Impressions

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Emergence

This volume is part of *Emergence*, an exhibition organized by Fathomers that ran from October 8 through December 15, 2024, at the Japanese American Cultural & Community Center in Los Angeles.

Emergence assembles artists, scientists, and artist-scientists working at the forefront of synthetic biology and contemporary art. Documentation of their projects as well as relevant writings and interviews, planning sketches, and other contextualizing materials are collected in this catalog. Some contributors draw from their work in medical or transdisciplinary research laboratories, where they confront new categories of life that destabilize our understandings of sentience, hybridity, and artificiality. Others engage the tools of synthetic biology as materials for creative experimentation and studio-based inquiry. Many contributors argue for decolonizing science and expanding access to biotechnologies through DIY and community science initiatives. Across *Emergence*, audiences and participants are invited to contemplate our human capacities for creation, destruction, recklessness, renewal, and hope. The exhibition prompts us to ask: Who has agency in this moment of making, learning, and living with? What forms of life are we choosing to cultivate? What will we nurture, and what might we leave behind?

Projects in the Exhibition

AfroRithm Futures Group
MultiPlanetary Garden

Marie Bannier Hélaouët and Albert Wu
Crying Organoids

Callie R. Chappell and Nasa Sinnott-Armstrong
IndiGROW

Michael Jones McKean
of kin and bone

Eduardo Padilha
Apoptotic Bodies

Pat Pataranutaporn
CyberBiome and *MicroPET*

Corinne Okada Takara
Floating Future Gardens

Henry Tan and Masato Takemura
Pillars of Creation

Tissue Culture & Art Project
The Use of Life (in Relation to the Industry of Men)

Fathomers is a creative research institute dedicated to producing sites and encounters that challenge us to live and act differently in the world. Fathomers cultivates the ideas of diehard dreamers, commissions projects that seem far-fetched, and collaborates with thinkers across disciplines to expand the limits of scale, scope, and support for artist-led projects.

Emergence was presented as part of PST ART: *Art & Science Collide*. PST ART is presented by Getty.

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創発 Emergence

Art from Life

Japanese American
Cultural & Community Center

October 8–December 15,
2024



Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.

Projects *in the* Exhibition

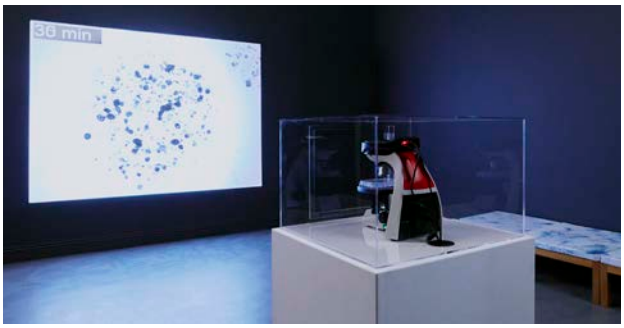


This page: *Emergence* banner in Little Tokyo, Los Angeles, 2024. Photo: Callie R. Chappell. **Opposite page:** Photos: Carson Davis. Brown



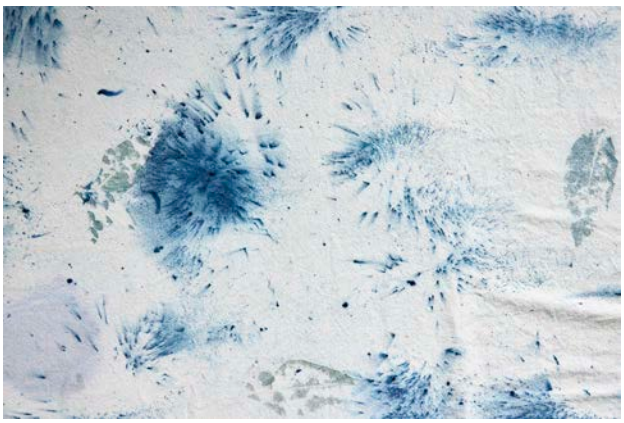
AfroRithm Futures Group: Ahmed Best, Dr. Lonny J. Avi Brooks, and Jade Fabello, in collaboration with Dr. Drew Endy, Jesse Gilbert, Raquel Horsford, Malaya, and Oguri

MultiPlanetary Garden, 2024
Video installation
Dimensions variable



Dr. Marie Bannier Hélaouët and Dr. Albert Wu, with Stanford Ophthalmic Stem Cell and Regenerative Medicine Laboratory members Dr. Aditi Swarup, Dr. Hala Dhowre, Dr. Sanja Bojic, and Julietta Picco

Crying Organoids, 2024
Organoids, bright-field microscope, and video projector
Dimensions variable











Dr. Callie R. Chappell and Dr. Nasa Sinnott-Armstrong

IndiGROW: Cushions, 2024
Fabric, indigoidine dye, *Indigofera* plant leaves, and chemically synthesized reduced indigo
24 × 24 in.

