the sisters work with communities around the world to create vastly-scaled Satellite Reefs. More than 40 of these have been fabricated, from London to Latvia, with 10,000 people so far contributing to this on-going eco-art happening.

Figurative, collaborative, worldly, and dispersed, *Crochet Coral Reef* offers a response climate change at once formal and material, monumental and tender.

**Giovanni Aloï:** The *Crochet Coral Reef* project resides at the intersection of mathematics, marine biology, handicraft and community art practice, and also responds to the environmental crisis of global warming and the escalating problem of oceanic plastic trash. Can you tell us how this idea came about?

**Margaret Wertheim:** Christine and I created the *Crochet Coral Reef* project from the intersection of a number of threads running through our lives – pun intended. We grew up in Australia doing handicrafts, which our mother taught us as young children, so when we discovered that you could crochet hyperbolic geometric surfaces we were enchanted. These forms are the frilly crenelated surfaces that corals and kelps and many other reef-dwelling organisms create in the biological structures of their beings, yet human mathematicians spend hundreds of years trying to show that such surfaces were impossible. That raises interesting questions for us about what it means to know mathematics. Does a brainless head of coral “know” hyperbolic geometry? We believe that in some sense it does, so we see our project in part as an epistemological exercise. As well as being a worldwide community craft endeavour, it’s also a collective project in applied geometry and an investigation into embodied knowing through craft.

The technique of hyperbolic crochet was invented by the mathematician Dr. Daina Taimina at Cornell, and it’s not coincidental that she is a great crafter who’d grown up in Latvia. A lot of mathematicians had thought it wasn’t possible to make physical models of hyperbolic geometry, but she realized she could do it with knitting and crochet. She started making these models to teach non-Euclidean geometry to mathematics majors at Cornell and her original algorithm is delightfully simple. From a mathematical perspective, her models are powerful pedagogical tools because they allow you to see and feel lots of formal properties of this rather abstract geometry. They are tangible tools for realizing intangible concepts – “things to think with” to use Seymour Pappert’s lovely phrase.

Once we learned the technique, my sister Christine realized that if she branched out from the simple geometrically precise algorithm and went wild, the resulting forms began to look much more organic. That’s because this is what natural hyperbolic organisms do

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*The technique of hyperbolic crochet was invented by the mathematician Dr. Daina Taimina at Cornell, and it's not coincidental that she is a great crafter who'd also grown up (in Latvia). A lot of mathematicians had thought it wasn't possible to make physical models of hyperbolic geometry, but she realized she could do it with knitting and crochet.*  
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**Anita Menning**

*Hyperbolic Plane*, from the *Crochet Coral Reef* project by Margaret and Christine Wertheim and the Institute for Figuring. Synthetic yarn. 2007 © Institute For Figuring, by Christina Simons



**Christine and Margaret Wertheim**

*The People's Reef - New York and Chicago*, project by Margaret and Christine Wertheim and the Institute For Figuring.  
Yarn and mixed media, 2007-2009 © Institute For Figuring, by Francine McDougall

– they're inherently "aberrant." Nothing in nature is mathematically precise; with real material things there's always deviation and "imperfection." Christine coined the lovely phrase "queering the code" to describe this process of going off the perfect mathematical grid, and I think it captures nicely the spirit of the project.

The *Crochet Coral Reef* queers all sorts of codes, including the code of who gets to be seen as an "artist." To date, we've had over 10,000 people involved in making more than 40 locally-based crochet reefs around the world. We call these the "Satellite Reefs" because they've "spawned," as it were, from the crochet reefs we make ourselves. Most of the people who participate in these projects are women. They come from all walks of life: there are scientists, mathematicians, housewives, and prisoners and we see all of them as our co-artists. From the beginning we wanted our project to draw attention to the power of the collective modality of art-making and in that sense, we were inspired by Judy Chicago's *Dinner Party*. Feminism is baked into the DNA of the project and for us, it's a critical dimension to the work – though this is unusual for an art and science endeavour.

Of course, the other vital part of the project's ontology is the disappearance of living reefs due to climate change. We grew in Brisbane, the capital of the Australian state Queensland, which is home to the Great Barrier Reef, so we've been following its travails all our lives. Literally the night we started the project, in December 2005, Christine made a joke that if the Great One ever

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*The term "freeform" crochet didn't exist then, but we were doing this in the 1970s because I think that neither of us really liked following patterns.*  
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disappeared our woolly one would be something to remember it by. Thirteen years later scientists are now saying that reefs could actually disappear by mid-century. Sadly, no one imagined this could happen so fast.

**Aloi:** When did you start crocheting and what aspect of the medium do you enjoy the most?

**Wertheim:** Our mother taught us to sew and knit when we were in primary school. I can't remember a time when I couldn't do handicrafts, and Christine and I grew up making our own clothes. All through high school and university, I made my own clothes. I used to be able to cut patterns, though I couldn't do that anymore, and Christine studied dress design for a year at one point and was quite a brilliant pattern designer. We taught ourselves to crochet in high school. I think it was the only craft our mother didn't teach us. I immediately loved it because it's so sculptural and freeform. The term "freeform" crochet didn't exist then (it's attributed to the Australian crafter Prudence Mapstone I believe), but we were doing this in the 1970s because I think that neither of us really liked following patterns. We wanted to explore and investigate the realm of the possible from the start.

Crochet is a powerful medium for sculptural making because it's so easy to go off in any direction you choose and to make it up as you go along. Knitting is more formal and technically more challenging. Knitters tend to look down on crocheters. Crocheters say "whatever" and get on with playing. Crochet seems closer to what living organisms do because it's kind of do-it-on-the-go. I like the feeling when I'm crocheting a new kind of coral that I can create it on the fly – which, in a sense, mirrors what evolution does.

**Aloi:** Can you explain the mathematical side of crocheting a little more?

**Wertheim:** Dr. Taimina's algorithm for creating hyperbolic surfaces is very simple: "Crochet 'n' stitches then increase one. Repeat ad infinitum." It's a bit like a recipe for creating fractals, although these surfaces aren't fractals. Historically, hyperbolic geometry was discovered in the early nineteenth century after a long period in which mathematicians had been trying to show that something like this wasn't possible. It relates to one of the axioms of Euclidean geometry, which is known as Euclid's "parallel postulate." This is basically a definition of parallel lines, and it makes sense intuitively, but it turns out that it isn't actually true, or at least it's not *necessarily* true. If you abandon this axiom what you get is a different kind of geometry, which came to be called "hyperbolic geometry."

Technically, it's the geometric opposite of a sphere, and you can think of it as a geometric equivalent of negative numbers. Just as we have positive numbers, zero, and negative numbers; so, you can think of the flat or *Euclidean* plane as a surface with zero curvature; the *sphere* is a surface with positive curvature, and the *hyperbolic* plane is a surface with negative curvature. If that sounds bamboozling, it should. Early mathematicians who worked on this were almost driven mad by it. Gauss, who helped develop this and who has been called the greatest mathematician since Euclid, was so troubled by it he kept his research private and didn't even publish his work. So, it's pretty astounding to me that brainless organisms like corals and sea slugs and lettuce leaves can be effortlessly producing these forms. It's an interesting case in which nature seems to surpass our wildest imaginings. Matter triumphs over mentation.

**Aloi:** You are a science writer, curator, and artist in Los Angeles where you direct the Institute for Figuring, a Los Angeles non-profit organization founded with your sister Christine to promote public engagement with the aesthetic



**Christine and Margaret Wertheim**

*Toxic Reef: CO<sub>2</sub>CA CO<sub>2</sub>LA Ocean, with Bleached Reef and Pod Worlds*, from the *Crochet Coral Reef* project by Margaret and Christine Wertheim and the Institute For Figuring. Yarns, videotape, plastic detritus, medical waste, and sand. 2006-2016 © Photo courtesy Museum of Arts and Design, by Jenna Bascom.

and poetic dimensions of science and mathematics. Can you tell us about the scientific element in this project? I would be specifically interested in knowing more about the challenges you have encountered in working with artists and scientists; how their worlds come to or fail to communicate, and what makes a successful “art and science” project.

**Wertheim:** In our experience, the art world has been very open to the project

but the science world has been pretty close-minded. I’ve been told lots of times by science people that this couldn’t possibly have any real science in it, which I find interesting. I think it’s a matter of gender. The project is created by two women, it is done mainly by women, and it involves a feminine handicraft, so how could it possibly be “real” science? At least that’s what some science people seem to think. Yet the hyperbolic geometry we are investigating is what historically opened the door to a revolution in the understanding



**Christine and Margaret Wertheim**

*Bleached Reef, from the Crochet Coral Reef project by Margaret and Christine Wertheim and the Institute For Figuring. Photo courtesy Museum of Arts and Design, by Jenna Bascom © Institute For Figuring*

of what geometry is. That revolution, which was explored most famously by the great German mathematician Bernhard Riemann, led to the mathematics underlying general relativity, which describes the structure of spacetime.

When I give workshops to teach people how to crochet these forms, I always begin with a half-hour introduction to non-Euclidean geometry in which we end up talking about general relativity and the shape of the universe. Audiences get it, and we have deep discussions about how we could tell scientifically if we live in a hyperbolic or a Euclidean universe. That's actually an open question and one of the primary questions astronomers are trying to answer today: What *is* the structure of our cosmos. Most evidence suggests that on the very large-scale our universe is Euclidean; but there is some intriguing evidence that, after all, we might just live in a hyperbolic world.

**Aloi:** The name of your organization, the Institute for Figuring is wittingly open to interpretation. Can you tell us about the multiple meanings inscribed in the word "figuring" and why it was chosen?

**Wertheim:** The word "figuring" is special to Chrissy and I because it's intrinsically interdisciplinary. "Figures" are numbers. They are also scientific diagrams. Humans have figures that artists draw. In literature, there are figures of speech and figures of fun. And as cognitive beings, we figure things out. As soon as I decided I wanted to create an organization to do science communication in a new way I knew it would be called the "Institute for Figuring".

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*I think that's where the Crochet Coral Reef project comes from: from the fact that as a child my mother refused to buy wrapping paper, so when we went to our friends' birthday parties we had to make our own out of butcher paper and glitter.*  
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The name came to me in a dream. Its acronym "IFF" is the logical symbol for "if and only if" and it's one of the logical operators underlying computers. In some ways "figuring" is an old-fashioned word, it's very nineteenth century, but it is making a big comeback now. Feminist scholars like Donna Haraway use it a lot because it's a word that foregrounds embodiment. Christine and I also like its playful qualities; figuring seems to connote something children do, and we like to say that the Institute for Figuring is "kindergarten for grown-ups."

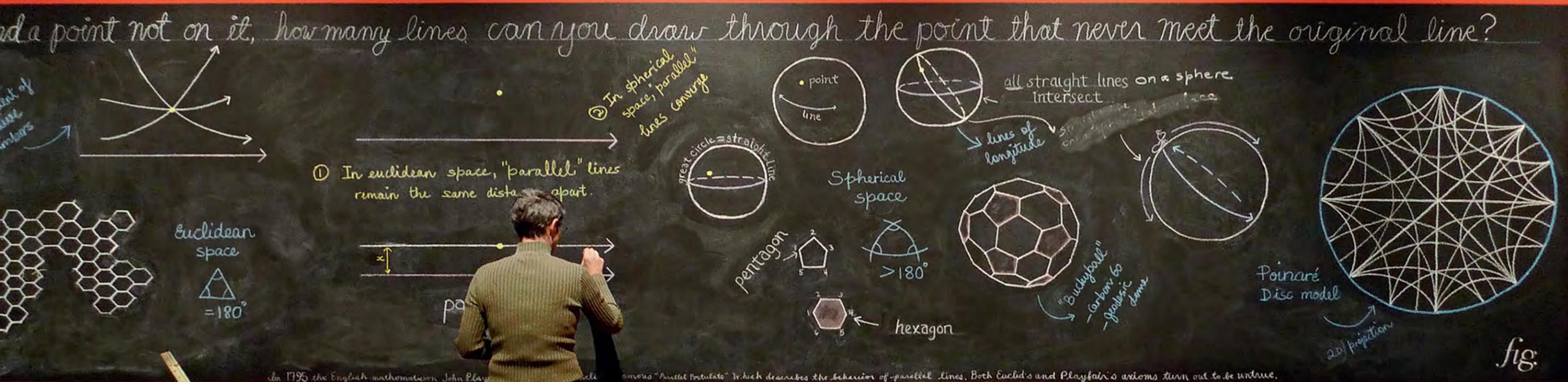
**Aloi:** Can you talk to us about your upbringing and how you and Christine came to be interested in art and science and eventually in the intersection between the two?

**Wertheim:** We grew up on the outskirts of Brisbane, Australia, which was an intellectual backwater and a very feral environment. We lived in the bush with poisonous snakes and spiders and it was pretty isolated. There was nothing glamorous about our childhood and we went to third rate state schools that had very few facilities. By contemporary standards they were appalling, and I very much regret not getting a better formal education. But our mother Barbara Wertheim was deeply committed to giving her kids educational play toys, so we had lots of drawing paper and crayons and building blocks. We had almost no shop-bought toys or games and were expected to create our own. I think that's where the *Crochet Coral Reef* project comes from: from the fact that as a child my mother refused to buy wrapping paper, so when we went to our friends' birthday parties we had to make our own out of butcher paper and glitter. Sometimes I resented that: "Why can't I just have the nice new stuff?" But now I'm hugely grateful to my mom. She was influenced by educational thinkers such as Maria Montessori and Rudolf Steiner and took early childhood-learning very seriously. I am what my mother made me. She also deeply encouraged my interest in mathematics and never hinted it wasn't something girls weren't supposed to do. It wasn't until I went to high-school that I encountered this attitude when our math teacher there made it clear that girls were beneath his dignity.

Chrissy and I are identical twins and after we finished high school, I went to university to study physics and mathematics while she went to art school. I don't think we thought about it as any sort of polar opposites – I certainly didn't. Through her, I got to live in a life in art and through me, she got to live a life in science. The *Crochet Coral Reef* project is a genuine synthesis of our lives and I think that's crucial: Christine really knows about "art", I really know about "science" – but neither of us believes in a simple parsing of those categories.

**Aloi:** Science, femininity, crocheting, and ecology. This is a powerful contemporary evolution of a long history of sewing, embroidering, and stitching that revealed the political power of arts and crafts throughout history. Do you see *Crochet Coral Reef* as linked to that tradition and how does it surpass it?

**Wertheim:** There's a big debate in the craft world about whether "craftwork" that aspires to be shown in art galleries should be called "craft" or whether that word should be jettisoned and that we should only use "art", which has all the connotations of prestige and power that "craft" doesn't have. "Craft" has such domestic roots and "art" has a long history of being defined against domesticity. But Christine and I are clear on this point: we deliberately want to keep the affiliations with domesticity and female making. Our mother taught us to do crafts as a matter of necessity, just as she was taught by her mother. We all grew up in environments where making-your-own was a financial need



**Margaret Wertheim**

Margaret Wertheim at the Maths Blackboard, Williamson Gallery, Art Center College of Design. Blackboard paint and chalk. 2011.

Photograph: Cameron Allan © Institute For Figuring

because shop-brought stuff was expensive. Now the tables have turned, and it costs a fortune to buy the yarn to knit a sweater. But crafts are also deeply pleasurable activities and craft-objects are often immensely beautiful. We want to honor that reality and maintain a connection with the history of female making. To make this clear we like to say that our project is in the tradition of "fancywork" – which is an even more old-fashioned, domestic term. That said, I insist that the *Crochet Coral Reef* deserved to be in the Hayward Gallery and to be categorized as "art."

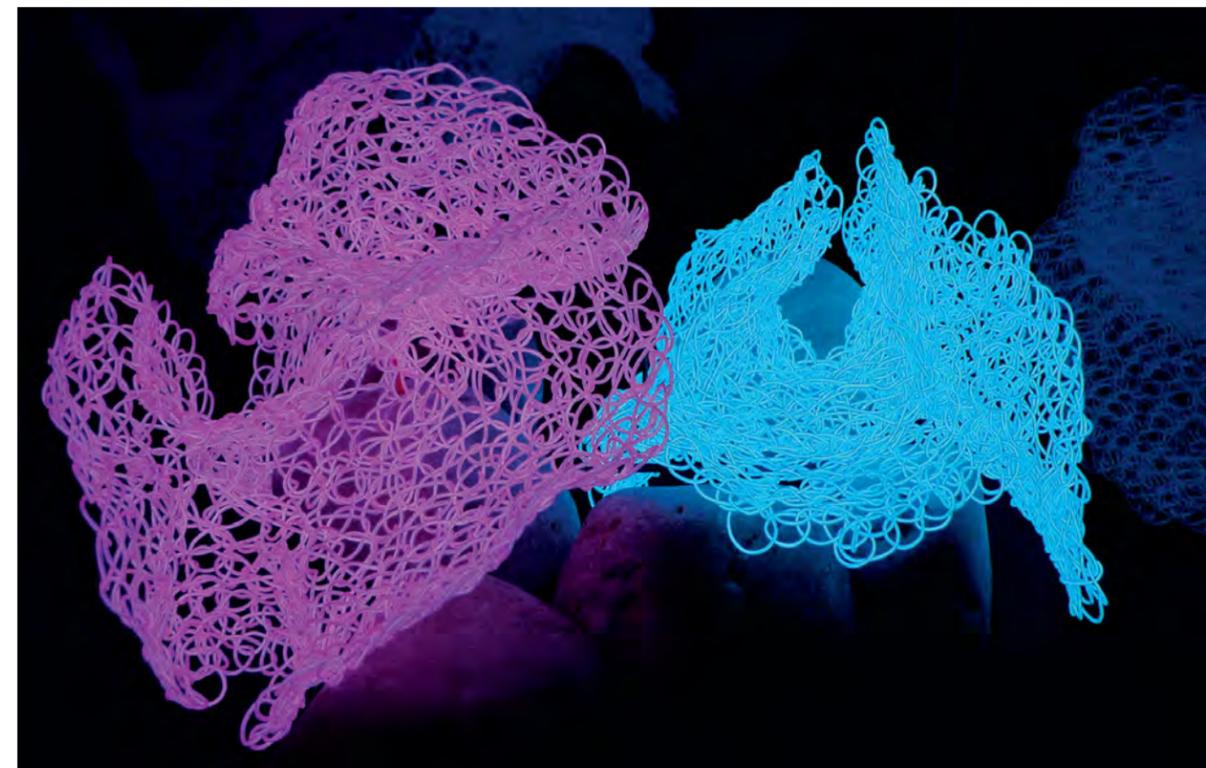
**Aloi:** I remember seeing the *Crochet Coral Reef* at the Hayward Gallery in London and was baffled by the intricacy and consistency of each individual piece. How long does it take to create one individual coral branch and how are decisions made with regards to shape, size, and color?

**Wertheim:** An individual piece can take anywhere from an hour to hundreds of hours to make. Christine has worked on one piece that's taken her at least 100 hours, probably much longer. You can do this on almost any scale: from



**Mieko Fukuhara**

*Staghorn Corals*, Mercerized cotton, super-magnets, biscuit tin, and lace, 2010. Photograph: Cameron Allan © Institute For Figuring



**Eleanor Kent**

*Electroluminescent Corals*, Electroluminescent wire, electronics, rocks, 2009 © Institute For Figuring

tiny to gargantuan, and of course tiny doesn't necessarily mean fast, because some of the greatest contributors to the project have made miniature pieces of byzantine complexity. Nadia Severns, who is a professional crafter and truly superb crocheter, has made a series of miniature beaded-crochet sea creatures for the project that took many hundreds of hours to complete. We estimate that over the course of the project hundreds of thousands of hours have been spent.

Everyone who sees our exhibitions intuitively grasps this: it's like time congealed. You can't get this effect without vast amounts of human labour and commitment. Craftworks often embody this commitment of time that is the essence of attention and care. Donna Haraway uses the phrase that we are living in a time of "response-ability" and points out how much we humans are called on now to be responsive to the world around us. The *Crochet Reef* is an active positive, actually create-ive response to a time of trouble. By this, I mean that the *Crochet Reef* is a response to the devastation of climate change in which people are actually creating something positive rather than sinking into despair. The work is psychically uplifting - for the participants and for exhibition visitors - without pretending there's no problem to face.

**Aloi:** So far, the project counts more than 10,000 participants. How is this collective artistic mind coordinated and how are important decisions made?

**Wertheim:** There are two parts of the project: the overall project which is created, managed, coordinated and produced by Christine and myself, and our project manager Anna Mayer. As was the case with Judy Chicago's *The Dinner Party*, the organization of the project isn't collective. Christine and I take all the responsibility and have done all the curation and project design. We bear all the costs of maintaining the project and its website and producing the books, and storing the artworks long-term. Personally, we have also crocheted and created a *Core Collection of Crochet Coral Reef* sculptures that travel around the world to places like the Hayward Gallery and the Smithsonian. This is the work that's permanent. In these installations, there are individual pieces by a small group of Core Contributors, about 50 people worldwide, who've made pieces specifically for the collection. They are really skilled, creative crafters who found out about the project early on and wanted to be part of it. Some of them, like Nadia Severns, Evelyn Hardin, Sue Von Ohlsen, Kathleen Greco, Anita Bruce, and Vonda N. McIntyre are craft masters who make mind-blowing imaginative things. They are part of the special evolutionary ecology of the project in that each of them has invented a new branch of the crochet "tree of life."

In addition to this *Core Collection*, there are separate reefs, called the "Satellite Reefs", that are made by local communities. There have been 40 of these so far in cities and countries such as London, Melbourne, Abu Dhabi, and Latvia. These reefs are created

by community members using the techniques Christine and I have developed. When a community is making one of these, we teach them the basics then let them loose to create their own version, so there's a sense in which *our* Reefs send out spawn. This parallels the way living reefs send out spawn that settle in new locations and start to grow into new reefs. So, the artistic process emulates the organic processes by which actual reefs multiply. Each community will have its own central group of organizers who coordinate the local makers and work with them on the design of their particular reef. Sadly, almost none of the community-based Satellite Reefs has persevered. Most institutions don't have a commitment to preserving community-created art, so except in a few rare cases, they are temporary works that existed only for the duration of the exhibition.

**Aloi:** *Crochet Coral Reef* installations have been exhibited in art and science museums worldwide, including the Andy Warhol Museum (Pittsburgh), the Hayward Gallery (London), the Science Gallery (Dublin), the Chicago Cultural Centre (Chicago) and the Smithsonian's National Museum of Natural History (Washington D.C.). Seen by more than three million people, the *Crochet Coral Reef* is now one of the largest participatory science and art endeavours in the world. What are the important messages you would like viewers to take home from the exhibitions?

**Wertheim:** That coral reefs are harbingers of radical climate change that is now inevitable. We all need to think about our own behaviour and what we can personally do to cut our consumption. This is not a problem of "them" but of "we" and of "me." We are all implicated in the environmental crisis that's unfolding. And as Donna Haraway teaches us there will be no easy solutions: we must live through this "time of trouble" as responsive beings attentive to what we can do with a sense of hope but without fantasizing that simple solutions will suddenly be invented to take the pain away. The message we'd like to convey with the *Crochet Reef* is that cumulative action counts. Coral polyps are tiny brainless organisms that can do almost nothing on their own, but collectively they build the Great Barrier Reef: the first living thing seen from outer space. We, humans, are also individually quite powerless, but collectively our actions matter and have import. It is by acting together that we can build new ways of being on the planet.

**Aloi:** You have been mentioning Donna Haraway a few times throughout the interview. So I assume that you are pretty much up to scratch with the humanities' awakening to the importance of animals, plants, and ecosystems. The recent philosophical shifts that have marked the past twenty years are tangible manifestations of this turn; something that I hope will impact the minds of those who study at university today. Have you and Christine been influenced by other authors besides Haraway?