IndiGROW: Dying Indigo, 2024
Bioengineered yeast, indigoidine dye, micro-centrifuge tubes, tabletop greenhouse, glass flask, and printed cards
30 × 60 in.

IndiGROW: Flask, 2024
Bioengineered yeast, DMSO, indigoidine dye, platform, liquid culture media, and glass flask
Dimensions variable

IndiGROW: Jeans, 2024
Bioengineered yeast, indigoidine dye, denim, and clothing rack
45 × 54 in.

IndiGROW: Lil Lab, 2024
Glass cabinet, cyanotype papers, Foldscopes, zines, and stickers
16 × 14 × 61 in.



Michael Jones McKean with assistance from Dr. Stephen Fong

of kin and bone, 2024
Wood, brass, steel, biomineralized synthetic nacre, glass, river pebble, basalt, ocher, suevite, oak, concrete, copper, coral, silver, fossilized whale bone, and titanium
179 × 30 × 98 in.
Made in cooperation with the Museu de Leiria, Portugal





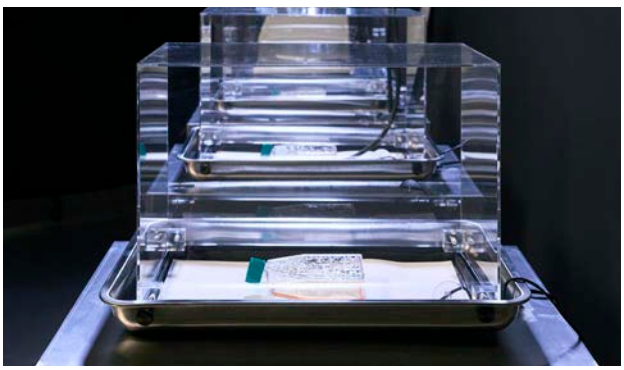


Corinne Okada Takara

Floating Future Gardens: Living Sensors – Plants Speak in Fluorescent Colors, 2024
Sonotubes, incandescent and fluorescent lights, Lego boards, 3D-printed components, Lego assemblies, GFP soybeans from InnerPlant, soybean plants, and soil
24 × 75 in.
Special thanks to Garrett Hayes, Tim Keller, Rod Kumimoto, and InnerPlant

Floating Future Gardens: Play Platform, 2024
Lego boards, custom wood platform, mirror, and custom 3D-printed Legos
48 × 72 × 4 in.
Special thanks to Mako Watanabe

Floating Future Gardens: Yatai Cart, 2024
Wood, bicycle wheels, custom 3D-printed Legos, *kokedama* moss balls, Lego boards, and metal screws
72 × 46 × 84 in.
Special thanks to Garrett Hayes



Eduardo Padilha

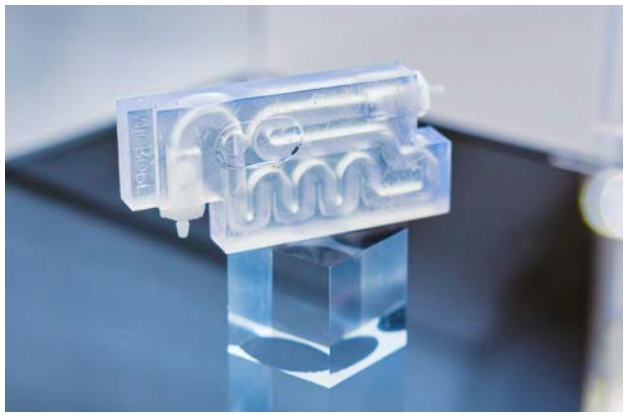
Apoptotic Bodies, 2024
Used embalming machine, stainless steel trays, cell culture flasks, Dulbecco's Modified Eagle's Medium, fetal bovine serum, silicone tubing, and flasks containing human cell line, immortalized human cell line, and cancer cell line
Dimensions variable

This page and opposite: Photos: Carson Davis Brown



Dr. Pat Pataranutaporn, Aria Xiying Bao, Brandon Dorr, Dr. David Kong, Pattie Maes, Dr. Galina Mihaleva, and Dr. Christopher Voigt

CyberBiome, 2021
Bidigital SmartSuit with optoelectronic device
Dimensions variable



Xin Liu, Dr. Pat Pataranutaporn, Dr. Benjamin Fram, Dr. Allison Z. Werner, Dr. Sunanda Sharma, Dr. Nicholas P. Gauthier, Dr. Erika Erickson, Dr. Patrick Chwalek, Kelsey J. Ramirez, Morgan A. Ingraham, Dr. Natasha P. Murphy, Krista A. Ryon, Dr. Braden T. Tierney, Dr. Gregg T. Beckham, Dr. Christopher E. Mason, and Dr. Ariel Ekblaw

MicroPET Component Prototype, 2022
Prototype of microfluidic chip
2 1/2 × 1 1/2 in.