**Wertheim:** Oh, yes. The influence of feminist science thinkers such as Heather Davis, Sophia Roosth, Evelyn Fox Keller has been critical on my work, not just the *Crochet Coral Reef*, and feminist artists such as Judy Chicago and Mierle Laderman Ukeles have been important to both of us. As with Ukeles work, our project is also a response

to waste. There is a whole part of the *Crochet Reef* that is made out of plastic bags and videotape and other cast-off plastic debris. The worlds' oceans are drowning in plastic and the *Reef* is also a response to that – we got into the plastic issue in 2006 long before it was fashionable. Ukeles idea of what she calls "Maintenance Art" has been a big inspiration for us over the years. We see our project also in the tradition of female maintenance work, of the caring activities that women do (so often invisibly) for other creatures – for babies and other beings.

**Aloi:** The *Crochet Coral Reef* has been exhibited in many countries around the world. Have you noticed differences in the ways in which the piece is received?

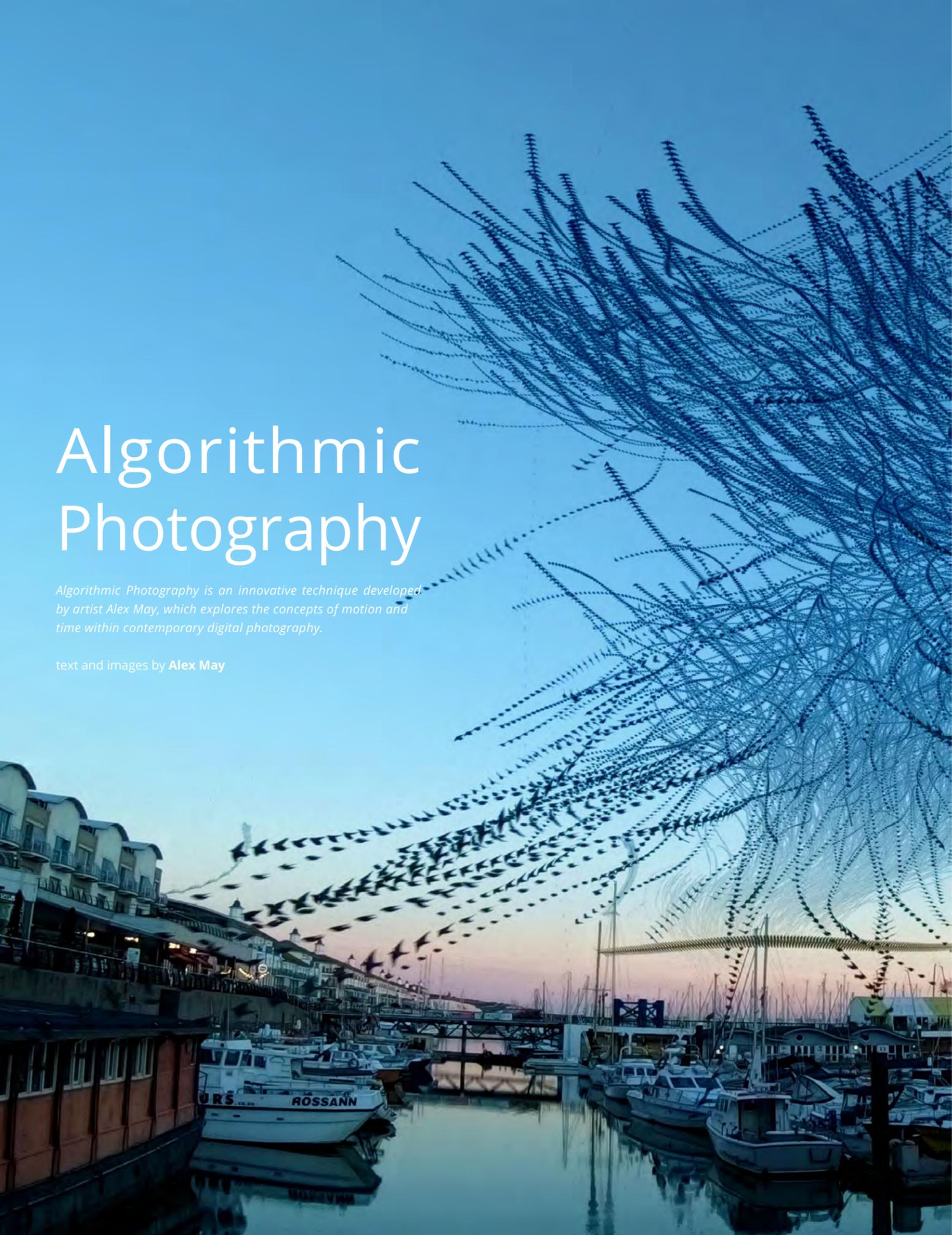
**Wertheim:** One of the lovely things about the project is how universal it seems. People respond everywhere with a sense of delighted recognition, even if they've never seen a living reef. It seems that these curly crenelated forms are embedded in our minds as "reef-like". When we started the project, I wondered if people who didn't live in coastal places would recognize it as a reef, but this cognition appears to be quite general. Sometimes people say, "Oh when I first walked into the gallery, I thought I was looking at a real reef!" Which is funny, because real reefs don't look much like this at all. Christine stresses that "it's not a documentary, it's an artwork." But it doesn't seem to matter how fanciful the architecture or the materials or the colours; as long as you do these hyperbolic forms the human brain reads it as a coral reef. One begins to wonder if this is embedded in some subterranean level of our minds. Or is it perhaps connected to the fact that life comes from the sea?

**Aloi:** What are you currently working on?

**Wertheim:** I'm writing a Ph.D. about the project and reflecting on the question of what it means that we find mathematics realized in the material world. Christine is reimmersing herself in the study of psychoanalysis and its relationship to the origin of language and ideas about the gendered self – which was the subject of *her* Ph.D. For both of us, making and thinking are equally important to be a being in the world.

Margaret Wertheim is an internationally noted writer, artist and curator whose work focuses on relations between science and culture. The author of six books, her writing has appeared in publications including the *New York Times*, *Aeon*, and *Cabinet*. Christine Wertheim is a poet, performer, artist, critic and curator who has authored three books of poetics and edited three literary anthologies. She is a faculty member at the California Institute of the Arts where she teaches courses on critical theory, feminism, pataphysics, and rubbish. The Wertheims's work has been exhibited widely, including at the Hayward Gallery (London), Science Gallery (Dublin), Andy Warhol Museum (Pittsburgh), Museum of Arts and Design (New York), Van AbbeMuseum (Eindhoven), and the Smithsonian (Washington D.C.) They are invited artists at the Venice Biennale of Art, 2019 titled *You Live in Interesting Times* curated by Ralph Rugoff. More info at: [margaretwertheim.com](http://margaretwertheim.com) / [christine-wertheim.com](http://christine-wertheim.com) / [thief.org](http://thief.org) / [crochetcoralreef.org](http://crochetcoralreef.org)

.....  
*The message we'd like to convey with  
the Crochet Reef is that cumulative  
action counts.*  
.....



# Algorithmic Photography

*Algorithmic Photography is an innovative technique developed by artist Alex May, which explores the concepts of motion and time within contemporary digital photography.*

text and images by Alex May

Art and science are lenses of the same instrument that curious people use for looking at and gaining insight and understanding of the world. In my art practice, I have had the opportunity to observe and reflect upon both sides. From being commissioned by the Francis Crick Institute in central London – the UK’s centre for genomic research – to design and create a permanent video sculpture for the front window of their flagship building that communicates the essence of the vital work that takes place there, to creating interactive digital artworks that reveal our skin microbiological flora (part of Eden Project’s *Invisible You* permanent exhibition), and video art responding to the bacterial processes involved in linen production. My *Algorithmic Photography* project is concerned with our perceptions of time and space. It is inspired by historic chemical photographic techniques and it uses cutting edge computer vision-processing to present a compound study of motion in the natural world through the eye of the algorithm.

The photographs are made by taking a video on location. This ranges in duration from a few frames to several hours – although my current preference is to take up to five minutes. I then post-process the video using a software patch I’ve designed using my open source visual programming system called Fugio. The patch analyses each frame of video and, depending on what algorithm I’ve chosen and what additional parameters and processing I might apply, it takes some amount of data from each frame and adds it to the final output photograph.

As a teenager, I was fascinated by the work of Eadweard Muybridge who devised a mechanical photographic system to prove a bet that a horse takes all its feet off the ground at once while running. The series of twelve images he produced, freeze successive moments in time allowing us to clearly analyse the stages of the horse’s motion. In my photographs, I also use a fast shutter-speed to capture motion in sharp detail and recombine these precise moments back into a single image. This is in contrast with how motion is usually communicated in the language of still photography: with a slower shutter speed resulting in a blur. Unlike Muybridge’s analytical approach, these artworks can indulge in the joyous overload of motion without needing a clear path between the beginning and end of their elements, resulting in a work that exists outside of time.

The photographs inspire curiosity and fascination of a world we are familiar with by presenting it in a new and novel way, and they are computationally complex but retain a natural quality that doesn’t require an understanding of the underlying algorithms to appreciate. As a photographer, the experience of developing this technique and the subsequent process of taking images has fundamentally changed how I perceive the world by sensitising me to complex relative motion over time by visualising how multiple bodies could simultaneously occupy the same physical space.

**Alex May** is a British artist working at the forefront of art science collaboration and digital preservation utilising a wide range of media, including virtual reality, photogrammetry, algorithmic photography, robotic artworks, video projection mapping, interactive installations, generative works, performance, and video and sound art. He has exhibited internationally including at the Francis Crick Institute (permanent collection), Eden Project (permanent collection), Tate Modern, Ars Electronica (Austria), LABoral (Spain), the Victoria & Albert Museum, Royal Academy of Art, Wellcome Collection, Science Museum, Bletchley Park, Goldsmiths, One Canada Square in Canary Wharf, the Museum of Contemporary Art in Caracas (Venezuela), the Science Gallery in Dublin, Princeton University, University of Calgary (international visiting artist 2016), Texas A&M University, and the Beall Center for Art + Technology, University of California, Irvine.

Alex is a Visiting Research Fellow: Artist in Residence with the computer science department of University of Hertfordshire since 2011, and a Digital Media Arts MA sessional lecturer at the University of Brighton since 2012, and the University of Hertfordshire since 2019.

See more of Alex’s algorithmic photography by following @alexmayarts on Instagram. The artist’s work is available for sale as giclee prints at <https://algorithmicphotography.com>



Alex May  
*Bats flying over the People's Park in Guangzhou* © Alex May



Alex May  
Crows at Charleston Farmhouse © Alex May



Alex May  
Seagulls over Brighton Pier  
with people on the beach © Alex May

# Laboratory Life

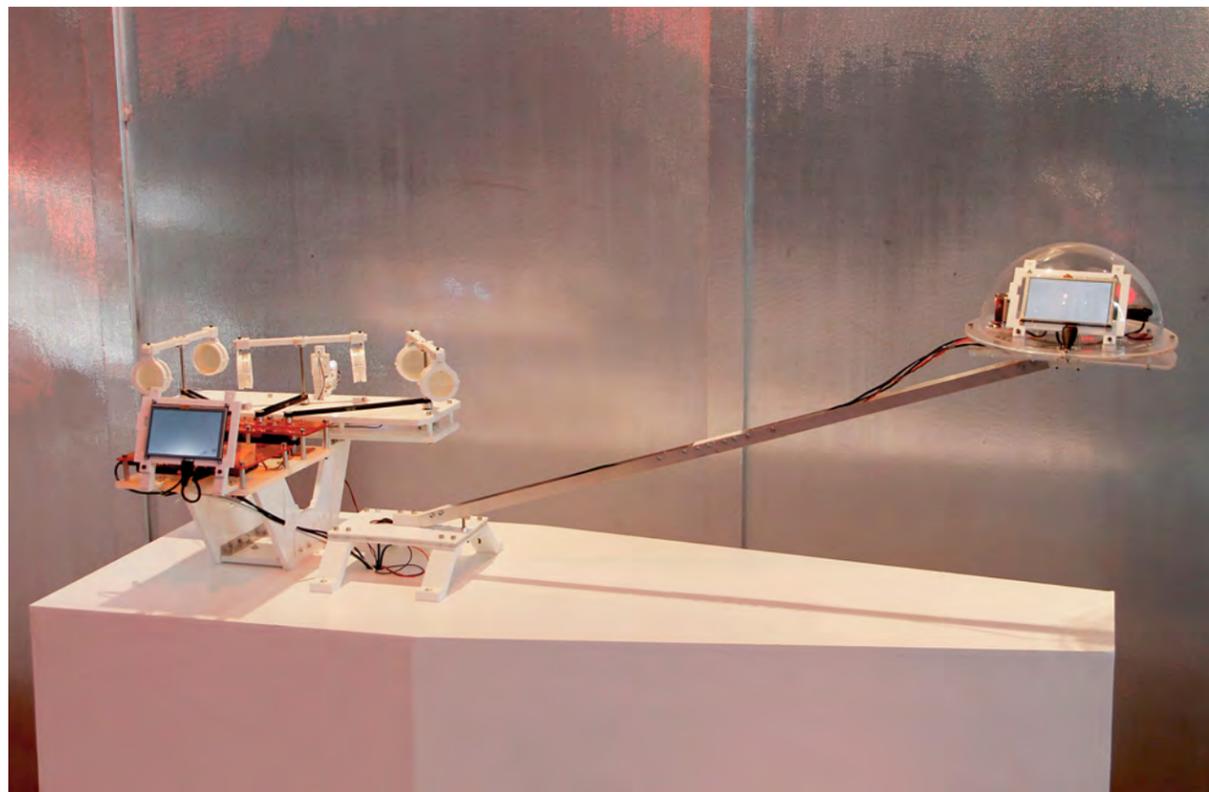
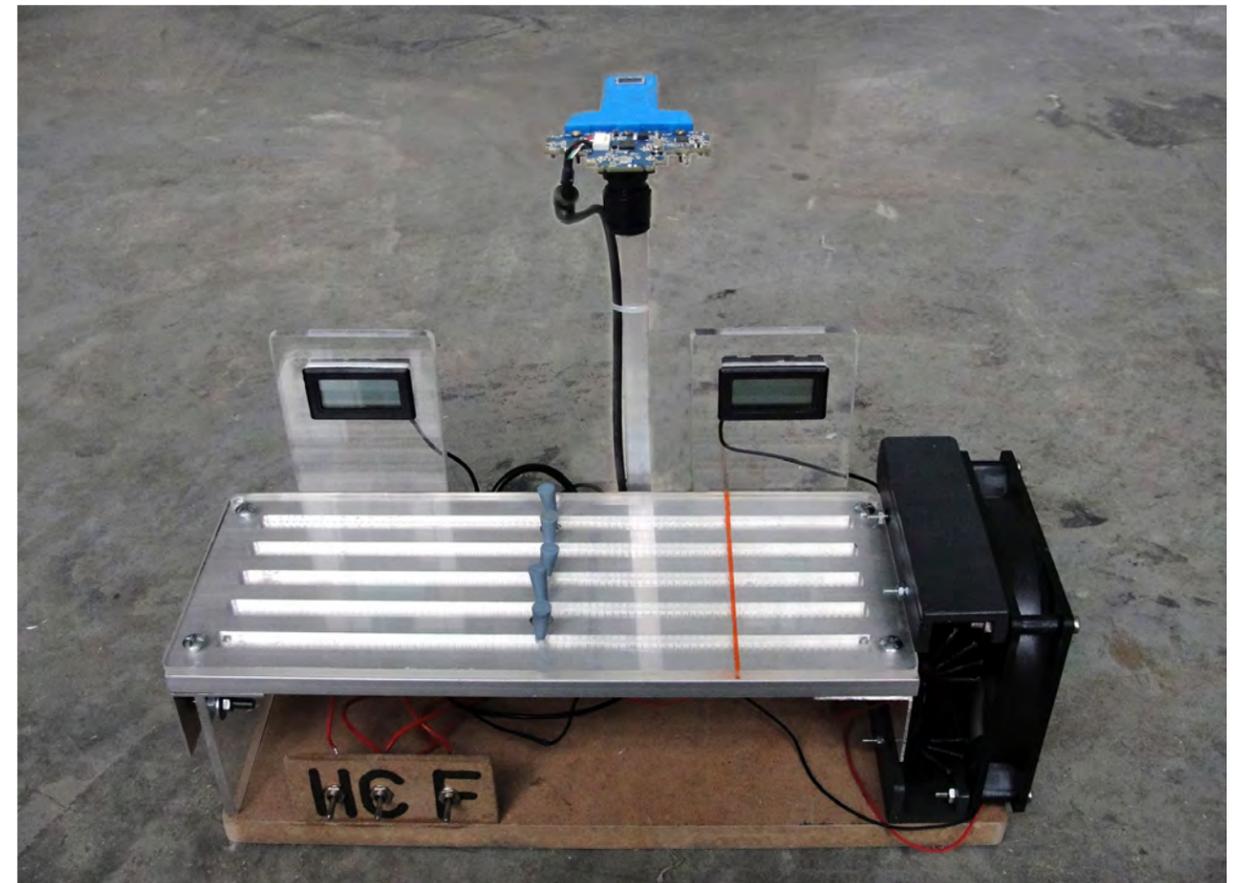
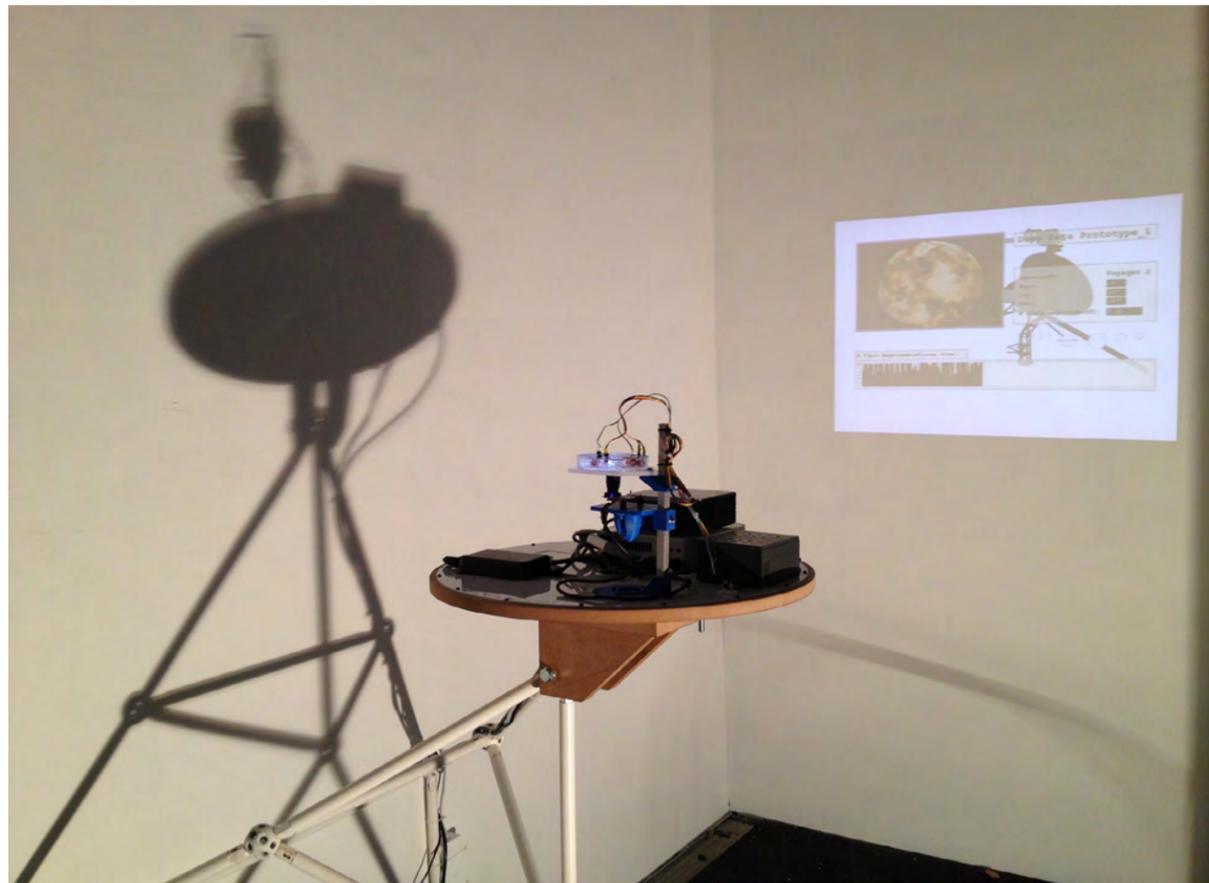
*This portfolio features a selection of projects which present experimental devices and processes as art works. While some works have come about through artistic research, others have come about through collaboration within scientific contexts, enabling the projects to examine the art/science interface from DIY science to the challenges of multidisciplinary practice in institutions. They frame the scientific experiment as both performative act in which anticipation and intrigue can play prominent roles, and as producer of new phenomena. Simultaneously they seek to subvert our common preconceptions of experiment as generator of empirical knowledge and of artwork as container for proposition and metaphor.*

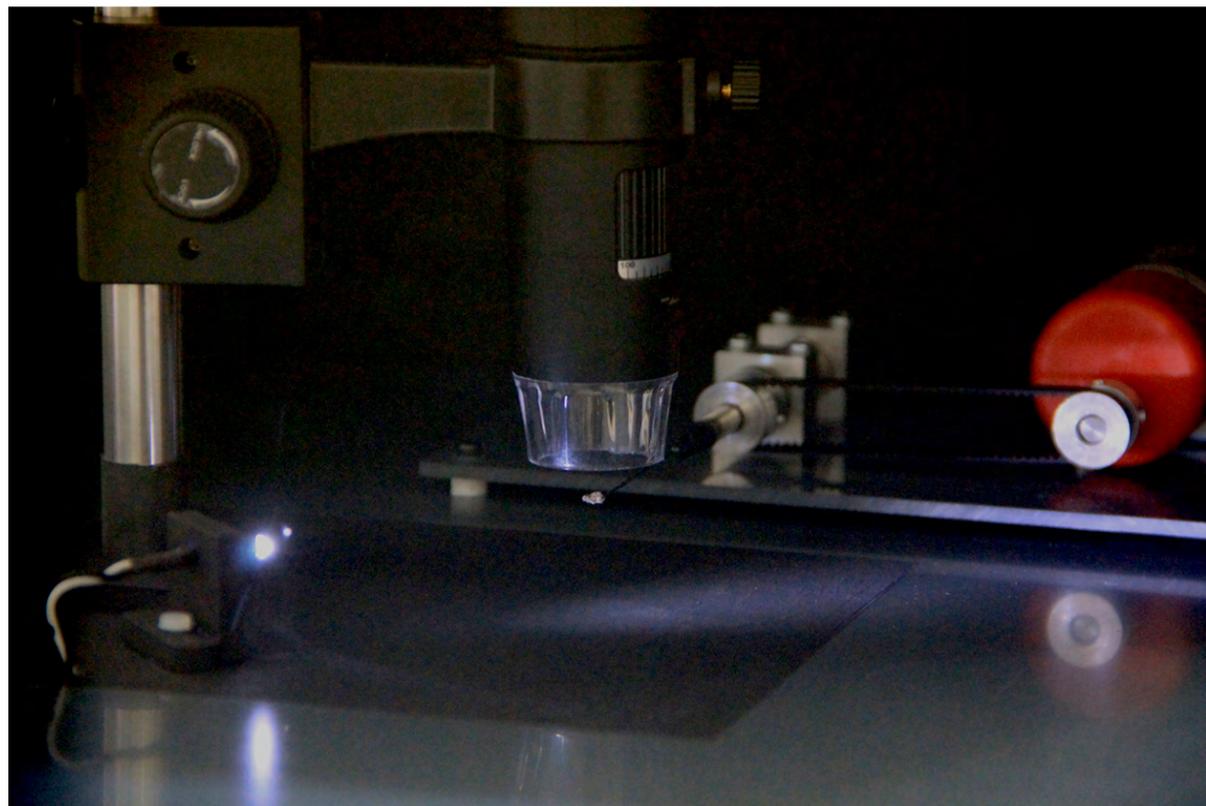
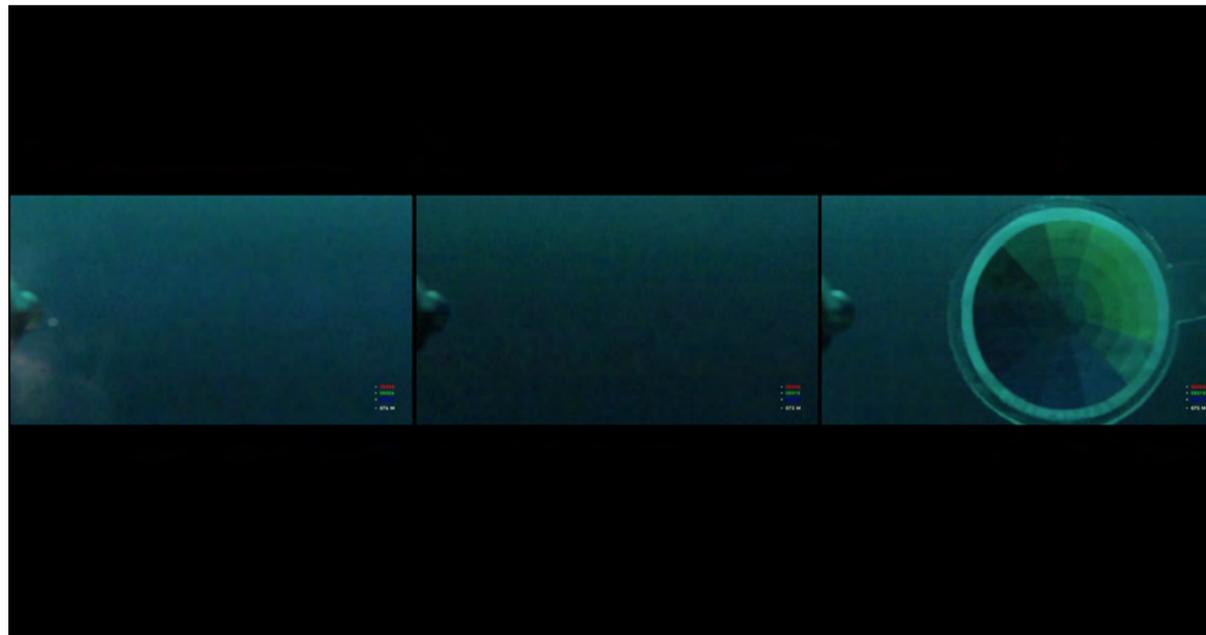
text and images by **Andy Gracie**



**Andy Gracie**

*Deep Data Prototype*, 2012 © Andy Gracie





**Andy Gracie**

pp. 196-197 - Top left: *Deep Data Prototype 1*, 2012 © Andy Gracie; Bottom left: *Deep Data Prototype 3*, 2012 © Andy Gracie

Top right: *Drosophila Titanus, Temperature Gradient*, 2015 © Andy Gracie; Bottom right: *200 metros video tryptich* © Andy Gracie

Above: *Drosophila Titanus*, 2013 © Andy Gracie; YFSTL\_ comet fragment replica, 2017 © Andy Gracie

**M**y own personal response to the deeply discussed and widely explored relationship between what is commonly termed as art and what is commonly termed as science is to test the limits of how far they can be practiced in parallel. This is in itself an umbrella experiment within which the rest of my body of work constitutes sub-experiments; varying strategies of exploring the hypothesis that somewhere is a locus where the art-practice and the science-practice absolutely must diverge. Each becomes unable to accommodate the specific aims and needs of the other. It is a place where the sci-art molecule is pulled apart and strange hybrid particles with curious properties pop into existence. This is the point of tension that I look for and where I endeavour to site my work. However, I also try to ensure that these exotic new particles are somehow constrained, that they and their provenance retain presence and agency in the artworks, that they have a role in the ongoing dialog and provocation that is the existence of the work.

The majority of my projects from the past 15 years present experimental devices and processes as artworks or art processes. In this context, the notion of experiment signifies an intervention with the material world in order to extract new knowledge or new meaning. They are Latour's transformative processes, Hacking's creation of phenomena, Pickstone's systematic creations of novelty. They are the experiment in its classical guise, as a system of interventions and observations for testing a hypothesis or making new discoveries, in both cases increasing knowledge, generating some form or model of understanding. The body of work frames the scientific experiment as both a performative act in which anticipation and intrigue can play prominent roles and as a producer of new phenomena demanding new forms of expression and interpretation. At the same time, these works seek to subvert our common preconceptions of experiment as a generator of empirical knowledge and of artwork as a container for proposition and metaphor. They pose the question of how we ascribe value to the outcome of an experiment. In what ways does culture assimilate the outcomes of (classically) non-scientific experiments and how can this form of pragmatic understanding contribute to the general body of human knowledge?

To paraphrase the seminal *Laboratory Life*, these experiment works exist as a form of inscription device. In these cases, they transform a set of scientific hypotheses into the figures and diagrams of wider cultural propositions and provocative, performative poetry. They project new entities out of an analysis of their inscriptions. This notion of picking apart, of probing, and reconfiguring is implicit and intentional. The application of 'probes' has been an ongoing one throughout much of this phase of works; whether as sensor or software tapping into discrete channels, a purpose-built device that travels into an inaccessible environment, or a multi-billion dollar spacecraft. The probe is the agent through which we intervene experimentally and experientially with the world, and which can exist as a tangible or abstract device. By itself or coupled with simulations and proxies, the probe as object or as act allows us to uncover and reveal the hidden workings and spaces of nature.

This portfolio includes works that embrace astrobiology, artificial selection, space research, and deep sea research. While some works have come about through my own transdisciplinary activities, others have come about through ongoing collaborations

within scientific and research contexts, thus enabling me to use these projects to examine the art/science interface with perspectives from DIY science and autodidacticism to the challenges of multidisciplinary practice in large institutions. The factors of what an experiment can be, and what the sophistication and application of an experiment can involve are greatly influenced across a range of working environments and approaches.

The images relate to four projects which belong in this body of work, *Drosophila titanus*, *Deep Data*, *200 Metros* and *You First saw the Light...*

The 7 year project *Drosophila titanus* proposed the development of a new species of a model organism for the colonisation of Saturn's largest moon. A blatantly ridiculous proposal. But what new ontological character does such a proposal assume when it is carried out with scientific rigour? Here is an unsettling proposition, a scientific process employed to resolve a poetic question. A ubiquitous and space-faring model organism serves as a proxy for the notion of human biological perfection and the right to access space.

The *Deep Data* series, so far consisting of three works, are astrobiological experiments in a simulation. Again taking terrestrial, but space tested, model organisms as the subject of experimental processes that expose them to certain conditions of deep space environments as revealed to us by space probes. The experiment tests how far limited simulations and accelerated timelines can prepare organisms for post-terrestrial futures.

*200 Metros* took an opposite direction, plunging into the deep sea instead of deep space. The project piggy-backed on a research voyage of the science ship Ramon Margalef off the Asturian coast of northern Spain. A custom designed capsule housing cameras and light sensors was submerged to the depth of 200 meters, the official border of the deep sea and the limit of light's penetration, to measure and record the phenomena of changing light spectra and pressures.

*You First Saw the Light...* is a survey of a fragment of comet captured in the stratosphere by a NASA ER2 research plane and housed in the Planetary and Space Sciences Research department of the Open University in the UK. It highlights the history and trajectory of a pre-solar system object, an epic voyage currently stalled in a glass vial in a research laboratory drawer. The project developed a novel way of imaging microscopic objects in three dimensions.

# COGITO in Space

*COGITO in Space is an experiential narrative sending thoughts into outer space as radio waves. The project exists both as a mobile installation and as experiential performative event staged inside the cabin of the Dwingeloo radio telescope in The Netherlands. For both versions of the project, a team composed by three neuroscientists prepare the subject with a lab grade electroencephalogram (EEG) device and a virtual reality (VR) headset, showing an experimental video of the Earth seen from space. The brain activity stimulated by the video is recorded and simultaneously transmitted into space in real time, using the antenna of the Dwingeloo radio telescope.*

text and images by **Daniela de Paulis**

**Sandro Bacci**

Guillaume Dumas writing the Interstellar Code at late hours. (detail)

Photo: Sandro Bocci, 2017 © ASandro Bacci

Andy Gracie is an artist working in art and science. His work commonly features mechanical apparatus that perform real-time experiments, commonly including video, sound, and performative elements. His practice employs scientific theory and practice to question our relationships with exploration and experiment whilst simultaneously bringing into focus the very relationship between art and science, and how new knowledge is culturally assimilated.

He has exhibited internationally in major new media shows and lectured on his work and its theory around the world. He has curated and coordinated interdisciplinary encounters, run numerous workshops and masterclasses, and taught students at universities across Europe. He was one of the founders of the internationally acclaimed DIY science collective Hackteria. Alongside his practical work, he is a regular presenter at art and science conferences around the world from the Finnish arctic to the US Library of Congress.

The first brain activity was purposefully sent into space in 1977, etched as sound in the *Golden Record* made by Carl Sagan and his team. The brain activity of Ann Druyan was recorded for one hour on June 3, 1977, with the help of Julius Korein and Tim Ferris of the New York University Medical as a single electroencephalography (EEG) channel and compressed into a one-minute sound recording.

Although a highly poetic gesture, the brain activity etched in the *Golden Record* does not convey actual information about human mental states or the human existential condition. Neuroscience has progressed much since, with modern EEG recording and analysis techniques allowing sufficient fidelity to capture individual brain states to the point where they can be used as individual 'fingerprints', and for the decoding of subjective and cognitive processes.

*COGITO in Space* began as a thought experiment in 2013, with the first public performance and radio transmission of brain activity into space as part of the 50<sup>th</sup> Design Biennale in Ljubljana in September 2014. (1) The project has been widely presented at conferences, festivals, and art events, gradually becoming more concrete at each presentation, thus starting to take shape in the mind of the public long before its staging at the Dwingeloo radio telescope in November 2018. The first public presentation of the project as a live performance was at the GOGBOT new media art festival in Enschede in The Netherlands, in September 2017. During this event, the brain activity of participants was recorded and transmitted into space as part of a live audio-visual performance, in remote connection with the cabin of the Dwingeloo radio telescope and in collaboration with radio operators of the CAMRAS team.

### Conceptual background of the project

*COGITO in Space* is an interdisciplinary, collaborative project and the result of six years research at the Dwingeloo radio telescope and ASTRON (the Dutch Institute for Radio Astronomy).

The intellectual background of the project grew over the years, thanks to the contribution of specialists from different fields, however, my reasoning behind it focuses mainly on two concepts: the unresolved question of Mind and Body Dualism and the Overview Effect. Another important reference was the novel *Solaris* by Stanislaw Lem and the homonymous film by Andrei Tarkovsky.

The reasoning around the project began as a reflection upon the use of the electromagnetic spectrum, and especially radio waves, by radio astronomers for gathering data of cosmic phenomena, and upon the type of knowledge, we gain from the discovery of such remote events that cannot be known through direct sensory experience. Working alongside radio astronomers over the years, I had the opportunity to better understand the relevance of radio transmissions in contemporary thought and their great cultural impact. My questioning focused especially on how radio waves transmissions have been expanding the human reach into the cosmos, towards places where manned space exploration might never be able to reach, allowing us to remotely explore outer space and exposing the conventional perception of our surroundings to a virtual yet uncannily real and detailed landscape, made of matter still to be defined. Radio waves have gradually become the mean for the virtual human space travel and the carriers of a new-found cosmic awareness and cultural contents, exceeding their scientific and tech



NASA

The very realistic photo of the first sample drilled on Mars. The hole called John Klein (on the right) was drilled by NASA's Curiosity rover on Feb. 8, 2013.  
Credit: NASA/JPL-Caltech/MSSS

nological function. One of the questions that originated from my research, and that eventually became one of the leading concepts of *COGITO in Space*, is "how does the knowledge acquired through remote observation of the universe influence our cognition and how does the mind interact with the matter of such distant universe and vice versa?"<sup>1</sup>

The photo of the first hole drilled on the Martian surface was pivotal for me in questioning the relation between the body and the mind in contemporary cosmology. The photo portrays a landscape upon which the human intervention has imprinted its mark, showing in great details the nature of the action and the surrounding landscape. The uncannily realistic scene is symbolic, in my opinion, of what I call the "Dualistic Problem in Contemporary Cosmology": the bodily, sensory response to the familiar looking matter, texture and colours of the landscape portrayed in images of cosmological objects, is held back by the mind. That reminds us of the abstract nature of the phenomenon represented in the image, belonging to a world that humankind might never experience directly through the senses. In this respect, radio waves allow us to travel with our thoughts much farther and faster than our senses, through a realm of abstract cosmological spaces.

As cosmology progresses in the discovery of the universe, the role of the mind in the interpretation of the picture of 'reality' remains largely unknown. The way our mind works might be fundamental to understanding the universe. The mirroring effect between mind and matter might be essential to comprehend our very unique - and possibly arbitrary - notion of the universe and our life within it.

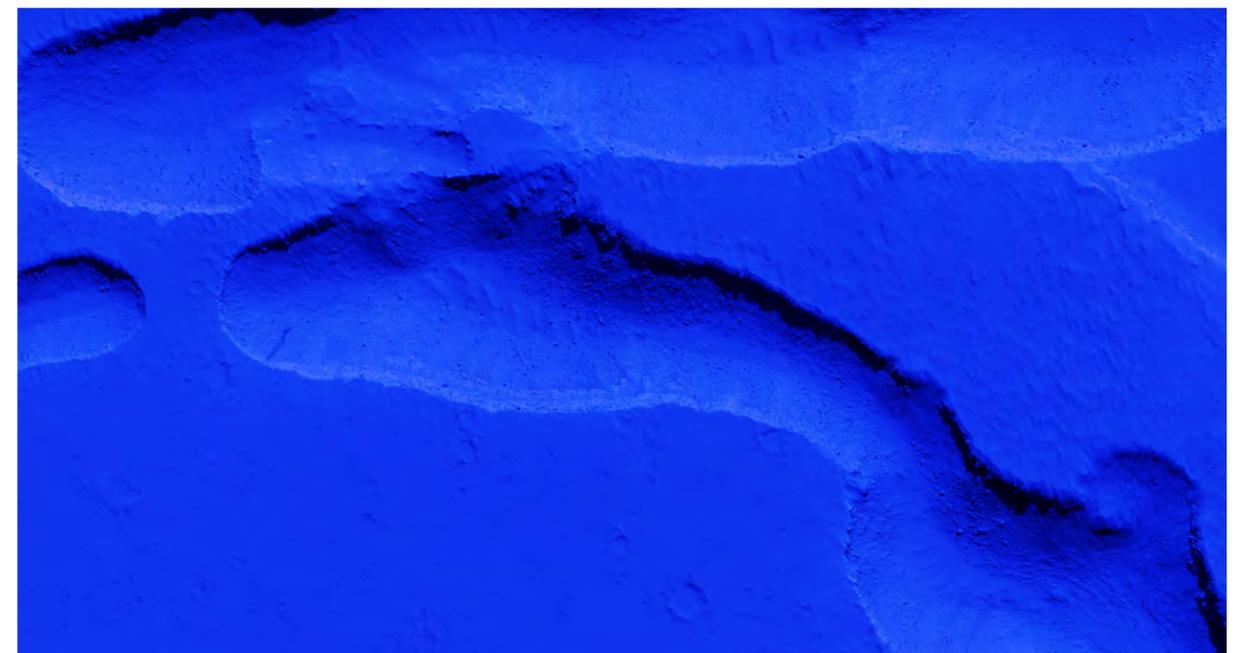
The conceptual framework underpinning *COGITO in Space*, touching upon notions of the philosophy of mind and the unresolved debate on the mind-body Dualism, eventually aims at creating a connection between the mind of the viewer and their idea of 'universe' and delving into the subjective existential questions on the origin and meaning of life.

The project reflects also upon the paradox of the human mind to overcome its own limitations, pushing the boundaries of knowledge towards what lies beyond itself. A paradox well expressed by philosopher Thomas Nagel: "Isn't it sufficient to try to understand ourselves from within - which is hard enough? Yet the ambition appears to be irresistible - as if we cannot legitimately proceed in life just from the point of view that we naturally occupy in the world, but must encompass ourselves in a larger world view. And to succeed, that larger world view must encompass itself".<sup>2</sup>

I named the project *COGITO in Space* following my reasoning on the concept of Dualism. The title, in fact, poetically refers to the changes of the understanding of fundamental concepts in Western thought - such as the concept of human cogito - towards a contemporary culture increasingly characterized and influenced by space exploration. The title, thus, suggests the expansion of the concept cogito as conceived in an era where notions of human form and movement were guided by anthropocentrism and framed within the Euclidean space, into the contemporary understanding of relativity and cosmological phenomena. Contemporary physics challenge the anthropocentric view and assert that space and time are not absolutes that extend equally throughout the universe. In the Theory of Relativity, in fact, space and time differ according to the movement of the observer. The virtual cosmonaut in *COGITO in Space* starts her journey within the Cartesian mind, localized in the brain and accurately measured through electrical signals, reaching for interstellar space where spatiotemporal references blur and eventually fade into the unknown, like the radio signal carrying the thoughts.

Since its early development in 2014, *COGITO in Space* has been informally supervised by space philosopher Frank White, co-founder of the Overview Institute and author of *The Overview Effect*, an influential essay in which he investigates the cognitive shift happening in the mind of the astronauts after witnessing the sight of the Earth from outer space. Frank White reports that as a result of the *Overview Effect*, the mind of the astronaut develops a notion of a unified planet and of greater ecological and social awareness. This concept deeply influenced the development of the project. The immersive video I created especially for the project in collaboration with filmmaker Sandro Bocci, aims at evoking the *Overview Effect* while at the same time leaving space for open interpretation and critique rather than functioning as an outreach platform by endorsing a particular current of thought.

The video includes some of the footage captured by the camera onboard the International Space Station, showing the curvature of the Earth as the station rotates. The footage, however, is greatly reinterpreted, combining the documentarist material with experimental film techniques evoking in the viewer memories, an aesthetic experience as well as sensory feedback. The images mimicking organic forms, intend to induce flickering, ancestral memories of our evolutionary past, from stellar dust up to our present place in the cosmos, for which the evolutionary history of the universe, life,



Daniela de Paulis

*COGITO in Space* VR video still image. Image by Sandro Bocci, 2017 © Daniela de Paulis

.....  
*The title poetically refers to the changes of the understanding of fundamental concepts in Western thought - such as the concept of human cogito - towards a contemporary culture increasingly characterized and influenced by space exploration.*  
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consciousness is perceived as a narrative intrinsic to one's body and mind. The footage, in virtual reality, manages to bring the images as close as possible to the retina, engaging the deep mind directly, rather than creating a field of view. Combining experimental footage with realistic views of the Earth seen from space, the video attempts to disrupt the familiar image of our home planet, inducing

a more introspective journey into the perception of our place in the cosmos, delving more deeply into subjective memories and mental associations. Towards the end, the video shows the iconic *Blue Marble* image, taken during the last manned lunar mission in 1972: supposed to show humankind its place in the cosmos, the photo seems to emphasize instead that we know our home planet only through photos. We don't know our home, we only know it through our subjective interpretation of the image, filtered through our individual memory and thought process. In my opinion, the lack of understanding of our home planet plays an important role in the struggle for the search of our identity as earthlings and our role in the universe. By receiving feedback from some of the project's participants, I realized that the sight of the blue planet, following a series of abstract images, surprises the viewer and inspires in their mind deep emotions of belonging and an almost mystical resonance beyond thought.

In the video the *Blue Marble* image is followed by a view of Martian dunes in Yves Klein's ultramarine blue, filling the retina with the colour to evoke what art historian Romain Rolland named the 'Oceanic Feeling', the sensation of being one with the universe and the source of all spiritual energy.

From the start of the project, I was interested in the idea of sending brain-waves into space generated by the sight of our home planet, shifting the Earth-centred perspective to the Cosmos-wide mindset. This vision seemed to evocative of a universal enough existential narrative, for which the human being is compelled to explore the unknown while grieving the consequences of leaving a part of herself behind.

*COGITO in Space* thus speculates about a hypothetical future in which humans might be confronted with the possibility of leaving planet Earth for the void of outer space. What would be the impact of this extreme journey on the human existential condition? The poetic reference for this aspect of the project is the novel *Solaris* by Stanislaw Lem, which addresses the psychological conflict of losing one's identity and memories of terrestrial life, letting go of one's sense of belonging to Earth during space travel. The experience of the project aims at creating a mirroring effect between the unknowns of the cosmos and inner subjectivity, echoing the thoughts of Dr Kelvin, *Solaris's* main character: "Man has gone out to explore other worlds and other civilizations without having explored his own labyrinth of dark passages and secret chambers, and without finding what lies behind doorways that he himself has sealed".<sup>3</sup>

### ***COGITO in Space* as 'River of Consciousness' and in relation to previous interstellar messages**

The broad questioning underpinning the development of *COGITO in Space* led me to reflect upon the complexity of human thought as possibly the most recognizable signature of our experience of life. When faced by the neuroscientists with the decision of which part of the thinking process to highlight in the brain activity recording for the project, I eventually opted for the possibility of representing the entire dynamics of the brain and to capture as much as possible the contradictory, and often conflicting, facets of the thinking process. As a result, the neuroscientists and I focused on recording spontaneous cognition, also known as 'stream of consciousness', the raw

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*The poetic reference for this aspect of the project is the novel Solaris by Stanislaw Lem, which addresses the psychological conflict of losing one's identity and memories of terrestrial life, letting go of one's sense of belonging to Earth during space travel.*  
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thinking process that is typically not object of study in neuroscience. The term 'stream of consciousness' was coined by philosopher and psychologist William James in *The Principles of Psychology in 1890*: "consciousness, then, does not appear to itself as chopped up in bits...it is nothing joined...it flows. A 'river' or a 'stream' are the metaphors by which it is most naturally described. In talking of it hereafter, let's call it the stream of thought, consciousness, or subjective life. In literary criticism, a stream of consciousness is a narrative mode or method that attempts to depict the multitudinous thoughts and feeling which pass through the mind".<sup>4</sup>

The idea of recording and sending into space a 'stream of human consciousness', challenges the notion of "interstellar message" as conceived by scientists, notoriously Frank Drake and Carl Sagan amongst others, who composed and transmitted into space the Arecibo message in 1974.

This and the following interstellar messages, focused on representing humankind's scientific and technological knowledge, emphasizing the mathematical and logical notion of intelligence. *COGITO in Space* focuses instead on the continuous thought process that occupies most of our individual narrative, on the existential struggle of being human, on the controversial nature of a sentient being, on her or his deepest thoughts and doubts, asking a potential extraterrestrial listener 'are you as controversial as we are, do you share our inner struggle? Can we empathize on what we don't know and cannot understand about our existence and the meaning of life?

The two different approaches to communicating with extraterrestrial intelligence are also highlighted in the novel *Solaris*. While hovering on a spaceship over the surface of the sentient planet *Solaris*, the scientist of the mission prompts Dr. Kelvin, the mission psychologist, to transmit his brain activity towards the planet, while focusing on the scientific purpose of the operation. (2) However, while the electrodes are attached to his head and the transmission of his brain activity takes place, Dr. Kelvin lets his mind wander through memories of his recent and old past, contaminated and overlapped with dreams.

### **Code for Interstellar Transmission**

The artistic requirement of recording the brain activity of the entire brain and conveying the complexity of human thought proved to be very challenging from the scientific and technological point of view. As an artist, I value scientific accuracy. In fact, I consider the scientific language as the 'material' of the project, making it an essential requirement that people experiencing *COGITO in Space* would not be deceived with regards to the accuracy of their experience and within the limits of current understanding of brain activity analysis. For the project, we use a lab-grade electroencephalogram (EEG) device. The EEG research has been developed in collaboration with neuroscientists Robert Oostenveld, Stephen Whitmarsh and Guillaume Dumas.

The EEG reading is able to detect the complex pattern created by the unique interaction of the brain waves in time, showing that the mind is engaged in negotiating different stimuli, produced both by the sensory and psychological experience. The EEG reading, however, is not invasive and cannot detect the object of thoughts, therefore it presents no privacy concerns.

For *COGITO in Space*, the neuroscientists developed a unique



**Daniela de Paulis**

The 32 electrodes EEG device used in *COGITO in Space*. Photo Sandro Bocci, 2017

code for interstellar transmission, the first of its kind, both accurate from the artistic and scientific perspective. The code manages to reliably convert the ‘river of consciousness’ measured by 32 electrodes, into a mono sound that can be converted into a radio signal that can be transmitted into space using a powerful antenna. Additionally, the code manages to retain the complexity of the original signal very accurately, communicating across space the spatiotemporal and psychological nature of our advanced mammalian brain. A potential extraterrestrial intelligence would be able to reconstruct the signal and perhaps understand how it was created. However, due to the great cosmic distances, it is extremely unlikely that the radio signals will ever be detected and interpreted before they blend in with the background noise of the universe.

The project has been presented at several SETI (Search for Extraterrestrial Intelligence) conferences and discussed with specialists in the field. As a member of the permanent SETI committee myself, I am very aware of the controversy in transmitting powerful signals into space in the attempt to communicate with extraterrestrial intelligence. For this reason, I chose not to target a particular celestial object with the *COGITO in Space* transmissions, keeping the transmitting antenna still and spreading the signal across the sky instead.

The work in progress for developing the first code for interstellar transmissions using EEG signals was possibly the most interesting part of the work: every two months the entire team met for short research retreats at the ASTRON guesthouse, the living and working facilities adjoining the scientific facilities and designated for radio astronomers. The guesthouse, as well as the cabin of the Dwingeloo radio telescope, became our spaceship, our safe ground control for working together, radio astronomers, neuroscientists, radio operators, artists, brainstorming ideas, sharing languages and methodologies, having in-depth conversations about all aspects of life.



**Daniela de Paulis**

The *COGITO in Space* team at the ASTRON guesthouse. Photo: Sandro Bocci, 2017

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*In my answer it emerged that the physical division between oneself and outer space is a perceptive illusion, as matter at the atomic level is a continuity, the difference between one's body and outer space being an instance of intensity and density of matter.*  
 .....

### Performance at the Dwingeloo Radio Telescope

On the 5 November 2018, *COGITO in Space* finally settled at the Dwingeloo radio telescope, its originally intended physical location. The project was designed from the start to be presented inside the cabin of a radio telescope that would mimic the post-human outer shell of the body, its life support system in a half human-half technological system. The Dwingeloo radio telescope was inaugurated in 1956 and established as part of the Dutch heritage in 2011. The cabin still features some of the original radio equipment, together with modern amateur radio devices and its environment has become the iconic filmic set for the ongoing project's performances since 2014.

I conceived the event at the radio telescope to be an experience for the visitors rather than a conventional exhibition opening, with several activities taking place throughout the day, in form of cinematic reality for which the extra-ordinary and ordinary mixed. The day started at the ASTRON auditorium with a symposium and keynote lectures by space philosopher Frank White, cultural anthropologist Fred Spier, retired NASA astronaut Nicole Stott and moderated by art critic Josephine Bosma. Frank White introduced the *Overview Effect* and his more recent concept of *Cosma Hypothesis*, suggesting that while exploring outer space, humankind should avoid repeating the mistakes committed during colonial explorations of Earth. Fred Spier is a professor of Big History at the University of Amsterdam. Big History is a cutting-edge field of research investigating the development of both natural and cultural events, from the Big Bang to the present, working along a very broad time scale from an interdisciplinary perspective, merging human sciences with physics, astronomy, and geology. Spier spoke about his experience of the Moon landing as a child and the cultural meaning of the Earth Rise photo, which for many years had a strong impact only on the American nar-



**Fred Spier**

Fred Spier speaking about the Earthrise photo, ASTRON auditorium, 5 November 2018. Photo: Sandro Bocci, 2018



**Cogito in Space team**

Live brain activity transmission into space. Dwingeloo radio telescope, 5th of November 2018. Photo: Sandro Bocci

rative, leaving Europe and the rest of the world almost indifferent. Astronaut Nicole Stott spoke about her personal experience of the *Overview Effect* from the International Space Station and her life on board, together with her crewmates. (3)

The symposium was followed by a conversation between myself, the neuroscientists, and Josephine Bosma, who asked about my background as a contemporary dancer and how that affected the making of *COGITO in Space*. In my answer it emerged that the physical division between oneself and outer space is a perceptive illusion, as matter at the atomic level is a continuity, the difference between one's body and outer space being an instance of intensity and density of matter: the blood running through my veins as I write is, in fact, as close to my skin – the body's membrane between interior and exterior space – as the air and materials touching it. My internal organs are, thus, a continuity with outer space. In *COGITO in Space* the body streams beyond its protective skin into the infinite space beyond it, poetically drifting towards the unknown.

The talks session was followed by a meditative lecture-walk in the area surrounding the scientific facilities, the Dwingelderveld National Park, mostly a flat landscape dotted with heathlands. The walk, guided by planetary scientist Maarten Roos, took the visitors along a straight line going from the radio telescope into the wide-open landscape and back, (4) allowing for the visitors to gaze as far as the horizon as if viewing the curvature of the Earth. The walk, lasting approximately one hour, was interspersed by cogitations on the origin of the cosmos, of life on Earth, the existence of possible extraterrestrial life, and was informed by Fred Spier's book *Big History and the Future of Humanity*.

The walk aimed at inspiring a sense of belonging to Earth be

fore virtually leaving the planet, as well as creating room for individual existential questioning. It was followed by an introduction into the history of radio astronomy and the Dwingeloo radio telescope by astronomer Roy Smits. The short presentation led the visitors inside the cabin through a seamless transition between the different events taking place and the different people performing them. (5) While the visitors started entering the cabin and taking their sit, I turned the engine of the radio telescope on, while the participant lying on a gravity chair was being prepared by the neuroscientists with the EEG device and the VR headset. As the people sat still, the radio telescope started tracking the star Betelgeuse, the departing point for the brain activity transmission, and this triggered the rotation of the cabin. Once reached the complete stop of the rotation, the curtains lowered, shortly after the video in virtual reality started playing while the brain activity was recorded and simultaneously, I started transmitting the signal into space, with the antenna of the radio telescope pointing still towards the sky. This action allowed for the brain activity to be spread across a large portion of the sky with the Earth's rotation. Before initiating the radio transmissions, I pronounced through the transmitter the call sign of the Dwingeloo radio telescope, PI9CAM – Papa India Nine Charlie Alpha Mike – the identifier of the radio station used, a standard procedure in amateur radio. The instantaneous visualization of the brain activity recorded was projected inside the cabin together with the visualization of the radio transmission happening simultaneously. The sound produced by the brain activity created hypnotic and repetitive patterns that generated a meditative mood inside the cabin: people experiencing the event seemed to draw their attention inwards and join the participant in her intimate journey with the mind in outer space.



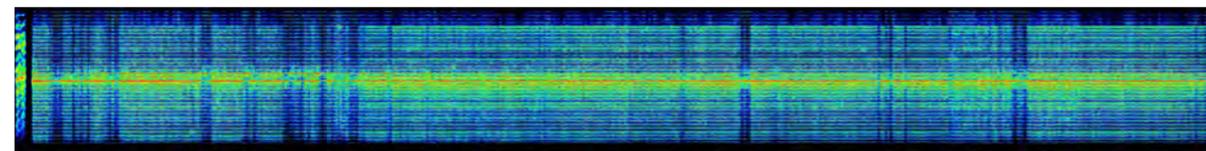
**Daniela de Paulis**

The artist and radio operator transmitting brain waves into space, 5 November 2018. Photo: Sandro Bocci

The performance ended with me speaking the call sign through the transmitter and resuming the radio transmission. The entire performance lasted approximately forty-five minutes and was repeated twice during the day. Following the event on the 5<sup>th</sup> of November, participants contacted me reporting to have lived a special day and that the experience will remain in their memory as a unique moment.

The performance used a purposefully objective and abstract language, assimilating the event to a scientific presentation, my intention being to allow for the experience to find its niche in the individual memory according to one's inner understanding, regardless of the specialist aesthetic appreciation by the participant and the observer. The work in progress and the event at the Dwingeloo radio telescope have been documented as part of a reportage filmed by Sandro Bocci. (6)

Drawing from diverse fields of research and sources of inspiration, *COGITO in Space* is a multi-layered art project, whose aim is to generate questions and meanings that might resonate and mirror very differently from person to person. The project is purposefully left dualistic, controversial and open-ended and despite its complexity, both conceptual and technological, it can be appreciated by people of all ages and cultures. The written record of individual experiences that is being collected throughout the ongoing presentations of the project, might provide over time some insightful material on the subjective perception of the visualization of Earth.



**Daniela de Paulis**

Waterfall of the *COGITO in Space* brain activity recording. Photo: Michael Sanders, 2018 © Daniela de Paulis

## Notes

- [1] A recording of the performance can be viewed here <https://vimeo.com/133392862>
- [2] “Dr. Kelvin, may I have your attention and concentration for a moment. I do not intend to dictate any precise sequence of thought to you, for that would invalidate the experiment, but I do insist that you cease thinking of yourself, of me, our colleague Snow, or anybody else. Make an effort to eliminate any intrusion of individual personalities and concentrate on the matter in hand. Earth and Solaris; the body of scientists considered as a single entity, although generations succeeded each other and man as an individual has a limited span; our aspirations, and our perseverance in the attempt to establish an intellectual contact; the long historic march of humanity, our own certitude of furthering that advance, and our determination to renounce all personal feelings in order to accomplish our mission; the sacrifices that we are prepared to make, and the hardships we stand ready to overcome... These are the themes that might properly occupy your awareness” (Lem 1970, p 167)
- [3] The recording of the symposium can be viewed here <https://vimeo.com/314485455> (Frank White, Fred Spier), <https://vimeo.com/315846047> (Nicole Stott). An interview with Fred Spier and Frank White with some poignant insights into the Earthrise photo can be viewed here <https://vimeo.com/321484428>
- [4] Reference to A Line made by Walking by Richard Long, 1967
- [5] The frictionless succession of events guided by different people was inspired by the performance This Progress by Tino Sehgal that I witnessed at the ICA in London in 2006.
- [6] The trailer of the reportage can be viewed here <https://vimeo.com/302670149>.

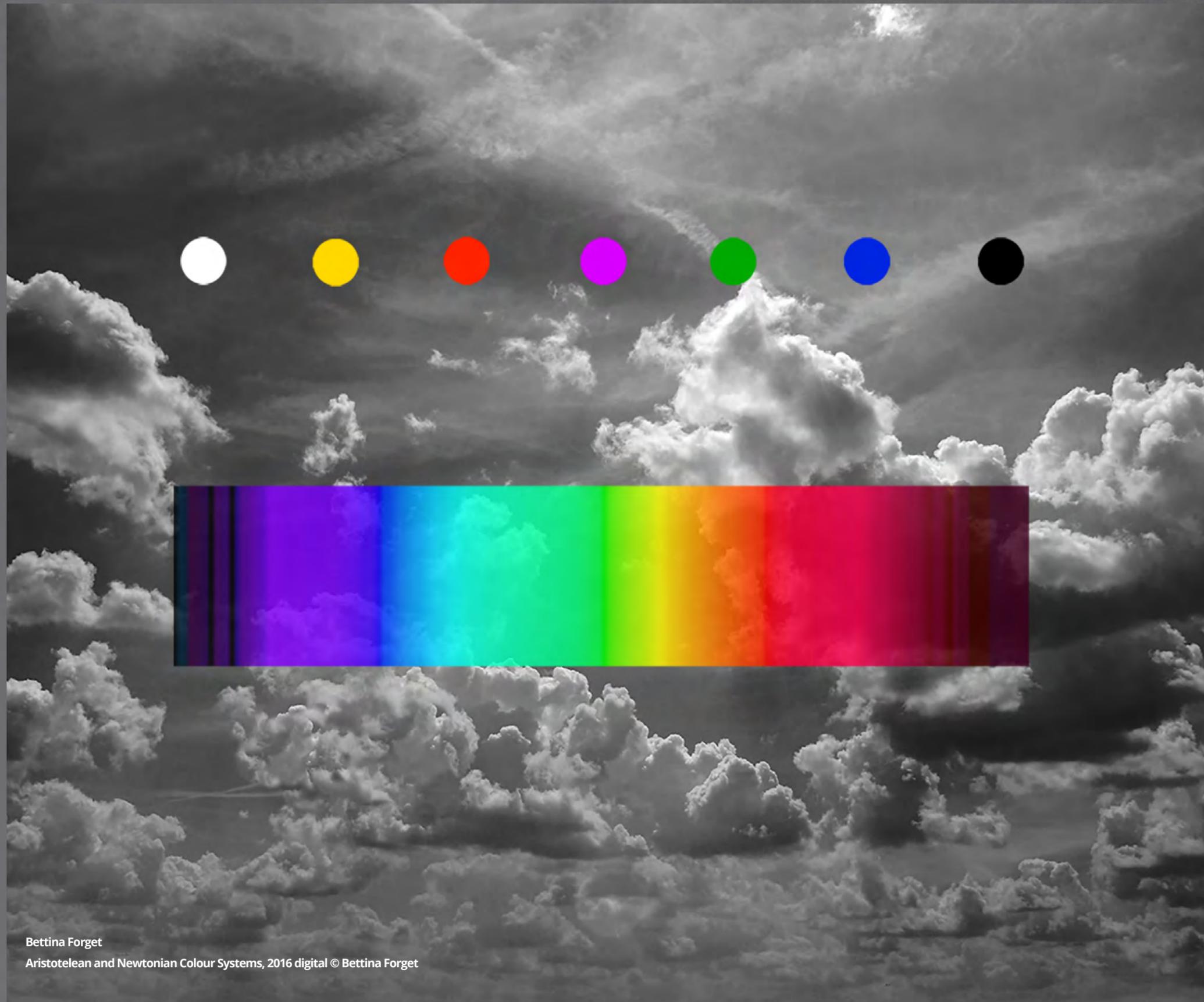
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**Daniela de Paulis** is a new media artist, licensed radio operator (IU0IDY) and trained radio telescope operator. Since October 2009 she has been artist in residence at the Dwingeloo radio telescope. She is collaborating with a number of international organizations, including Astronomers Without Borders, for which she is the founder and director of the Arts programme. She is member of the permanent international SETI (Search for Extraterrestrial Intelligence) committee, the only worldwide forum for SETI scientists, and member of the METI (Messaging Extraterrestrial Intelligence) advisory panel. She is a regular contributor for the Wow! Signal Podcast. She has published her work with the Leonardo MIT Journal, Inderscience, RIXC and Cambridge University Press, amongst others.



Bettina Forget  
Aristotelean and Newtonian Colour Systems, 2016 digital © Bettina Forget

## Goethe's Color Theory: Optics and Visual Poetry

*What happens to the scientific process when mathematics is substituted with poetry? In the 18th century, the German poet and amateur scientist Johann Wolfgang von Goethe did just that in his quest to formulate his own theory of colour in his book Zur Farbenlehre. Goethe's methodology of mixing qualitative and quantitative data did not prove fruitful in the development of science. However, Goethe's interobjective, Romanticist philosophy of the Naturforscher may provide a scaffold for artists who are interested in scientific inquiry, and anyone who is interested in reflecting on the relationship of the human experience and nature.*

text by **Bettina Forget**

What happens to the scientific process when mathematics is substituted with poetry? In the 18th century, the German poet and amateur scientist Johann Wolfgang von Goethe did just that in his quest to formulate his own theory of color in his book *Zur Farbenlehre* (1810), known in English as *Theory of Colors*. Goethe vehemently objected to Isaac Newton's theory that color was a result of the refraction of white light. He dismissed Newton's rationalist approach of the mechanization of nature and deemed the physicist's mathematical explanations to be simplistic and limiting.

The study of color has attracted much interest because it is situated at the intersection of art and science. Color can be examined by investigating light waves, energy fluctuations, and by calculating refraction angles and focal points. At the same time color can be understood as an emotional prompt, as a political cue, and as a communicative tool employed by artists.

Today we know that Goethe's assertions regarding the properties of light and color are scientifically unfounded, but how can his interpretation of natural phenomena aid in our understanding of the natural world, and shape our understandings of artistic and scientific inquiry?

#### Goethes Vision of Science

Goethe is renowned for literary works such as *Faust* (1809) and *The Sorrows of Young Werther* (1774), but he also had a passion for the study of the natural sciences. Goethe was an avid amateur botanist, hoping to uncover an archetypical, primordial plant form, the *Urforn*, which would underlie the structure of all plants, and which he later described in his essay *Versuch die Metamorphose der Pflanzen zu erklären* (*Metamorphosis of Plants*) (1790). He also amassed a vast mineral and rock collection, driven by his curiosity about the formation of the Earth.

However, Goethe's best-known foray into the field of science was his work with optics and color, which drew on his prowess as a poet, painter, and amateur scientist. Goethe's approach to science reflects the basic tenets of German Romanticism, which foregrounded aesthetic experiences, intuition, and a close relationship with nature. This philosophical stance was a reaction to the Industrial Revolution and the Rationalist mindset that accompanied the Age of Enlightenment. German *Naturphilosophie* (philosophy of nature) rejected the mechanistic view of nature proposed by Enlightenment philosophers such as Hume and Locke. Instead, nature was understood as a dynamic whole, steered by the principles of *Polarität* (polarity), and *Steigerung* (intensification). The concept of *Polarität* posits that nature is driven by the dichotomies of repulsion and attraction, such as the poles in magnetism, alkaline, and acid in chemistry, and plus and minus in electricity.

As Astrida Orle Tantillo clarifies in *The Will to Create* (2002), Goethe's polarities are not antinomies, there is no implied hierarchy in the pairs. Rather, polarity describes the interplay of opposing forces, a dynamic engagement that is the source of the creative impulse in nature. In Goethe's view, each half of a polar pair seeks its opposite, and this desire for wholeness is the basis of the creative force. The term *Steigerung* refers to nature's tendency toward complexity, for example, the evolution of life from simple single-celled organisms to more complex beings. However, as Tantillo points out,

there is no teleological goal, no climactic end-point to this development. Goethe understood nature to be a dynamic system where every organism is constantly adjusting to its environment by developing new, complex forms.

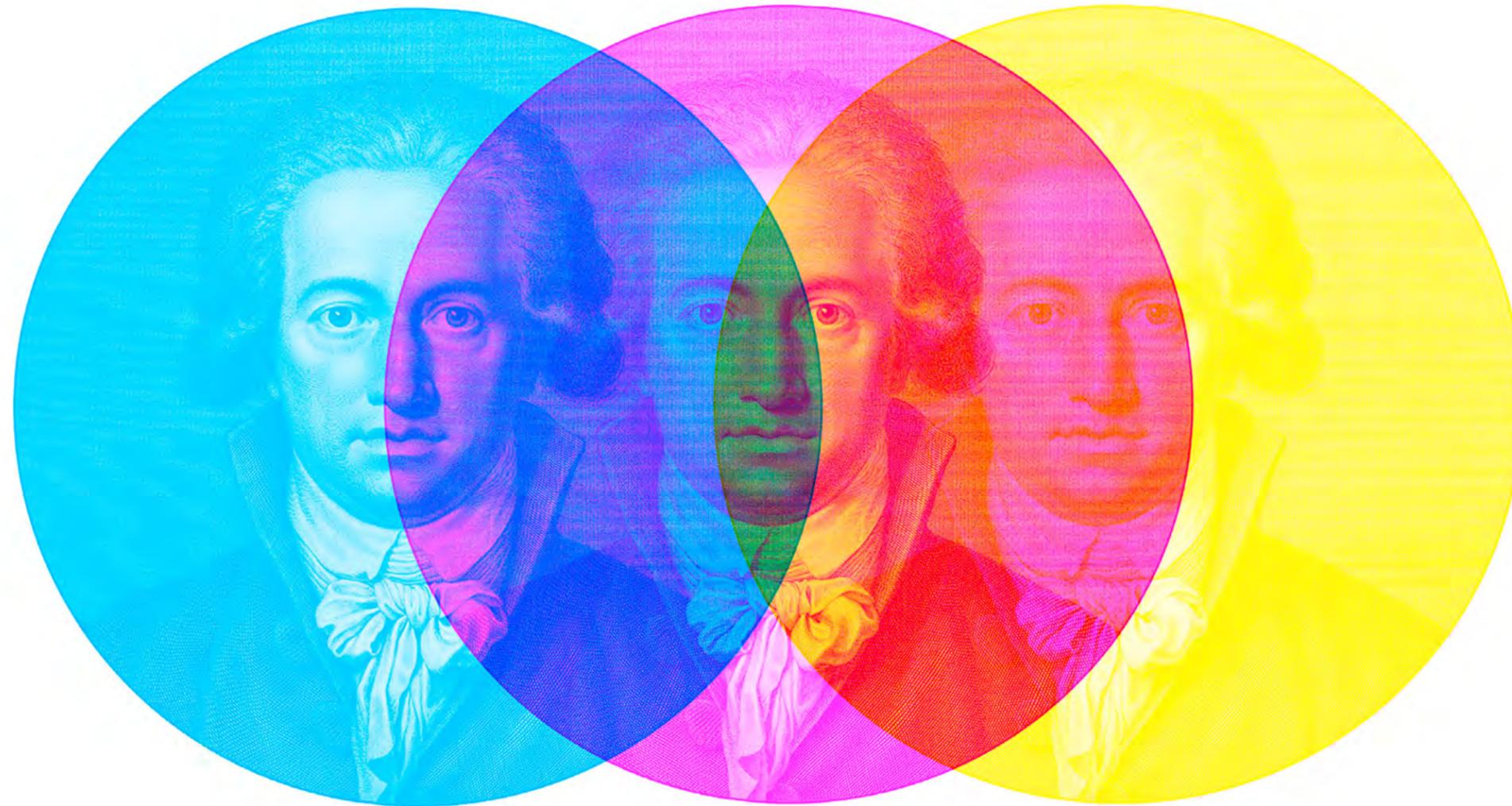
Tantillo's reading of Goethe's philosophy of nature highlights how much his thinking foreshadowed modern concepts of science, such as complexity thinking and environmental science. Scholar Kate Rigby even connects Goethe's scientific work with contemporary concepts such as eco-criticism and biosemiotics.<sup>1</sup>

Goethe saw himself as a pioneer of science, which was a burgeoning field, just emerging in the wake of the Age of Enlightenment. During Goethe's lifetime, the idea of what, exactly, constituted science was still very much in flux. As Denise Phillips outlines in *Acolytes of Nature* (2012), there existed a vivid debate in Europe about which disciplines should be included in the field of science. For example, the physicians Hermann von Helmholtz and Emil du Bois-Reymond insisted that only those disciplines that are grounded in mathematics should be counted as sciences, excluding areas of research such as botany, zoology, and anatomy. Indeed, there were discussions about the kinds of observations and experiments that should be performed, and even disagreements about the fundamentals of the scientific method. By the early 1800s, the German term *Naturwissenschaft* (knowledge of nature), included both the physical sciences (the study of inanimate natural objects, typically through experiment) and natural history (the study of natural organisms, typically through observation). While the word *Naturwissenschaft* is typically translated into English as "science," its literal meaning is "field of systematic knowledge," and thus may include different kinds of knowing. The contentious discourse about the epistemological framework of science along with the emergence of the term *Naturwissenschaft* form the backdrop for Goethe's own inquiry into the natural world.

Goethe aimed to establish a new methodology for science, one that included qualitative as well as quantitative data. Modern science differentiates between primary and quantitative phenomena on the one hand, and secondary, qualitative phenomena, on the other. This is to say that in scientific inquiry, qualitative, sense-based experience is traced back to underlying mechanical, quantitative properties. Goethe, however, rejected this rationalist approach and instead accepted qualitative experience as valid primary data. Whereas Newton measured wavelengths and calculated focal points, Goethe, ever the poet, maintained that color cannot be measured, only experienced and described. "Characteristically," notes the philosopher Hjalmar Hegge, "Goethe never uses a quantifying method. ... [His] theory of color deals with these phenomena as *qualities* and tries to explicate the relations between these" (italics in the original).<sup>2</sup> Goethe's approach to primary and secondary phenomena was to distinguish between "inner" (qualitative) and "outer" (quantitative) cause-and-effect relationships. He saw the establishment of connections between what he called the qualitative "sense eye" and the quantitative "eye of reason" as the real task of science.

One of Goethe's main criticisms of Newton's methodology was that the British scientist only focused on quantitative data, constructing abstract hypotheses. Goethe deemed this to be insufficient and simplistic. He saw scientific hypothesizing as a preliminary scaffolding upon which to build a comprehensive theory. For

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**Bettina Forget**

*Goethe's Colour Theory: Optics and Visual Poetry, 2016 digital image © Bettina Forget*

Goethe, qualitative research trains the sensory imagination, allowing the *Naturforscher* (the investigator of nature) to develop a “scientific qualitative cognition”.<sup>3</sup>

Goethe believed that this type of cognition was an acquired skill, one that could be trained by making repeated observations, and it required a full immersion into natural phenomena. “When we are able to survey an object in every detail, grasp it correctly, and reproduce it in our mind’s eye, we can say that we have an intuitive perception of it in the truest and highest sense”.<sup>4</sup>

Goethe understood the *Naturforscher* as a mediator between the subject (the investigator) and the object (nature itself). Goethe acknowledged that the investigator is part of the investigation and that reality is neither in the subject nor in the object, but in the activity in-between. Tantillo connects this object/subject relationship with the concept of *Polarität*: because each half of a polar pair is entangled in a dynamic interplay, it is impossible to distinguish the influence of each component on each other, including the influence of the investigator and the object of study. For Goethe, a *Naturforscher* needed to be able to differentiate between his or her subjective responses to a natural phenomenon and the workings of nature’s own processes. To do so, the *Naturforscher* engaged with nature through an iterative series of experiments, each comprised of three steps.

First, Goethe saw personal experience as the basis for all investigation into nature. This constituted the qualitative data gathered through the *Naturforscher’s* mindful presence in the world. The second step was to deconstruct this qualitative data in a series of replicable experiments. These experiments should

underlie a strict, transparent methodology and be accessible to a wide audience. Goethe explained in his essay *Der Versuch als Vermittler von Objekt und Subjekt (The Experiment as Mediator between Object and Subject)* (1823) that “the main value of an experiment lies in the fact that simple or compound, it can be reproduced at any time given the requisite preparations, apparatus, and skill.”<sup>5</sup> The third and final step was judgment, where both qualitative and quantitative data come into account, and a theory was constructed. Rather than expressing this element as a mathematical formula, Goethe proposed to formulate it as a short sentence, to make science more accessible and democratic.

The democratization of science was a cause close to Goethe’s heart. His own political and philosophical position was one of inclusion and egalitarianism, and he was troubled by the professionalization of science that took place in Germany in the early 1800s. Goethe saw that there was increasingly less room for amateurs and dilettantes in the emerging field of *Naturwissenschaft*. However, as Denise Phillips points out, while a scientific elite was beginning to establish itself in Germany’s universities, there were still independent *Naturforscher* who belonged to a decentralized network of science clubs, learned societies, and civic associations. As a high-profile participant in this active community of amateur scientists, Goethe felt that his work could help shape the field of science by popularizing his own experiments with color. To make his book *Zur Farbenlehre* accessible to the general public, Goethe included instructions on how to build an affordable prism, as well as a series of cards which could be used to recreate his own color theory experiments. For those who were unable to procure a prism, about half of the cards illustrated

the color effects that one would have seen with a prism, thus making his theory of colors accessible to those interested parties with lesser means. For Goethe, the process of scientific experimentation was not the purview of an elite of experts, but a democratic act that both trained the mind and brought the individual closer to nature.

Goethe's methods may seem unscientific by today's standards, but his insistence that the experimenter's qualitative experience is an integral part of scientific inquiry led him to a fundamental shift in the understanding of color: that color is both a physical quality of an object as well as a subjective response to a natural phenomenon. In *Goethe's Colors: Revolutionary Optics and the Anthropocene* Heather Sullivan describes Goethe's science as an epochal break, noting that one of his most important contributions to science was the emphasis on the human observer within the experiment and that "we are in a colorful world that we co-create."<sup>6</sup>

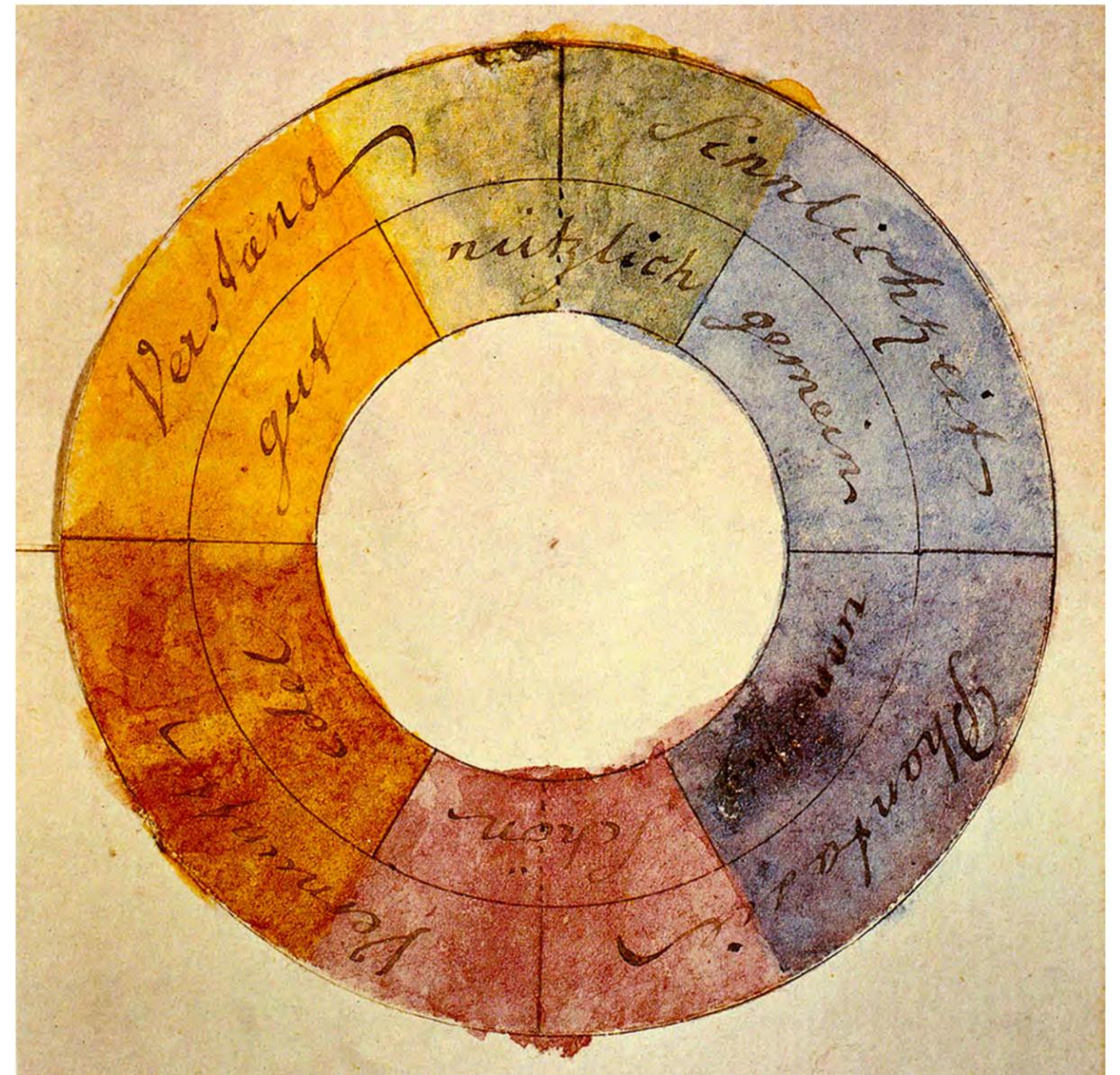
#### From "What is Color?" to "Where is Color?"

Is color in the eye of the beholder? Newton's color theory describes color as a purely physical phenomenon. Color exists independently of human existence, it is "out there." Goethe also investigated the physical properties through his prism experiments. Yet, his most significant contribution is his study of the physiological aspects of color, acknowledging that color changes depending on ambient light conditions and the influence of adjacent colors. Goethe included the idea of color being "in here," of being created inside the human mind. In effect, Goethe changed the conversation from *what* is color to *where* is color.<sup>7</sup>

Today, scholars are still divided about the questions of the *location* of color. Objectivists and Realists insist that color is fixed and that it exists independently of the mind. Specifically, in philosopher Ian Gold's words, colors are "identical to an optical property of objects such as their *surface spectral reflectance*, that is, the disposition of objects to selectively reflect light of different wavelengths in different proportions" (italics in the original text).<sup>8</sup> The author further notes that color realism maintains that "colors are external, perceiver-independent properties of the environment."<sup>9</sup> On the opposite side of the spectrum, Subjectivists, or Antirealists, propose that there is no color "out there," and believe that all color is produced in the brain and is subject to change. Relativists like Evan Thompson fall between the two camps, suggesting that color is a combination of both factors. Thompson proposes what he calls an "ecological" account of color: "on one side, the world is considered as an animal-inhabited environment, rather than a neutral material universe where the living creatures have been removed; and on the other side the perceiver is treated as an active exploring animal, rather than a disembodied spectator who serves as little more than a repository for color sensations."<sup>10</sup> The discussion about the fundamental nature of color continues to this day, a discussion that has been taking place for millennia.

#### What Is Color?

The ancient Greeks believed that color was a result of the intermingling of light and dark. Aristotle's modification theory placed white and black at the far points of the spectrum and red at the very center. All other colors were the result of modulating light and shadow, with yellow, the lightest color, closest to white, and blue, the darkest



Johann Wolfgang von Goethe  
Farbenkreis, 1810. Public Domain

In his investigation of light and color, Newton examined the physical properties of color and discovered that color is the result of the refraction of white light.

color, closest to black. This was the dominant understanding of color until Newton revolutionized it with his prism experiment in 1666.

In his investigation of light and color, Newton examined the physical properties of color and discovered that color is the result of the refraction of white light. In his experiment, Newton drilled a hole into a board and used it to cover his drawing-room window. He then placed a white screen 22ft. away from the window and allowed the light beam from the hole to pass through a prism. The result was an elongated strip of rainbow colors. Based on this observation, New-

ton drew the conclusion that the prism refracts the light at different angles. Light rays that are refracted less travel a shorter distance through the prism and appear blue, rays that travel a longer path are refracted more and appear red.

Goethe attempted to replicate Newton's experiment but neglected to use a board with a pinhole. When he held the prism up to the light no spectrum was projected onto the screen, only white light was reflected. Eventually, Goethe looked directly through the prism by holding it in front of his eye. He then noticed that when he glanced at an area of high contrast, colored borders would appear at the edges of light and dark objects, a phenomenon now termed "border spectrum". Flaring up from a dark area were lines of blue and purple, whereas white areas produced yellow and red bands. Based on this observation, Goethe concluded that color is the result of both light and shadow, much like the ancient Greeks had proposed centuries ago.<sup>11</sup>

.....  
*Goethe writes in a letter to a friend that, in essence, "colored phenomena are far more physiological than is realized".*  
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Goethe described the mix of light and dark as a *Steigerung*, an intensification of the interplay of light and darkness, which produces the effect of color. In effect, Goethe proposes a heterogeneity of shadows that counters Newton's refrangibility of light. While the notion of black is completely absent from Newton's color theory, it forms an integral part of Goethe's theory; much like a painter, he connects hue and tone.

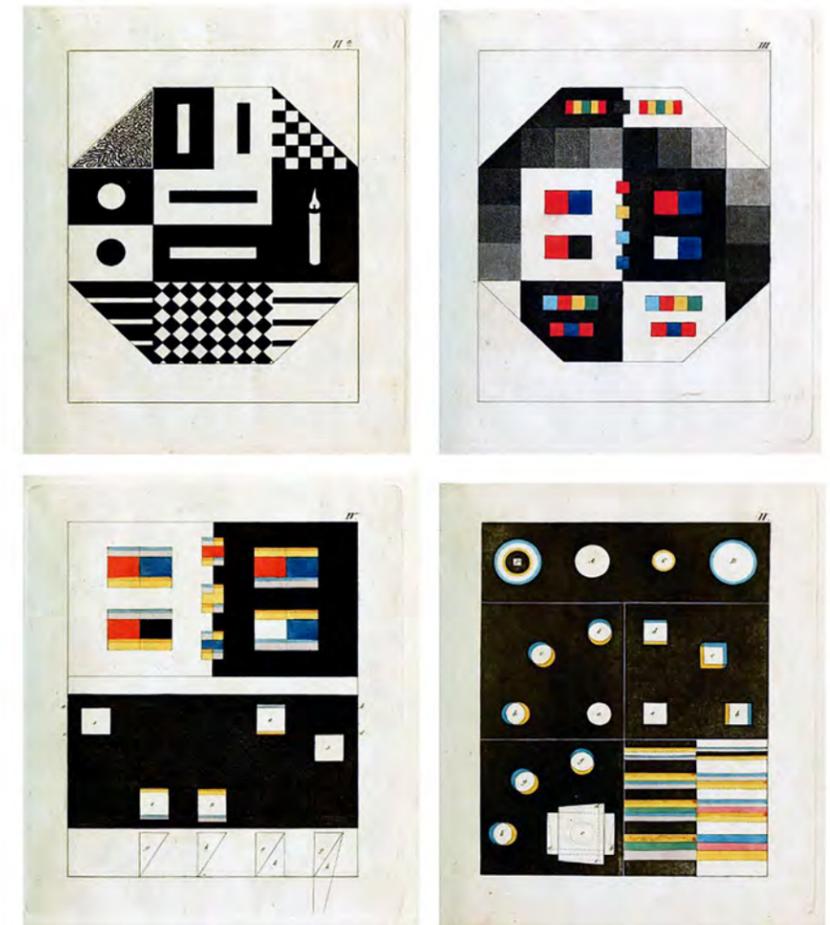
Goethe was intrigued by the border spectrum phenomenon and decided to investigate it further. To this end, he prepared a series of cards featuring high-contrast designs which, when viewed through a prism, would produce a range of color effects. Most cards featured a variety of black and white geometric patterns to better examine border spectra, others alternated various color combinations. For example, one card design showed a small white dot on a black background. Seen through a prism, the dot is surrounded by a spectrum of red, yellow, green, blue, and violet. However, if this experiment is reversed (a black dot on a white background), a different spectrum emerges. Looking at the white card through a prism, the color spectrum produced is blue, violet, purple/magenta, red, and yellow. This is a spectrum that Newton did not describe, and one of Goethe's main arguments in refuting Newton's *Optics*.

We now know that Goethe was mistaken about the physical nature of color. However, while Goethe committed some fundamental logic errors in his theory of colors in terms of physics, his realization that the human experience of color is an integral component of optics helped to change the conversation about color from the "what" to the "where."

### Where is Color?

One of Goethe's most influential contributions was the inclusion of physiological phenomena in the discussion about color. As part of his extensive series of experiments on the subject of color, Goethe investigated how ambient, environmental changes and adjacent colors influence the way we see color. Goethe was particularly interested in two phenomena: afterimages and colored shadows.

Afterimages appear when we stare for a prolonged period at an image of high contrast or color density and then look at a blank space. We see an illusionary image which is inverted: if the image we focused on was black, the afterimage will appear white; if the image was a vivid red, the afterimage will appear in its complementary col-



Johann Wolfgang von Goethe

Illustrations of experiments in *Zur Farbenlehre* 1810. Public Domain

or, green. The cause for this is physiological: the cones of the retina, the red, green, and blue color receptors become fatigued when we stare at a particular color for a long time. When we look away from the intense color and onto a plain, white surface, the fatigued cones are inefficient, and the resulting imbalance between the red, green, and blue cones causes a temporary image of the opposing color to appear. Goethe's understanding of polarity (black/white, complementary colors) and the subjectivity of human experience help explain how afterimages work.

Goethe also experimented with shadows and observed how we perceive them not as purely grey, but as colored. He had noticed the effect of colored shadows in nature, as, for example, the warm glow of the setting sun causes blue shadows to appear on snow-covered fields.<sup>12</sup> The effect occurs when an object receives light from two differently colored light sources (for example a light with a red filter and a light with a green filter) and then casts two shadows in complementary colors (the shadow cast by the red light appears green, the shadow cast by the green light appears red). After performing

a series of these experiments Goethe concluded that the effect is not due to any kind of physical refraction of the light, but that it is caused by human perception. He writes in a letter to a friend that, in essence, “colored phenomena are far more physiological than is realized.”<sup>13</sup> However, this time the cause is not physiological, but psychological, it is the brain that plays tricks on us. Delabarre proves this by proposing a simple experiment, in which he encourages the reader to isolate an apparently colored shadow by looking through a tube, which restricts the observer’s view. Once the source of the colored light is removed, the shadow appears neutral in color. Delabarre calls the colored shadow effect a “deception of judgement”<sup>14</sup> and quotes Delbœuf as saying “the sensation of color can depend upon an act of thought alone.”<sup>15</sup> Color is not just in the eye of the beholder, but also in the mind of the beholder. We turn from the “what” and “where” or color to the “how” of color.

### How Is Color?

*In visual perception, a color is almost never seen as it really is—as it physically is. This fact makes color the most relative medium in art.* — Josef Albers, 1965

Heather Sullian remarks that Goethe was prescient in his insistence that scientific inquiry should address the subjective experience of the observer in nature. “We are never truly outside the system,” notes Sullivan, “we must remain constantly alert to our tendency to see ourselves rather than the world.”<sup>16</sup> Indeed, Goethe’s *Farbenlehre* considered the subjectivity of human perception as being a major factor in the understanding of color theory. His methodological exploration of color and human perception not only resonated with his contemporaries such as the philosophers Schopenhauer and Hegel, but also inspired artists centuries later, most notably the Bauhaus artist Josef Albers. Brenda Danilowitz suggests that “Goethe’s spirit must have permeated the very air of the early Bauhaus, which opened in Weimar in 1919, nearly a century after the great writer’s death.”<sup>17</sup>

Goethe’s *Farbenlehre* became a model both for Albers’s own creative practice, for his teaching at the Bauhaus, and later at Black Mountain College and Yale University in the United States. Albers recalls “my reading of Goethe’s *Theory of Colors* goes back to a far-distant past, probably to a time before I joined the Bauhaus in 1920 when I was 32 years old...” Albers’s magnum opus is his book *Interaction of Color*, (1963) which he developed during his many years of teaching of color theory. However, the book is not a traditional textbook but a series of visual exercises and experiments aimed at developing an awareness for the interplay of color effects and human perception.

Albers explains that *Interaction of Color* is “a record of an experimental way of studying color and of teaching color, placing practice before theory.”<sup>18</sup> Indeed, Albers eschewed rote learning and the fabrication of tedious color wheels and diagrams. Instead, his exercises were hands-on, trial-and-error experiences which encouraged students to play with different hues, tones, and intensities. His aim was to get his students to “see color action as well as feel color relatedness.”<sup>19</sup> Albers’s focus on exercises and experimentation in his *Interaction of Color* echoes the set of cards that Goethe created to accompany his *Farbenlehre*. Both Goethe and Albers used visual

aids, experiments, and hands-on activities to help observers better understand the connection between color and human perception, both underscored the subjectivity with which our brains process visual stimuli. Albers distinguished between different types of vision, making a distinction between the neurobiological process of “ocular seeing” and the subjective process of “vision,” which required imagination.<sup>20</sup> For Albers, color was a product of both culture and nature, it was real and imagined, a dialogue between object and subject.<sup>21</sup> This differentiation between modes of seeing connects to Goethe’s *Farbenlehre*, which aimed to train both our qualitative “sense eye” and the quantitative “eye of reason.” For Goethe, seeing was an active pursuit. He proposed that the eye possessed its own creative abilities, that it could independently produce color. Therefore, one could never be certain whether a color really exists, or whether is produced by the eye.

The idea of active sight is echoed in the writings of Gilles Deleuze, who coined the term “haptic color.”<sup>22</sup> Deleuze differentiates between haptic and optic visuality. Optic visuality is passive and relates to cognition and how the brain synthesizes objects in space. Haptic visuality is non-subjective and active, as though the eye has a “touch function.” According to Carolyn Kane, both Goethe and Deleuze see color as haptic, physiological, and immersive. Kane points out that color is often seen as subservient to form, but that both Deleuze and Goethe place color perception before cognition, that “color predated the organization of reason and the cognitive sense.”<sup>23</sup>

Can color be considered an entity in its own right? So far, we have examined color as an independent thing in itself, as a spectrum, as a phenomenon of human cognition, as a biological response to stimuli. But how we experience and understand color is also tied to the “real” world “out there,” to objects of color. Can we experience a color without considering its form?

Ricardo Piñero Moral and Yvonne zu Dohna posit that color can and does exist independently of form and symbolism and that it directly affects the emotion and perception of the viewer. The authors propose that color is pictorial, that it is its own reality, and it is not merely a characteristic of something else. For Piñero Moral and zu Dohna “color is considered to be without form, syntax, and pragmatics.”<sup>24</sup> This, they term the “rhetoric of color,” where the emotional affect is produced by the interplay between color (or an artwork) and the observer and connect this rhetoric to the larger field of aesthetic experience theory. The rhetoric of color, the authors suggest, has the power to persuade and communicate, because sight is an active sense, not a passive one. Seeing is imagining, it is, in effect, the brain which sees.

The artist James Turrell questions this rhetoric of color through an exploration of color, light, and object. His installations create uncertainty about whether color is produced by light, by the objects, the spaces being lit, or by the viewers’ own perception. As Patrick Beveridge notes, the surfaces of Turrell’s *Ganzfeld* light installations are calibrated in such a way that they do not give rise to gradations of intensity in the light that they reflect. As a result, viewers experience spaces that appear to be flooded by homogenous fields of light. Turrell’s work poses a paradox: it gives visitors the impression of being immersed in pure light, while at the same time highlighting the fact that it is the object’s surface that is the key to producing the unique light effect. “Normally we don’t see light,” Turrell explains,

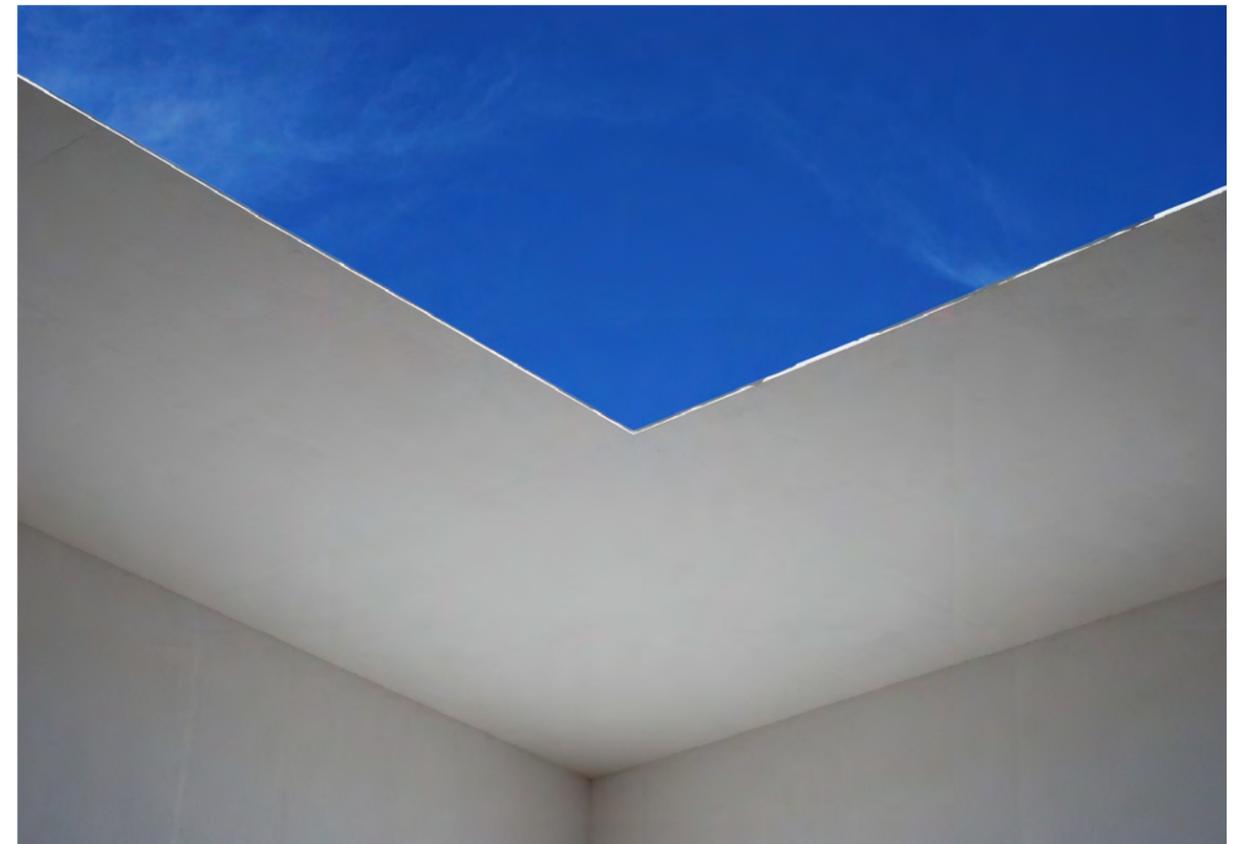
.....  
*Albers explains that Interaction of Color is “a record of an experimental way of studying color and of teaching color, placing practice before theory”.*  
.....

“but we see something that light reveals.”<sup>25</sup> This observation connects with Evan Thompson’s viewpoint, who argues that “We . . . do not see colors without seeing something as colored and consequently, the fundamental element of color perception is the seeing of a colored thing, not the color sensation. . . . we do not see light that is in the air or that fills the air.”<sup>26</sup> However, Turrell is not interested in joining the ongoing discussion about the location of color, he is not siding with Objectivists, Realists, or Relativists. Rather, suggests Michael Govan, installations like Turrell’s *Skyspace* are designed to make us question our senses, to foreground our experience of color; human perception is Turrell’s true medium. “The greatest revelations borne by Turrell’s art are a deeper understanding of what it is to be a perceiving being and an awareness of how much of our observation and experience is illuminated by the inner light of our own perception.”<sup>27</sup> Extending the work of Goethe and Albers, Turrell’s installations create a dialogue between light, color, object, and the human sensory system.

.....  
**May Pearce quotes Turrell as saying**  
**“What takes place while looking at**  
**the light in a *Skyspace* is akin to**  
**wordless thought. But this thought**  
**is not all unthinking or without**  
**intelligence. It’s just that it has a**  
**different return than words”.**  
 .....

Mary Pearce highlights a further component that is part of Turrell’s work: language. Pearce remarks that Turrell’s work coincided with the linguistic turn in late twentieth-century contemporary art, a time when the study of color veered away from the idea of color as a source of visual pleasure and toward the concept of color as a linguistic and connotative function. Indeed, Turrell contemplated the relationship between language and visual perception, stating that “If you only have five names for color, you only see five colors.”<sup>28</sup> However, notes Pearce, color might remain one step beyond our comprehension. She quotes Turrell as saying “What takes place while looking at the light in a *Skyspace* is akin to wordless thought. But this thought is not all unthinking or without intelligence. It’s just that it has a different return than words.”<sup>29</sup> Again, Turrell leaves us with a conundrum, much like his disorienting installations that make material surfaces both appear and disappear. Is color extra-linguistic, or can we only see colors for which we have a word? Is our perception of color dependent on language, and if so, how do language and culture shape the meaning of color?

While Turrell does not provide us with easy answers, Goethe does overtly assign specific meanings to color. To illustrate his theory of colors, Goethe created a color wheel which placed complementary colors opposite each other to illustrate the physical as well as the physiological aspects of color. To this color wheel, Goethe also added associations pertaining to emotions and character traits. He called this version of his color wheel *Farbenkreis zur Symbolisierung des menschlichen Geistes- und Seelenlebens*, (1809) (*Color Wheel for the Symbolization of Spiritual Life*). He associated red with “beautiful,” orange with “noble,” yellow with “good,” green with “useful,” blue with “common,” and violet with “unnecessary.” These six qualities were in turn nested under four categories of human cognition. The rational was associated with the beautiful and the noble (red and orange), the intellectual was associated with the good and the useful (yellow and green), the sensual was associated with the useful and the common (green and blue) and the imagination was associated with the unnecessary and the beautiful (purple and red). The inclusion of the quality “unnecessary” in the last pairing may seem counter-intuitive, since Goethe valued the use of imagination both in art and in the investigation of nature. However, if the term “unnecessary” is read as “without purpose,” or as “without a goal,” then



**James Turrell**

*Skyspace*, Israel Museum, Jerusalem. Public Domain. Photo: Xsteadfastx

it could implicate the open-ended playfulness that is an integral part of the imagination.

This color wheel was preceded by an earlier version from 1798/9 which Goethe created in collaboration with his colleague and friend, the poet Friedrich Schiller. The pair were inspired by the medieval quadripartite system, which organized the world into groups of fours, such as the four elements, the four humours, the four cardinal points of the compass, the four seasons, the four ages of man, the four times of the day, and the four phases of the Moon. Titled the *Temperamentrose* (Rose of Temperaments), Goethe and Schiller allocated twelve occupations (ruler, tyrant, hero, adventurer, hedonist, lover, poet, public speaker, historian, teacher, philosopher, pedant) to a wheel of twelve colors. Overarching these categories were four temperaments, or personality types, following the theory of the Greek physician Hippocrates, who categorized humans as sanguine, choleric, melancholic and phlegmatic. These associations may seem fanciful, but remember that Goethe was explicit about the need to connect quantitative and qualitative data. His color wheels are examples of creating connections between the empirical (the polarity of complementary colors, arranged on the color wheel in a way that complementary colors lie opposite each

other) and the subjective (assigning allegorical and mystic meanings to color). Goethe drew a distinction between symbolic color, which reflected nature, and allegorical color, which constructed meaning, “a distinction which rested on the belief that colors had a direct, not simply mediated, effect on the mind and feelings.”<sup>30</sup> For Goethe, color was not only physical and physiological, but it was also moral.

Since color occupies such an important part of the primary natural phenomena, filling the simple circle (or wheel) assigned to it with an immense variety of hues, it is no surprise that in its more general elemental manifestations, with no relationship to the nature or configuration of the body on which we perceive it, it should produce a specific effect on the sense of sight, and, through this conduit, on the human soul, in combination with an either harmonious or characteristic effect, although often not so harmonious, but always defined and significant, that is tightly linked to the moral sphere. Therefore, color, considered as an element of art, can be put to the service of the highest aesthetic goal. (Goethe, *Zur Farbenlehre*).

Goethe’s associations of colors with moral connotations were informed by cultural context as much as by aesthetics and human emotion. In the third volume of his *Farbenlehre*, in the section titled Allegorical, Symbolic, Mystical Use of Color, Goethe remarks that many of the associations made between color and meaning are grounded in cultural conventions. As an example, he states that the color green is typically assigned the meaning of “hope”. Therefore, to be able to grasp the meaning of the color green, one must first be familiar with the culturally assigned symbolism associated with the color. Goethe also discusses cultural conventions in connection to color in the section “Considerations” derived from the *Evidence of Experience and History*. There, he provides insights such as “Lively nations, the French, for instance, love intense colors, especially on the active side; sedate nations, like the English and Germans, wear straw-colored or leather-colored yellow accompanied with dark blue.”<sup>31</sup>

While these comments may read like prejudicial generalizations, they nevertheless illustrate Goethe’s interest in relating color with social and cultural contexts. In the nineteenth century, this was an innovative idea. In the early 20th century, observes Timon Beyes in *Color and Organization Studies* (2016), the study of color, meaning, and cultural context became more commonplace, and began to take on a commercial aspect. Beyes calls this period the “age of color,” as industrially produced colors became widely available and began to permeate fashion, interior design, and product design. Since this time, color and commerce have merged in the world of modern business practice in the form of color forecasting agencies.

As Whitfield and Whelton note, “these [agencies] produce reports on the colors for particular product categories that should be acceptable to the public in the next year or two,”<sup>32</sup> so that manufacturers can adjust the color palettes of future products according to the predicted *Zeitgeist*, potentially increasing their profit margins. Today color is associated with corporate brands, such as the bright color spectrum of Apple Macintosh products, the “golden arches” of the fast food giant McDonalds, or you may ask “What can brown do for you?” when shipping a parcel with UPS. The commodification of color by corporations such as Pantone and Adobe poses the ques-

tion “who owns color?” as these large multi-nationals occupy the hex and CMYK space. Beyes notes that “color is the gift that lends aura to commodities. A liberating and corruptive force, both authentic and deceitful, magical and poisonous: such is its ambiguity.”<sup>33</sup>

Werner Heisenberg commented on the influence of *Zur Farbenlehre*, noting that while Newton’s color theory may have influenced research in the field for the following century, “Goethe’s color theory has in many ways borne fruit in art, physiology and aesthetics.”

Indeed, Goethe’s Romantic version of science, which eschews mathematics in favor of subjective experience and judgement, faded from view at the beginning of the 20th century. His proposed method of training scientific qualitative cognition, as it turns out, is not a reliable method to construct scientific knowledge. However, we may consider Goethe’s *Naturphilosophie* as a call for deeper reflection on natural phenomena, and an acknowledgement that the scientist, the human being conducting science, is inextricably linked to the natural phenomena under investigation. The realization that the experimenter is part of the experiment was integral to Heisenberg’s own work in quantum physics in the 1920s, and the contextualisation of science and society became the focus of philosophers of science in the middle of the 20th century with thinkers such as Kuhn, Latour, Feyerabend, and Haraway.

While Goethe is not a household name in the visual arts today, he nevertheless inspired an in-depth engagement with color in modernist and contemporary art, as we saw in our review of the works of Joseph Albers and James Turrell. Goethe’s investigation of the relationship between color effects, human perception, and meaning provides fertile ground for further creative explorations.

Goethe’s methodology of mixing qualitative and quantitative data did not prove fruitful in the development of science, but his focus on observation, subjectivity, experimentation, and popularization has left marks on how we understand and use color today, and foreshadowed new thinking in science and in art. Goethe’s model of the *Naturforscher*, the investigator of nature, may provide a scaffold for artists who are interested in scientific inquiry, and anyone who is interested in reflecting on the relationship of the human experience and nature.

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# Dynamic Form: Klee as Artist and Morphologist

*Guided by the themes of formation and growth in the artist Paul Klee's work, which resonate with those of my own practice, this essay has developed in parallel with my own progression from an empirical understanding of form as object towards a conceptual understanding of form as process. Here, I advance an original outline of the relationship between Goethe's concept of morphology and Klee's art. Central to this is the atypical consideration of certain works by Klee as morphological studies. Following Goethe's concept of morphology as the study of form and formative process, I interpret Klee's artistic representation of the dynamic nature of form and, based on particular examples, propose Klee as a morphologist.*

text by **Gemma Anderson**

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Between 1892 and 1896, while at secondary school in Bern, Klee attended lessons on 'Morphology and flowering plants', 'Classification of simple plant types according to Fankhauser's principles',<sup>1</sup> 'Description of individual examples of flowering plants', 'Designing a herbarium' and 'The Linnaean system'<sup>2</sup> where he copied out detailed descriptions of various classes, orders and genera that subdivide the plant world.

As a youth, Klee was an avid walker, hiking around Beatenberg alone when he was fourteen. This experience inspired him to collect natural curiosities and flowers for pressing. He continued to make numerous collections: flowers, leaves, roots, seedpods, rocks, crystals, lichens, corals, molluscs, butterflies, seahorses and sea urchins, many of which appear and are transformed in his art.<sup>3</sup>

In his early thirties, especially during the years 1912–14, Klee became particularly interested in the subtle energies and dynamics that make things live, germinate, grow and move; to summarize, he became interested in genesis. Through this interest in germination and formation, Klee's work shifted in a gradual progression from a macroscopic to a microscopic view of form (1912–14). This interest also indicates a transition from a study of form as peripheral, motionless and visible towards a study of the internal, dynamic and invisible nature of form.

Klee's appointment at the Bauhaus in 1921 helped him to clarify and communicate his ideas and methods. Many of his students remarked on his ability to make them see nature afresh, as if for the first time and from a viewpoint that was both scientific and thoroughly creative. Klee reflected on his own methods: "As their talent develops, guide pupils towards nature, into nature. Make them experience how a bud is born, how the leaf grows, a butterfly unfolds, so that they may become just as resourceful, flexible and determined as nature".<sup>4</sup> In his elementary painting class, Klee taught students to see 'not form, but forming, not form in its final appearance, form in the process of becoming'.

Although it was not possible for Klee to encounter Goethe in person, when Klee moved to Weimar to work at the Bauhaus in 1921, he walked to work past Goethe's Garten Haus in the Ilmpark (River Park). He also frequently visited the Goethe Haus on the Frauenplan in Weimar, where the original drawings from Goethe's *Metamorphosis of Plants* and Goethe's colour studies were among the exhibits. Klee also attended a lecture by Rudolf Steiner in Munich in 1908 on Goethe's theory of metamorphosis.<sup>5</sup> It is clear from a letter Klee wrote to Katherine Dreier on 30 March 1926 that this lecture excited Klee's interest and revealed his interest in Goethe's Archetypal plant form.<sup>6</sup> This interest manifested through artworks like *Strange Plants* (1924) that made clear reference to Goethe's concept of the Urpflanze.

### Goethe and Klee: Thinking alike from the eighteenth to the twentieth century

Klee's writings reveal him as a thinker remarkably similar to Goethe, as their views on plant life, nature study and form often coincide. Goethe and Klee shared a deep interest in nature, plants and the concept of the archetypal form. They also shared a similar methodology rooted in observation. Klee followed the study of nature that Goethe advocated; his own search for archetypal forms and his willingness to learn their laws and inner workings gradually led him to a new way of seeing, as the art historian Sara Lynn Henry articulates:

No attempt to understand the intellectual background of Klee's ideas on nature can ignore the fact that his approach to nature shares more in common with that strain of scientific mysticism which originated from Goethe and which has attracted disciples right up to our own day, than it does with any more recent development in the history of ideas.<sup>7</sup>

For Goethe form was never static, but always in a state of becoming. Klee shared this view: "It is precisely the way which is productive, that is the essential thing, becoming is more important than being".<sup>8</sup> For Klee too, all of creation was essentially a matter of forming, of building and shaping primordial elements and ideas. This realization could only come from a study of form and through a familiarity with the processes, which brought form into being, in short, the phenomenon of formation.

Klee viewed the work of art and its creative processes as analogous to the constant metamorphosis of the living world, an idea which he knew through Goethe's writings.<sup>9</sup> In a lecture at the Bauhaus in 1921, Klee outlined the concept of genesis as "multilayered historicisation linked to artistic work".<sup>10</sup> He later applied the 'genetic' as a visual concept in the series of drawings *Infernal Park* (1939).

Like Goethe, Klee's morphological insights emerged through intensive and sustained observational study of as many plant types as possible.<sup>11</sup> Klee's *Fantasy Flora* series points the mind in the direction of Goethe's archetypal plant. As discussed by scholars such as Huggler, Haftmann and Verdi, Klee, like Goethe, wanted to discover Urformen and Ursetzen (primary forms and principles) out of which all related forms develop.

Both Goethe and Klee's application of thought and reflection to their observations led to an intuitive understanding of the common forms and processes that pervaded all plant life. Goethe and Klee both realized that only by penetrating to the smaller units, which made up the complex composite plant, could the inner dynamics of nature be confronted, an approach that is also evident in my own Goethe-inspired drawing method.<sup>12</sup>

Through meditating on the plant's essence rather than its appearance, Goethe discovered that all parts of the plant were essentially modifications of the leaf, proposing "the plant is nothing but leaf".<sup>13</sup> Based on my own study and the literature discussed, I consider Goethe and Klee as sharing a similar quest: to discover the underlying morphological features that are shared by all plants. This interest was not to recount the history of plants but rather a history of the plant, looking for similarities between plants rather than differences. As comparative thinkers, they aimed to discover analogies between apparently dissimilar things, an aim that is shared by my own Isomorphology study.<sup>14</sup>

Klee and Goethe's reference to the 'genetic treatment' meant a gradual advance achieved by observing, contemplating, speculating, analysing, penetrating and slowly comprehending objects to such an extent that it is possible to step away from the object and to recreate it in the mind.<sup>15</sup> The observer must look beyond the surface to see the essence of a thing and the forms that lie concealed within. Goethe believed that the essential form of a plant can only be seen if the eye has penetrating spiritual power which he called 'intuitive judgement'. Klee also described this capacity as



**Paul Klee**  
*Assyrian Game*, 1923. Oil on cardboard, 37x51cm.

'visible penetration',<sup>16</sup> consisting of dissecting or visualizing the inner working of an object until it is possible to grasp its essence. An image should, therefore, show not only external appearance or final form but the process of formation as well.

Klee searched for the 'nature' rather than the appearance of things and the formative process behind the form. He did not seek to represent objects but rather to make visible dynamic process. This quest for the invisible archetype behind countless visible species was accompanied by a desire to uncover the unifying features linking even the most diverse beings and reinforces the similarity of Klee's thinking to Goethe's.<sup>17</sup> This linking does not necessarily imply a scientific relationship but is better understood with a pluralist framework, in which there are many ways to make relations between things. For Klee, the economy of nature's invention lay hidden beneath an endless array of appearances in an order that remained concealed from the ordinary observer. "Nature can afford to be prodigal in everything, the artist must be frugal to the smallest detail".<sup>18</sup> Klee's a priori flower types do justice to this economy, offering a glimpse of the basic floral types and forms out of

which nature has created endless variety. Klee created an order for these basic forms, for example, in the artwork *Assyrian Game* (1923). In his 1923 essay 'Ways of nature study', Klee suggested plane sections as a method to penetrate appearance by dissection, a method that Goethe has also used.<sup>19</sup> This knowledge of structure can lead to knowledge of how something was formed and how it functions; anatomy becomes physiology. Goethe recognized one such relationship of form and function as the development of the plant that is governed by the alternating processes of expansion and contraction and proposed two basic tendencies that shape the growth of the living plant: linear-vertical and helical-spiral.

Klee realized that in the process of coming to terms with the world through images, he had to extract something typical: "from a series of examples I shall automatically discover the typical" Klee, like Goethe, wanted to discover primary forms and principles out of which related forms develop, an aim that is shared by my own Isomorphology study.<sup>20</sup>

Goethe's morphological insight was enriched by his preoccupation with natural sciences (especially plant sciences), which he developed into *The Metamorphosis of Plants* (2009 [1790]) and other works. Although philosophically similar, it is important to note that Klee represented the nature of form through visual artworks whereas Goethe realized his studies through literature. Klee's art, like the Goethe drawing method I have developed in previous work, achieves a visual approximation of Goethe's conception of morphology.<sup>21</sup> I will now explore the visual dimensions of Klee's work, which allow form and colour to grade through time, through which I propose Klee brings Goethe's morphology into new aesthetic dimensions.

### **Klee as a morphologist**

The art historian Sara Lynn Henry considers the years between 1912 and 1914 as a turning point for Klee. She describes how after years of observational study, Klee understood the nature of form well enough that he could break the bonds of nature, pick up the pieces and begin to create anew. Until this point, Klee had patiently trained his eye through observing stones, flowers, animals, and people. The transformation in his thinking is revealed through this reflection:

One day when looking at a shell, it became appallingly clear to me that its existence was not as trivial as I had formerly believed. More and more, I felt that there was a common bond between everything. And then I knew: the world is the power of imagination, imagination – power.<sup>22</sup>

Developing a drawing practice inspired by Goethe's methodology in my own work has helped me to understand Klee as a 'visual morphologist' in the following ways:

- Klee's observational study accumulated into a morphological knowledge, that allowed him to improvise with form and follow Goethe's vision of the morphologist 'to go on forever inventing plants and know that their existence is logical; that is to say, if they do not actually exist, they could for they [...] possess an inner truth and logic'.<sup>23</sup>
- Klee's understanding, both empirical and conceptual, of the com-

mon forms and symmetries of animal and plant bodies is evident in many works, for example, in the cell-like *Assyrian Game* (1923).

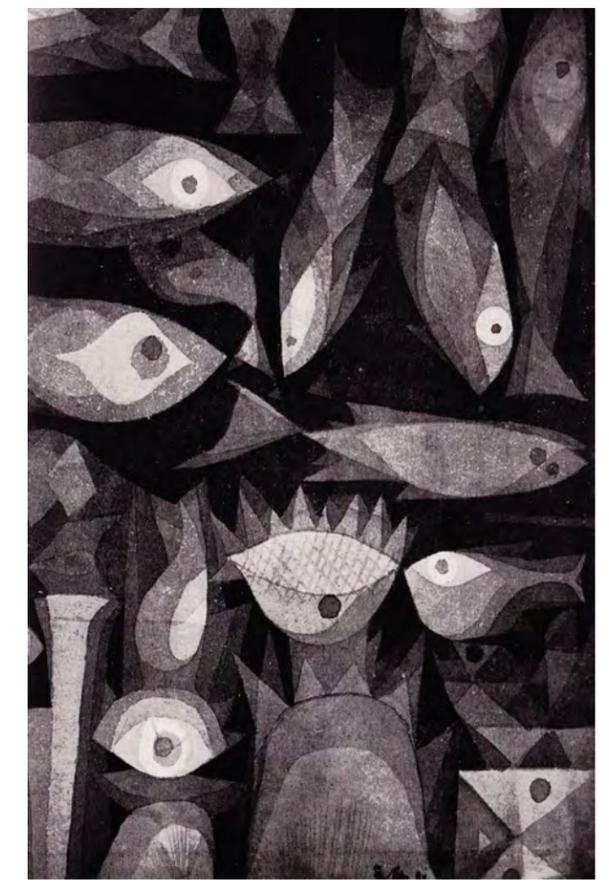
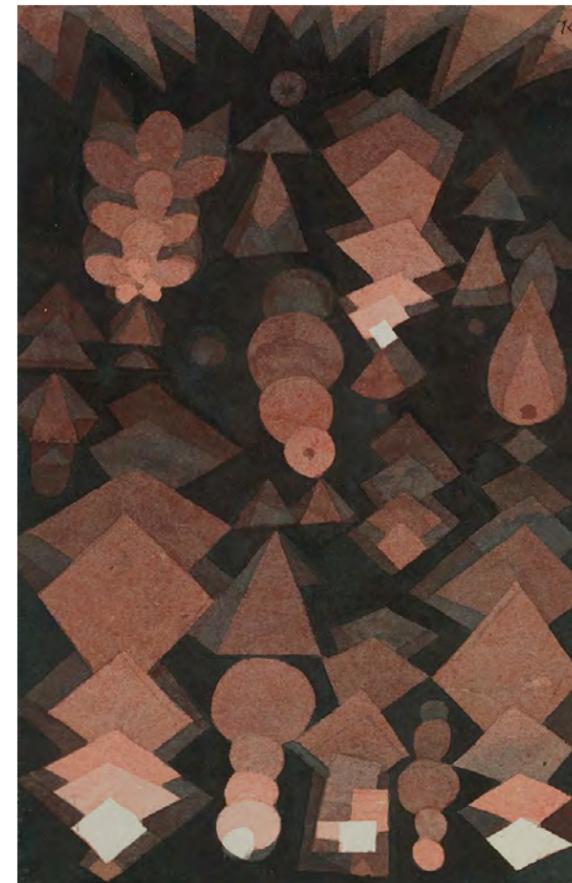
- Klee's work conveys the sense of building (bildung), revealing his view of form as formative and dynamic process not as a static object.
- The works *Suspended Fruit* (1921), *Fishes* (1921), and *Fugue in Red* (1921) can be interpreted as 'developmental series' in different ways.

To begin exploring Klee as a visual morphologist, I will discuss the work *Komedie* (Comedy 1921) that I was able to observe first hand and draw in the *Paul Klee* exhibition held at London's Tate Modern in 2013. *Komedie* is composed of a series of totem-like figures: plant, animal and human, which Klee has created through an improvised recombination of formal elements that he knew from his observations of the plant and animal world. The figures appear as alien, unearthly beings and yet they resonate with a strange familiarity. Each individual is a complex composite of segmented parts that, on closer inspection, becomes recognizable as an example of a particular variety of the basic plant forms. These include spiral, tubular, four-fold, radial, spherical, three-fold, eight-fold, budding and bilateral forms. Klee added his abstractions of the rhythmic lines and textures of plants to different areas of the figures. These forms, which can be found in the most common garden plants, are recombined with wit and humour to form new plants, people and animals, which do not exist of this world yet could in a world that Goethe imagined:

[...] that is to say, if they do not actually exist, they could, for they are not the shadowy phantoms of a vain imagination, but possess an inner necessity and truth. The same law will be applicable to all other living organisms.<sup>24</sup>

*Komedie* is just one example of Klee's work as a visual morphologist. In it, Klee has realized the potential of the morphological study that Goethe imagined. In *Komedie* it is clear that Klee is drawing from his own observations, from nature's model, and his observations and drawing practice have provided the key to invent with. We can see this invention in Klee's recombination of familiar forms, observed and sourced from nature (especially plants) and although they do not exist in the physical world, they do exist in the theoretical space of drawing and do possess their own internal necessity and order.

In the works *Suspended Fruit* and *Fishes*, Klee shows a number of forms evolving through a developmental sequence. Each stage of the development of the form is graded with a layer of watercolour, the result being an impression of form evolving through the added dimension of time. In this work, Klee is representing the dynamic nature of form: as a moving, formative process. To Klee, the concept of mobility meant motion in space and also in time. Klee explored the conceptual and visual possibilities of plants as temporal, moving and transformative entities and reveals his own insight into the formative nature of fruit, flower, seed, and root. Representing growth as a progression of form through time and space is at the core of Klee's visual morphology. This ability to improvise with form in a time se-



Paul Klee

*Suspended Fruit*, 1921. Watercolour on paper, 22.9x30.9cm and *Fishes*, 1921. Watercolour on paper.

quence sets his work apart from modern time-lapse photography that can only capture a series of instances, whereas the artist can conceive, intuit and represent formative process as a continuum. It is remarkable that Klee developed methods and understanding to represent and therefore communicate this dynamism, considering the era's social and technological limitations. Klee's colour gradation method, combined with the gradation of form, emphasizes and 'makes visible' nature as a dynamic rather than static reality.

#### Klee's colour gradation method

Klee's colour gradation technique can be understood as a continuous contrasting movement of tone and colour generated through a numerical ratio method.<sup>[25]</sup> Klee compares the intensity of gradation of colour to sound, describing the movement/ gradation of colour along a 'tonal scale' (mixing each colour for each gradation) and suggesting colour gradation as a signifier of gradual change over time by adding a sense of motion and transformation.

As part of his teaching at the Bauhaus, Klee drew a colour scale as a kind of musical score; he also drew a linear representation of tonal scale and used proximity and number of lines to create tonality. Further, he described types of tonal representation as:



**Paul Klee**  
*Fugue in Red*, 1921. Watercolour and pencil on paper on cardboard, 24.4x31.5cm.



**Paul Klee**  
*Komödie*, 1921. Watercolour over oil-colour drawing on paper, 12x17.7/8" (30.5x45.5cm). Courtesy of Lily Klee (Knapping Fund) 1946.

standing, gliding (soft or hard), striding (small or large) and leaping.<sup>26</sup> He then outlined tonal gradation in numerical ratio terms and the 'blending' method where relative black (or colour) increments are applied in one direction and relative white (or complementary colour) are applied in the other direction 'relatively declining rate of black increase and relatively declining rate of white increase'. He defined graduated colours as 'scales as artfully ordered movement, reminiscent of the structured division of tones we find in musical scales [...] tonal action of wide and narrow range'.<sup>27</sup> Klee went on to provide numerical tables to show this colour increase and decrease. The repetition element is the concept of enhancement or dwindling, occurring again at every stage. Klee gave examples of simple variations of colour gradation, changing the directions of lines to show how colour gradation can work in a non-linear structure, for example as a graded circle or cube.

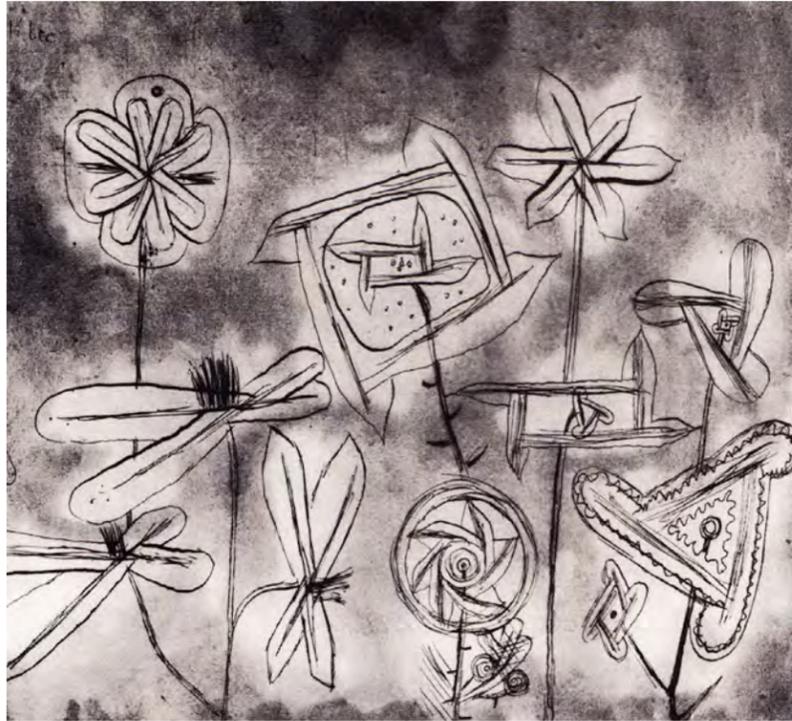
Klee also used the musical terms major and minor to describe types of contrast 'direct major contrast/indirect major contrast'<sup>28</sup> – implying that he considered scales as a structural articulation of the movement of natural form (for example, in the work *Fishes*). For Klee, colour gradation also had an emotional charge and tension; he talked of the character and movement as varying from a quiet rise and fall to an open struggle, characteristics also evident

in biological movement. Through the colour gradation method, using the dimension of colour, Klee's work implies a clear analogy with how the development of form might be approached. "Exactitude winged by intuition is at times best".<sup>29</sup>

The specific works by Klee discussed here can be interpreted as visual realizations of the potential of Goethe's dream of the morphologist – one who knows form and formative processes well enough to 'to go on forever inventing plants' and Klee followed this sentiment through plant-inspired artworks, which formed part of over 9000 artworks produced in his lifetime.<sup>30</sup> Klee's work, as visual art, with its aesthetic dimensions, brings new dimensions to Goethe's morphology. Klee's ability to 'make visible' the formative and dynamic nature of plants still surpasses many contemporary scientific representations of living form, which present a static version of a dynamic subject. Klee's work points us towards a dynamic morphology; one that represents growth, time and process, suggesting many possible other realities and reminds us that everything is moving.

Moving away from and towards nature: From observation to abstraction

I place myself as a starting point of creation where I state a priori formulas for men, beasts, plants, and the elements for all the whirling forces.<sup>31</sup>



**Paul Klee**  
*Moving Blossoms*, 1926. Pen on paper on cardboard.

Klee wanted to bring new combinations of the basic forms of nature into being. I interpret this impulse as a desire to simulate an analogue to nature through artwork, as a way of gaining insight and understanding into the 'nature' of form. To do this, he needed to investigate the forms of nature in order to create an alternative order and analogous universe. 'Wherever I look I see architecture, linear rhythm, rhythm of planes, work on the pictorial means begins with the examination of nature for creative possibilities'.<sup>32</sup> Klee's ability to abstract from nature allowed him to transition from the direct observation of and dialogue with the natural world around him towards a view of nature that was both outside and inside, as an imaginative play of consciousness. He invented according to the principles of nature, as well as according to his own imagination. Comparable to my own process in the Isomorphology study, creating artwork (and all that is involved within that) is Klee's method of coming to know the natural world and of experimenting in unique ways with this new knowledge.

In *Moving Blossoms*, a deceptively simple sequence of raising, twisting and unfurling reveals Klee's knowledge of the three basic patterns of growth in developing plants: the vertical, the radial and the spiral. Klee's micro-macro understanding of the natural world is reflected visually with the insight that just as the crown of a tree unfolds around a central axis, so too do the leaves' veins derive from a central system. This insight came through his artistic practice of drawing and observation. He represents these centres of growth as a series of overlapping planes 'that reflect small-scale articulation of the whole'.<sup>33</sup> In 'Prehistoric Plants' (1920) we see the transcendence of a conventional vision of plant growth and development, representing a move towards a liberation and recombina-



**Paul Klee**  
*Prehistoric Plants*, 1920. Pen on paper on cardboard. Courtesy of Frau Lily Klee (Knapping Fund) 1946.

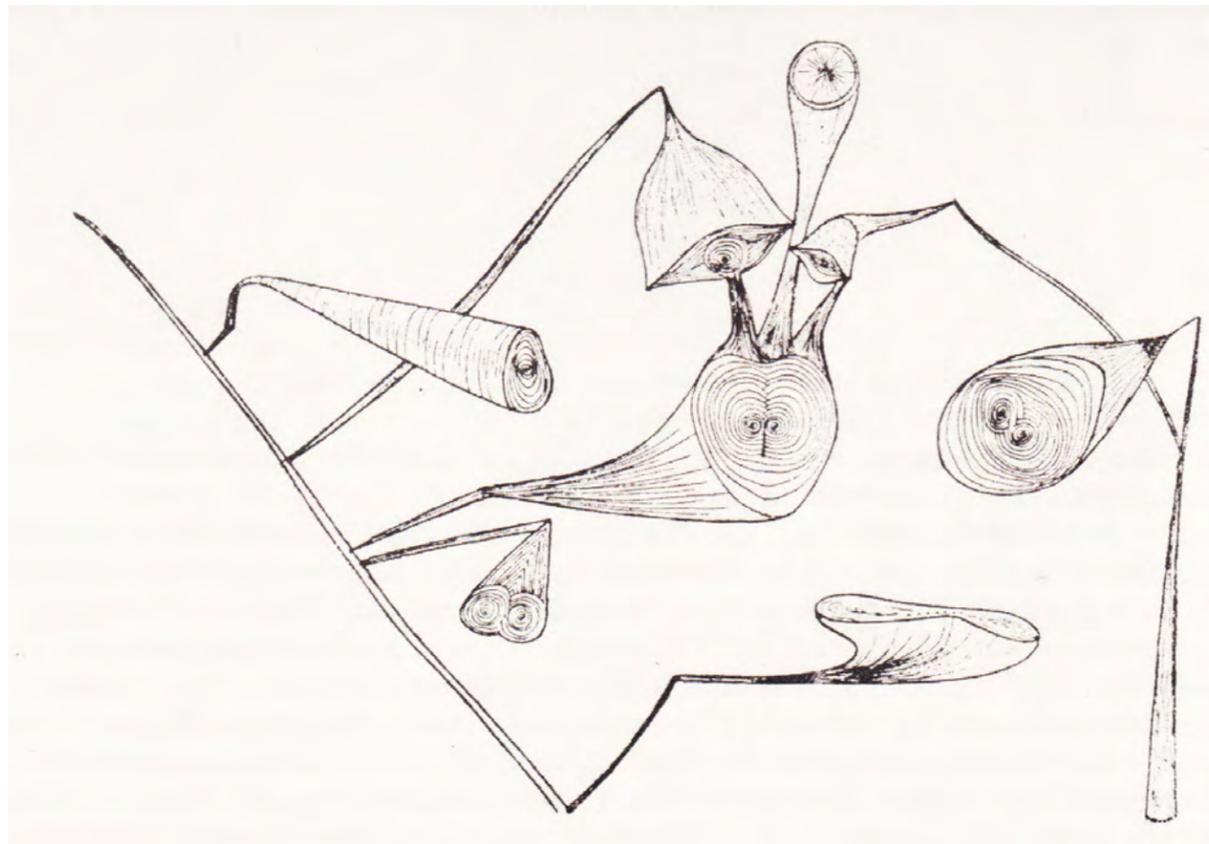
tion of plant form, allowing us to question our own conventions and to ask 'what is a plant?'

Klee invents a new order that can exist only in the theoretical space of drawing through the series *Fantasy Flora* (1920-23), which is based on Klee's observations of plant forms. In order to make his *Fantasy Flora*, he did not begin with the forms of exotic wonders of nature; he needed only to learn the basic anatomy of the common flowering plant.

For the artist, dialogue with nature remains a condition *sine qua non*. The artist is a man, himself nature and a part of nature in natural space. Yet the artist is more than an improved camera; he is more complex, richer and wider.<sup>34</sup>

The explanation for the large volume of plant works by Klee was that formative impulses are more visible in living plants than in the majority of animals. The further Klee explored the nature of plants, the closer he felt to the very centre of things, to the moment of genesis that he was searching for.

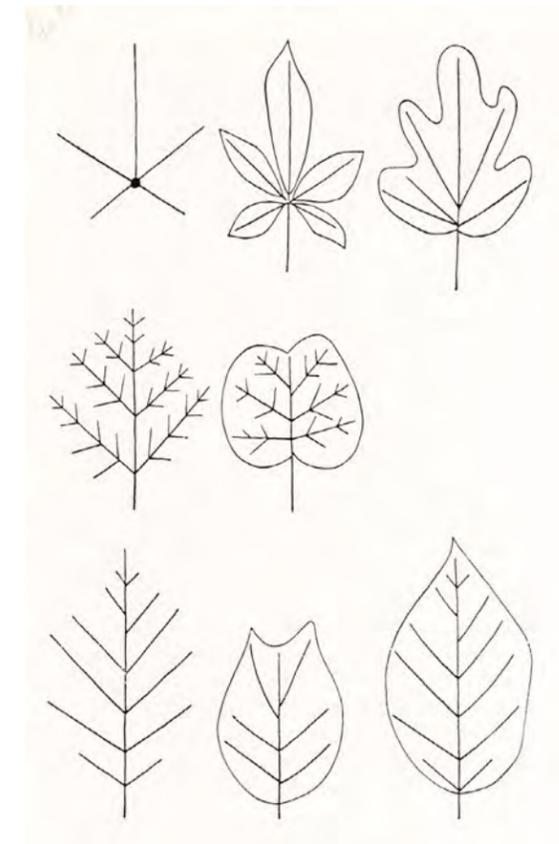
Klee's improvisational method was first used in his figurative work of 1912 when he began to construct figures, plants and landscapes by intuitively recombining a series of basic forms. Klee's ability to create apparent disorder through his interpretation of the natural world gives us an insight into his ontology; he wrote, 'there is a world that exists between the worlds our senses can perceive'.<sup>35</sup> In order to improvise, he needed to employ his knowledge of growth and to create extemporaneously with an artistic approach that emphasized both the genesis of the image and the vegetal process of becoming. Klee called this approach of combining the



**Paul Klee**  
*Family Matters*, 1927. Pen on paper on cardboard.



**Paul Klee**  
*Illuminated Leaf*, 1929. Pen and watercolour on paper on cardboard, 30.9x23cm  
*Pedagogical Drawings of Leaves*, 1932. Pen on paper.



*Klee learned the basic morphological and geometric types from nature and endeavoured to indicate their formative processes through art.*

appearance of the subject intuitively with its essence or inner structure 'psychic improvisation'.<sup>36</sup>

Klee learned the basic morphological and geometric types from nature and endeavoured to indicate their formative processes through art. He often built his works gradually through the repetition and layering of these basic, germinal elements. Germination and growth proved to be Klee's favourite motifs; his spiral flowers can be seen in the process of unfolding and rotating. Sometimes Klee would reveal this inner structure by an 'x-ray' view as in *Quadrupula Gracilis* (1927) and *Family Matters* (1927) or by cross-longitudinal sections in which forms are liberated and exchangeable, for example, in *Flowers* (1915) plants become geometric configurations. Klee saw natural forms as progressions of geometric forms; for example, he presents the palm leaf as a progression and regression of angles on the basis of a circle divided into twentyfour sections.

Klee used this method to create *Illuminated Leaf* (1929) and *Negotiated Curves* (1929), combining two different types of branching as the basis of the improvisation. Klee derived and sorted certain types of forms and basic principles from nature, which could be used by his art and design students at the Bauhaus.<sup>37</sup> He saw life forms as composite creations and believed that, by scaling down to separate parts, he could offer an understanding of nature's creative methods that could be applied through artwork. His search for

these constituent parts led him to reduce the forms he worked with to a series of rhythmically repeating units, analogous to the single cell in nature. Klee's ability to intuit form was recognized by Foucault who stressed the evidence of knowledge of the most fundamental elements in Klee's work, saying 'these elements, apparently the simplest and most spontaneous, those that are hidden and never seem to appear, it is these that Klee spreads out across the canvas'.<sup>38</sup>

Klee used eleven different geometrical elements comparable to the form species of Isomorphology.<sup>39</sup> He then integrates and recombines them through different works, for example, *Assyrian Game*. The emergence of different elementary forms in Klee's work are symbolic as signs of nature's growth processes, including radiation, spiral movement or stratification.

Klee's work, like Goethe's, reveals an understanding of the leaf as a reflection of the articulation of the whole. Building on this understanding, Klee devised diagrams of structural types of leaves and then improvised new types from this understanding,<sup>40</sup> saying 'the power of linear radiation produces an individual typology of leaf forms'.<sup>41</sup> Klee noticed how the invisible 'nature' of the leaf and tree lay in the patterns of development of the stem or trunked branches and full foliage. In discussing leaves, he noted the gathering of form-creating energies by drawing bundles of veins at the base of the stem and the linear branching of these veins into typical branch-

ing patterns, he then asked his students to create imaginary leaves on the basis of these rules. One student described how Klee paced around the room saying a few words softly with long pauses 'we had to admit that the first thing we had to do was learn to see before we could learn to draw'.<sup>42</sup>

Klee's knowledge of shared forms amongst seemingly unrelated species inspired many poetic comparisons that he made visible and therefore shareable through drawing. Klee's work reveals analogies between the most disparate beings, and creates the impression of having reduced the complex natural world to a subjective semblance of order. At this level the forms of plants and animals can meet; the hidden shapes of crystals, diatoms and protozoa all reveal hidden kinship. These comparisons rely upon the discovery of hidden formal resemblances. For Klee it was not just plants and organic nature that could grow and radiate energy but abstract geometries and signs as well. Klee was inspired by a combination of geometry and nature to create new combinations of forms, which show his liberation from observation.

In 1926, Klee departed further from observation and began to construct his plants out of geometric forms, as in *Time of the Plants* (1927). In these works, Klee made trees out of triangles and squares, fruits out of ovoids and circles, flowers out of cones and pinwheels. Klee was particularly fascinated by the mathematics of the plant world and seems to have believed that nature is composed in geometric characters: triangles, circles, hexagons, etc. This was not a retreat from nature itself, but a penetration into nature's own geometries found in organic structures and the laws of growth and change that can be understood as a move towards nature, not away from it. Nevertheless, the work appears more abstract and is often assumed as abstracted or removed from nature. Klee recognized this exchange between the geometric and the generative or metaphysical, saying 'the possibilities become numberless and infinitely variable'.<sup>43</sup> Klee transposed the qualities of an instance of nature into a highly simplified type and developed one type or form genetically out of another. The task for Klee was clear: to enjoy the greatest freedom in building a bridge between the world within and the world without – a relationship that Goethe describes poetically in this quote:

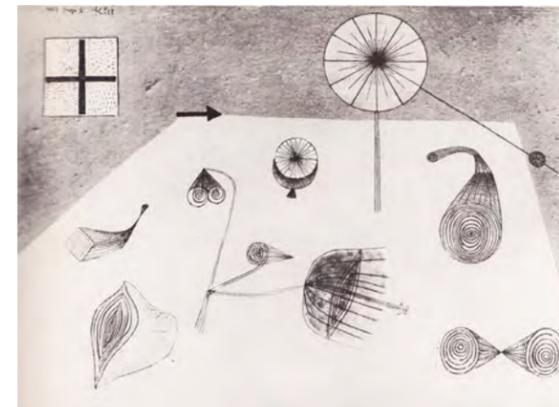
Seek within yourself, there you will find everything. And you should rejoice if, outside of yourself, you find something in nature, which says yes and amen to everything we find in ourselves. We know of no world except in relation to man, we want no art which is not a likeness of this relationship.<sup>44</sup>

### Klee, science and the Bauhaus

Klee's method did not evolve in isolation; he studied widely in the arts and sciences in order to forge this new ground. I will now explore the diversity of Klee's research through specific examples of his practice.

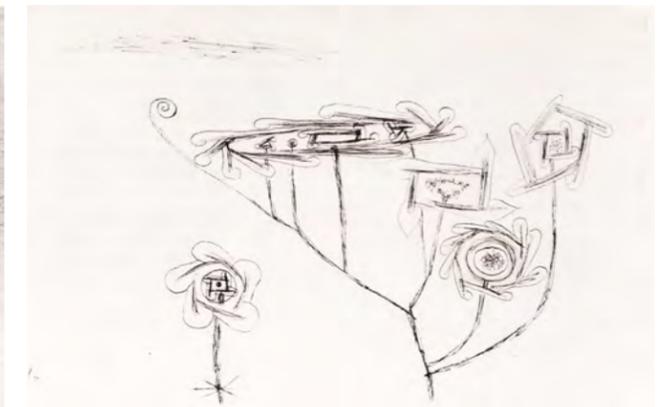
During the 1920s and 1930s Klee experimented with ideas from biology, meteorology, astronomy, geology and physics, and combined these ideas with basic systems of artistic construction: perspective, geometry and visual use of musical rhythm and melody. An important factor during this time was the great interest at the Bauhaus in the sciences and technology. By 1926 physics, mathematics, mechanics and chemistry were all part of the basic curriculum at the Bauhaus.

Klee's concepts and images of nature ranged beyond the visible universe to include the invisible: plant anatomy, cell structure, weather patterns, geological strata, cell fertilization/ division/



**Paul Klee**

*Time of the Plants*, 1927. Pen on paper on cardboard (courtesy of private collection, Rome).



*Super-Culture of Dynamoradiolaren*, 1926. Pen on paper on cardboard (Kunstsammlung Nordrhein-Westfalen, Dusseldorf)

growth and the laws of statics and dynamics. Evolutionary theory also inspired Klee to create new forms, as he said 'the earth looked different in the past and will look different again', as things must also look different on 'different stars'. This realization of the continual genesis of new forms gave him a freedom to create new forms he referred to as 'images of nature's potentialities'.<sup>45</sup>

Klee's scientific investigations informed his own lectures at the Bauhaus, including his *Principal Order* lecture with sketches of the structure of plants and leaves referred to as 'observational drawings' showing the structural energies in leaf and veins' and *Structural Formation* discussing the most primitive form and rhythms as the repetition of horizontal and vertical lines (1922).<sup>46</sup> Klee depicted water as rhythmic wave patterns as influenced by scientific imaging of the vibrating sound line, where each line could function not only as part of the whole but as a discrete unit that could be traced and read from one end to the other, 'graphing the oscillations, path, variations and individual "personality" of each wave'.<sup>47</sup> Klee infused his depictions with enough 'irregularity of rhythm' to stimulate or affect 'life' – implying abstract rhythms within a living order, thus taking the step from the natural to the 'supra-natural'.<sup>48</sup> Klee gained the ability to abstract nature while also remaining close to its basic principles through his access to the scientific knowledge of his time.

Teaching affirmed Klee's own practice, as he gained further insight into the nature of his own studies by sharing with others. Beginning with the very basic elements, he taught the building of image forms as geometric shapes and simple colour and tone gradations, which he applied in his own work. He also developed a series of lectures on statics and dynamics in 1924, investigating each theme formally through various modes of shift, rotation, reflection, movement and counter-movement. As the outcomes of the scientific investigation of others were fundamental to Klee's artistic achievements, Klee deliberately emphasized the parallels between artistic and scientific analyses of the natural world. Klee believed that for the artist, like the scientist, analytical, even microscopic, observation reveals insights into the genesis and structure of objects that are not accessible to the superficial gaze.

Is it not true that even the small step of a glimpse through the microscope reveals to us images which we should deem fantastic

and over-imaginative if we were to see them somewhere accidentally, and lacked the sense to understand them?<sup>49</sup>

Drawing analogies between the micro- and macrocosm is constant in his thinking, and Klee understood the fractal nature of the tree as differentiated into branches, twigs and leaves and these again into stalks, veins and leaf tissue: 'in this pattern can be found ideas and relationships that form an image in miniature of the pattern of the whole'.<sup>50</sup> The work *Moving Blossoms* was inspired by microscopic animal life and related to the drawings of an imaginary species 'Super-Culture Dynamoradiolaria' (1926). Klee was familiar with the rarefied language of the taxonomist and used this knowledge to create science-inspired titles for his works.

One scientist who introduced Klee's generation to the microscopic world was Ernst Haeckel, who made pioneering studies of the marine fauna diatoms and radiolarian. Haeckel was a self-confessed disciple of Goethe and extended the Goethean view of nature to encompass microscopic life.<sup>51</sup> Klee owned Haeckel's *Art Forms in Nature* (1889–1904) so he would have been familiar with the forms of diatoms and radiolarian.

Klee's embryonic images make clear biological references as in *Ab Ovo* (1917) and *Rock Grave* (1932): 'if such fantastic forms exist under the microscope, why should they not encourage the artist's imagination and freedom?'<sup>52</sup> The process of cell division is the subject here and reiterates Klee's emphasis on embryology in his teachings (which came from Haeckel). In these images, the viewer sees inside the egg to a biological foetus with suggestions of internal organs, revealing the influences of biological diagrams and the work of Haeckel. Klee's art went a step further and suggests that the proto-genesis of form could be symbolized by the division of a circle by an arrow.<sup>53</sup> In *Twins* (1930) Klee shows a more sophisticated understanding of cell theory; two cells quiver with protoplasmic energy and their internal structure suggests chromosomes surrounded by cytoplasm and with a pencil line indicating the cell wall. Klee applied his knowledge of cell division in the work *Genesis and Natural Division of the Cube* where even pure geometry can be subject to organic processes.

### Twentieth-century influences

While Goethe was a significant historical influence on Klee, it is important to also note the significant influence of Goethe on the work of Klee's contemporaries, in particular Karl Blossfeldt, Ernst Haeckel and D'Arcy Wentworth Thompson.

In 1928 Klee gave his father a copy of the first edition of Karl Blossfeldt's *Art Forms in Nature* (1928) and in 1929 Kandinsky gave Klee his own personal copy. The influence of this book can be seen particularly in the individual portraits of various parts of plants that he made between 1929 and 1934, a series that began the same year that the Bauhaus held an exhibition of botanical photographs by Blossfeldt, *Archetypal Forms of Art*.

Although the influence of the pioneering biomathematician D'Arcy Wentworth Thompson on Klee is not evident in the literature, comparison can be drawn between their works. Thompson realized that forms mathematically alike could belong to organisms biologically remote and that nature repeats its basic forms throughout the entire range of its creations.<sup>54</sup> Thompson discovered a number of physical reasons why certain forms are possible in nature, which he presented in *On Growth and Form* (1917).<sup>55</sup> Klee was also familiar with Theodore Andrea Cook's *Curves of Life* (1914). Klee's gridded structures as in *Analysis of Movement* (1932) transformed structure and motion into a periodic yet living system and are therefore close



Paul Klee

*Growth Stirs*, 1938. Coloured paste on paper and cardboard, 32.4x48.7cm. Private collection, Switzerland.

to Thompson's transformation diagrams, and show the basic type forms of nature, such as the spiral and hexagon, using graphs and mathematical formulae. Klee shared Thompson's interest in how honeycomb structures arise but approached the questions with different methods and motivations. Thompson believed it could be quick and easy to extrapolate the dynamics of an object from its basic structure. As Klee became more interested in three-dimensional modulations of changing topography, he devised a method of rhythmically distorting an abstract grid to simulate topographical configurations.

Klee's discussion of motion is found in his 1924 lecture on 'pictorial mechanics'; Klee's understanding that the dynamic is the normal state was very unusual. He described 'statics' to his students not as the 'unmoving' but rather as movement brought into equilibrium, as 'the study of the equilibrium of forces'.<sup>56</sup>

The book *Paul Klee's Enchanted Garden* explores a number of philosophical perspectives on Klee's work.<sup>57</sup> Particularly interesting is the idea of an aesthetic forming of the self that relates to Foucault, who formulated an 'aesthetics of existence' and used Baudelaire and Manet as examples of artists who worked on themselves through their art. Klee said 'I am my style', implying that his work and his self were forming simultaneously.<sup>58</sup>

Comparing artistic process to a kind of 'birthing' is a theme in Merleau-Ponty's phenomenology, which aims to encounter the world in a 'pre-conceptual' way (Merleau-Ponty 1996). Merleau-Ponty's phenomenology shares much with Goethe's philosophy; therefore, it is not surprising that Merleau-Ponty thinks about Klee within this philosophical framework. While discussing Klee's work, Merleau-Ponty states 'the line is the blueprint of the genesis of things [...] with Klee, painting is a kind of philosophy, the grasping of the genesis of things'. Merleau-Ponty believed that art can only present something when it 'shows how things come into being, and how the world becomes the world'.<sup>59</sup> Merleau-Ponty's view relates to Deleuze and Guattari's belief that art is a form of thinking, a composite of percepts and affects.<sup>60</sup> As Klee's work developed, objects themselves no longer mattered, only his reactions to them, until his attitude to the colours in his paint box became more important than studying nature.

*I place myself at the remote starting point of creation, whence I state a priori formulas for men, beasts, plants, stones and the elements and for all the whirling forces.*

#### **Art as visual analogy to nature's creative processes**

At the heart of Klee's thinking was an intuition that pure form could be animated with a life of its own. Through drawing, form could come into being, grow, divide, combine and even reach its own demise; therefore, visual problems and natural problems became analogous. The three-dimensional space of the cell and the two-dimensional space of the page paralleled one another in process. Every step in image making is abstract and dynamic, providing the scaffolding (the simplicity of structure that mass can build around) around which the image is formed genetically (the linear energy gives direction and a guide to the creativity/chaos). The analogy with nature seemed to be real for Klee, as nature permeated his consciousness to the point that he grew a world within, as logical and real to him as the natural world without.

I place myself at the remote starting point of creation, whence I state a priori formulas for men, beasts, plants, stones and the elements and for all the whirling forces.<sup>61</sup> With this statement Klee was rejecting his previous direct perceptual relationship with nature, commonly perceived as figurative, and adopting a more metaphorical and abstract view, where concepts of metamorphosis and genesis were central. He aimed to place nature at the service of his imagination and to find a visual language that paralleled and simulated rather than duplicated nature's creative processes. This shift in Klee's work proved a liberation. No longer tied to the representation of objects in nature, but instead to a genuine re-creation of them through his art, re-building an intelligible world: 'an inbetween world, another possible nature, which intends creation, causes what is not to become visible, yet without falling into the subjective imagination's service'.<sup>62</sup> Klee's visual analogies of nature are sites (locations of artistic production) where the intelligence of the artist resonates with the living processes of nature, which he described as 'a new naturalness, the naturalness of the work'.<sup>63</sup>

The analogy of the seed is central to Klee's broader concerns with the process of germination in both nature and art; he says 'despite its primitive smallness the seed is an energy center charged to the highest degree'.<sup>64</sup> Just as the seed was charged, or connected to the point by the line of the shoot, so too was the artist charged by 'his own form creating energies' to create lines. Klee's interest in the parallel aspects of artistic creation and creation in nature is clear in his teachings at the Bauhaus from 1921. In drawing, he saw the starting point of creation as the passive dot. When the dot moved, it became a line, which in turn became a surface. Therefore, movement was central to Klee's thinking: 'movement is the basis of all becoming, the eye follows the path prepared for it through the work, itself recorded movement, received as movement'.<sup>65</sup> In nature

Klee saw the starting point as the seed from which emerged a shoot and developed into a stalk with leaves, after this came a flower and then the fruit or seed again.<sup>66</sup> In *Growth Stirs* (1938), Klee's marks are suggestive of embryonic elements, which he evolves into his own visual language. The marks can be interpreted as the germ cells of art rather than of science.

Klee used analogies and metaphors to think about his work and himself, 'my little plant of a soul will soon be able to strike new roots again', and it is precisely this analogical thinking that made Klee's work so moving.<sup>67</sup> Klee also described himself as the crystalline type. Lyonel Feininger also compare Klee to a plant, 'his method of working can really be compared to the organic development of a plant'.<sup>68</sup> Theodor Daubler also compares Klee to a plant after his time in Tunisia in 1914: 'the plant shot up at once. Now it is putting forth flowers', speaking of his fiery watercolours implying that 'when Klee draws, new roots sprout forth; and colourful flowers emerge when he paints'.<sup>69</sup>

'Art relates to creation in the manner of a metaphor. It is always a model, in the same way that the earth is a model for the cosmos',<sup>70</sup> this relates to Goethe's outlook: 'Art is parallel to creation: sometimes it is a sample, just as earth is a sample of the cosmos'.<sup>71</sup> This metaphorical level of understanding helped Klee to develop his micro-macro comparative repertoire of plant themes and images.

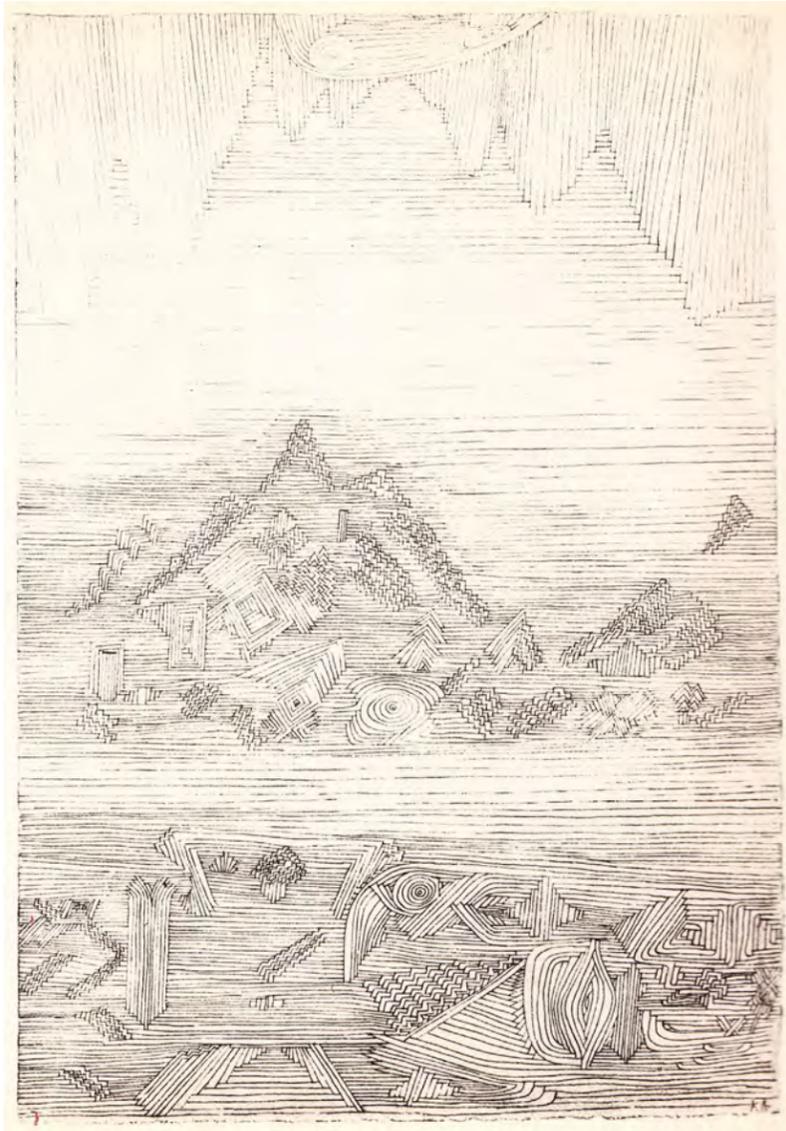
Amongst Klee's models for a formal cosmos or 'little worlds' is the 'blossoming apple tree, its roots, its rising sap, its trunk, its construction, its sexual function, the fruit, its core and seeds. A system of conditions for growth'.<sup>72</sup> Klee takes the tree as analogy for the artist – the medium is the trunk, the works are the fruits. The tree became an analogy for the macro and the microcosm 'precise analogies for the laws which govern the existence are repeated in the smallest, outermost leaves'.<sup>73</sup>

With Klee, it is also possible to make the comparison between the artist and the gardener, carefully selecting and tending to creative processes of growth, tending to aspects within conditions of artistic weather and inspiration to cultivate something wonderful. When a plant produces a fruit, it is the sign of the success of previous stages of its development equally, the artist is a historical being, bearing artistic fruits grown from time and experience, a creative achievement parallel to those of a gardener. Klee believed in letting things grow of their own accord, which was reflected as he patiently waited until the creative image formed within.<sup>74</sup>

#### **Towards a developmental morphology**

Although there is no reference to the concept of 'ontogeny' in Klee's writings or in the literature on his work, he does talk about development. The concept of ontogeny, as outlined by morphologist Norman MacLeod as 'the conceptual and physical development of parts and the development of existing and known structures through actions which change the proportions and in the end create something new', is a useful tool for interpreting a selection of Klee's works.<sup>75</sup> The biological concept of ontogeny and the new science of embryology were emerging in Klee's time through Haeckel (using images as arguments) but ontogeny is now better understood in contemporary developmental biology and means a developmental sequence, for example, the development of a human embryo to an adult. This repetition of forms with slight variation in a connected series becomes an analogue for the evolution of organisms and artworks.

In *Fishes*, the progression of form takes place within the



**Paul Klee**

*View of a Mountain Shrine*, 1926. Pen on paper.

body of the fish itself, suggesting time, movement and growth simultaneously. Klee was attracted to the underwater world of fishes because of their freedom of movement (in any direction, whereas humans are much more restricted). The 'fishness' of the fish is maintained through the transformations; each stage bears a unique gradation of colour, repetition of the same form at different angles and scales, moving forwards, backwards and sideways, creating a feeling of emergence from a dark background. Klee's watercolour washes elevate the forms to a resonant poetry. The fishes appear transparent; we see the traces of their development through a clear membrane, like a cell, representing Klee's penetration of form beyond surface appearances. In these works, Klee, like the fish, allows for many perspectives: above, below and alongside the forms.

Klee's *Suspended Fruit* (1921) can be read as an abstract on-

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*Klee's artistic work brings qualities and dimensions that reach beyond the purely biological. These works can also be interpreted through the conceptual tools of music: as a musical fugue, interpreting each shape as a different voice, each meandering through nature's basic patterns: a polyphonic progression in time and space.*  
 .....

togenetic series. The abstraction in this work is not from observation, but from an insight into the growth of plants from thought and experience itself. In *Fugue in Red*, the circle is analogous to the embryo that, through a series of transformations, becomes a different shape (adult). This occurs through a progression of forms, grading from white to black through pale pink, pink, deep pink, purple, grey purple, grey and black. The transformation from triangle to square, through the repetition of forms with slight variation, becomes an analogue for evolution as descent with variation, while echoes of form grade through shadows and colours in other directions and other aesthetic dimensions. Klee's expansive way led to the dimensional promotion (or inversely, de-motion) of his work from 3D-2D to 4D-2D (here the fourth dimension is time). In this interpretation of Klee's work as an ontogenetic or developmental series, I am mapping this biological concept onto artistic practice.

Klee's artistic work brings qualities and dimensions that reach beyond the purely biological. These works can also be interpreted through the conceptual tools of music: as a musical fugue, interpreting each shape as a different voice, each meandering through nature's basic patterns: a polyphonic progression in time and space. *Komödie* is set on horizontal lines on the page like musical bars, rhythmic in line, punctuated by solid notes of chequerboard, diamond and rectangular patterns, rhythms, melodies. What better analogy for music than to attempt to visualize and simulate the metamorphosis and rhythm of life itself? This representation of nature developing through periodic stages, abstracted through repeated and generalized shapes, is set into motion by progressive colour and tone gradations. In *View of a Mountain Shrine* (1926), Klee creates a sense of growth through the repetition of the form, and in the work *Omega 5 (Traps)* (1927) the repetition of forms is similar to the isomorphology form range.

The image becomes a visual chronicle, incorporating evidence of its own development as the layering of form and colour creates a sense of form travelling through time and space. In this combination of artistic, biological and periodic nature, we learn to see the growth and developmental process through a simultaneous visualization of multiple dimensions, thus, the artwork as visual chronicle. Art plays an unwitting game with ultimate things and yet it reaches them.<sup>76</sup>

First, Klee studied the static forms of nature and of the pictorial space, and later he set these forms into motion to visualize genesis and growth. Klee even arranged his teachings to emphasize first the statics and then the dynamics of each topic, although the categories were never mutually exclusive.<sup>77</sup> Similarly, in biology there is the study of structure at rest (anatomy) and the study of functions (physiology), genetics of heredity and evolution. Even Klee's attitude to his work resonates with the process of evolution:

You will never achieve anything unless you work towards it. You cannot break in halfway through the process, and least of all start with any result. You must start at the beginning. Then you will avoid all trace of artificiality, and the creative process will function without interruption.<sup>78</sup>

One of the foundations of Klee's teaching was that no artist, and much less the student, should rely on ready-made forms, but start at the beginning, in order to build.

### Conclusion

That such a visual equivalent to Goethe's theories should only have come into being a century after his death is understandable when we remember that the artistic conventions of Goethe's day were still

prioritizing the outward appearance of things. Goethe was aware that even the most painstaking representation of the resemblance of things was not nature itself. At a different time and in a different place, Klee was aiming to uncover the 'nature of nature', through viewing and studying nature's inner life, its processes and its dynamics: 'A form should retain the footprints of its dynamic development'.<sup>79</sup> Klee's artistic approach made this dynamic development visible.

Klee was aware that nineteenth-century biology had discovered that each step of the evolutionary ladder was a variation of the one before and he realized that if the forms of nature had been different in the past, they could be different again in the future: 'different forms may well have arisen on other stars, in its present form, this is not the only world possible'.<sup>80</sup> Klee embarked on a systematic study of the world around him, and believed in the potential of human creativity: 'the future slumbers in human beings and needs only to be awakened'. That Klee was an accomplished natural scientist has long been acknowledged.<sup>81</sup> Klee was always a scientist in the service of art and has been described as 'the true forerunner of the surrealist approach to natural history' by Rene Crevel because of his distortions and deformations of the natural world in the stage-like space of the pictorial plane.

What was new in Klee's work was a result of the impact of modern science and of his willingness to represent the phenomena themselves, working towards a dynamic representation of nature. Klee's work rendered visible, and interpreted, the invisible processes of natural form, and therefore made these visible to others, opening minds and making life larger than it usually appears.

[In Klee's universe] everything is a dynamic nature; static problems make their appearance only at certain parts of the universe in edifices, on the crust of the various cosmic bodies [...] there is a microscopic dynamic and a macroscopic dynamic, between them stands a static exception: human existence and its forms.<sup>82</sup>

Although Klee's science was in the service of art, his ability to visualize the dynamic nature of form was ahead of the scientific visualizations of his time. Understanding Klee's work as analogous to ontogeny, and therefore evolution, makes the potential of Klee's methods very exciting. Klee's artistic research employed the methods of drawing, printmaking and painting, bringing a qualitative and unique aesthetic to morphology, to re-create the dynamic nature of nature. In the twenty-first century, we are still a long way from successfully representing nature as a dynamic reality – as process. Popular culture still has a tendency towards object-based thinking, but there has been a shift since the 1980s (postmodernism) in how we understand human identity (physically and conceptually) as entirely mutable rather than as fixed. The need for representation and insight into the dynamic nature of the natural world is reflected in the emerging field of 'process philosophy of biology' (Dupré, Nicholson and Dupré). We live in a moving present and changing objects cannot exist in a fixed state – such that it is possible to argue that there are no static objects. Like Klee, I endeavour to move closer to the dynamic nature of nature through art and find it helpful to think of a plant as an instance or slice of reality, and rather than represent this slice I aim to represent this slice within a continuum, as 'life represented alive'.

I believe that with Klee's works as inspiration, and through my own variations on his methods, as informed by contemporary biology, a move towards a more dynamic representation of nature and even towards a visual simulation of nature's processes that goes beyond analogy may be possible, as Herbert Read indicates 'the work of art is not an analogy it is the essential act of transforma-

tion; not merely the pattern of mental evolution, but the vital process itself.<sup>[83]</sup> This rather bold statement can be applied to specific works by Klee, where the movement and action that generated the artwork reveals a deep intuition into the hidden movements and actions of nature.

This anticipated artistic practice brings the combination of insight, imagination and intuition that Goethe believed was so complementary to science; drawing from art and from science towards a dynamic representation of nature, itself a process, in constant formation, without end.

## Footnotes

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- <sup>[16]</sup> Ibid, p.150
- <sup>[17]</sup> Verdi, R. (1984) p.26
- <sup>[18]</sup> Klee in Ibid, p. 27
- <sup>[19]</sup> Moe, O. H. (2008) p. 56
- <sup>[20]</sup> Klee in Haftmann, W. (1954), p.150
- <sup>[21]</sup> Anderson, (2017)
- <sup>[22]</sup> Klee in Haftmann, W. (1954) p. 47
- <sup>[23]</sup> Goethe, J. W. von (1962–67) pp. 310–11
- <sup>[24]</sup> Goethe, J. W. von (2009) *The Metamorphosis of Plants (1790)*, London: MIT Press, p. 4
- <sup>[25]</sup> Klee, P. (1992) *Paul Klee Notebooks*, Woodstock: Overlook Press, p. 340
- <sup>[26]</sup> Ibid, p.349
- <sup>[27]</sup> Ibid, p.347
- <sup>[28]</sup> Ibid, p.383
- <sup>[29]</sup> Klee, P. (1949) *Paul Klee [Reproductions, with Extracts from Klee's Writings]*, Klee-Gesellschaft: Bern, p. 41
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- <sup>[45]</sup> (Klee, p. (1961) p. 92
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- <sup>[51]</sup> Lynn Henry (1981) p. 55
- <sup>[52]</sup> Klee in Lynn Henry (1981) p. 44
- <sup>[53]</sup> Ibid, p. 22
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- <sup>[55]</sup> Ibid, p. 229
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- <sup>[57]</sup> Baumgartner, M. (2008)
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- <sup>[59]</sup> Ibid, p.88
- <sup>[60]</sup> Ibid, p. 92
- <sup>[61]</sup> Klee, P. (1964) p. 345
- <sup>[62]</sup> Klee in Lynn Henry (1981) p. 92
- <sup>[63]</sup> Ibid, p. 148
- <sup>[64]</sup> Ibid, p. 65
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- <sup>[78]</sup> Haftmann, W. (1954) p. 30
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- <sup>[80]</sup> Lynn Henry (1981) p. 10
- <sup>[81]</sup> Verdi, R. (1984) p. 7
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