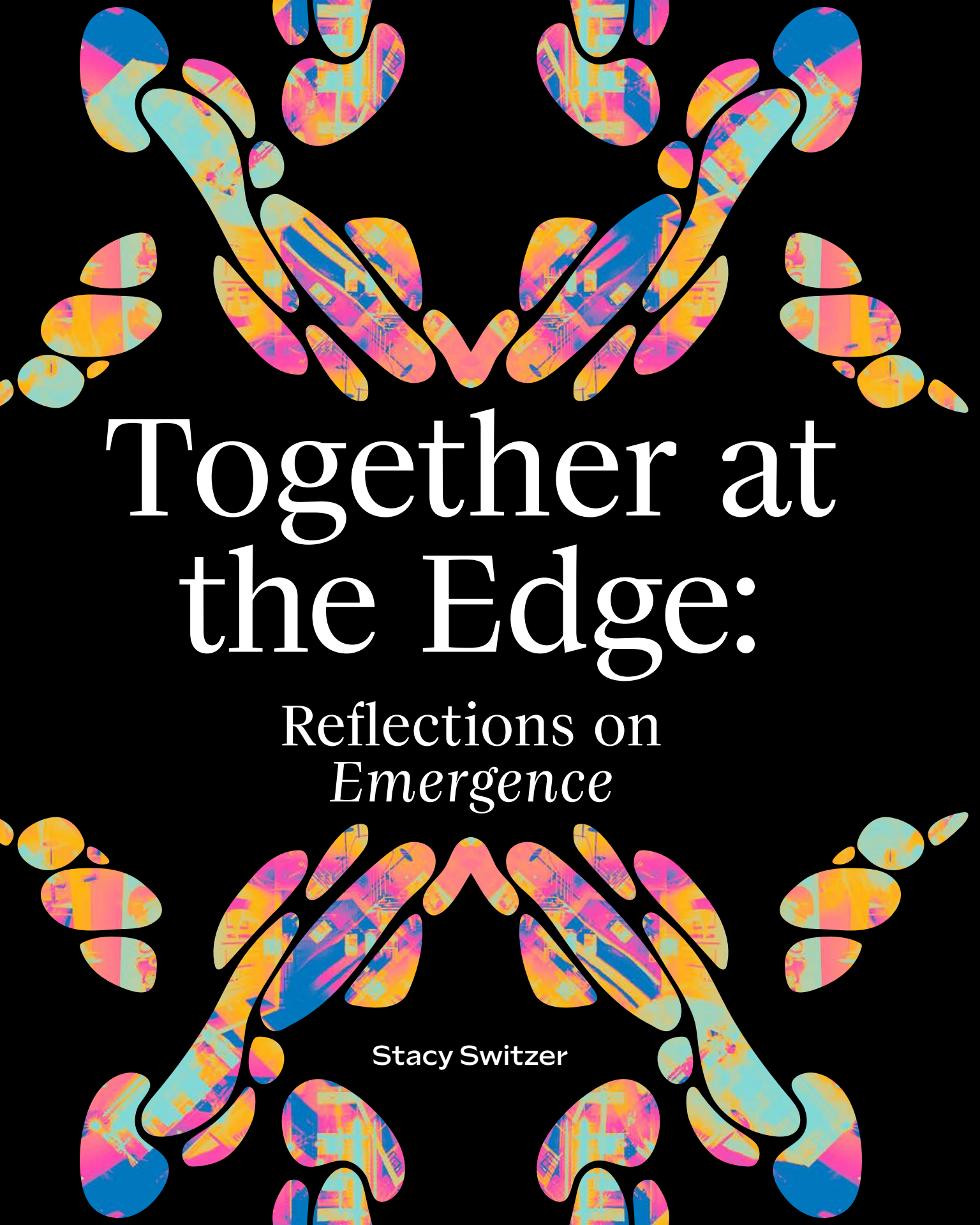
Henry Tan, Masato Takemura, Pakchira Chartpanyawut, Weeratouch Pongruengkiat, Woraporn Pongsamart, Dr. Pat Pataranutaporn, Jirapat Thaweechuen, Tanis Phongpisantham, Pongsakorn Wechakarn, Sumeth Klomchitcharoen, and Kookpedz Studio

Pillars of Creation, 2024
Clinostat LED hologram, brain organoid incubator, electrode array prototype, tourbillon dementia clock, DNA printer-synthesizer prototype, laser projection, and *hamsa* rug
Approx. 108 1/4 × 86 2/3 × 84 2/3 in.



Tissue Culture & Art Project

The Use of Life (in Relation to the Industry of Men), 2024
Cellular agriculture and biofabricated products, traditional animal products and parts, synthetic materials, custom-made bioreactor, HC11 Mammary Epithelium cell line and nutrient media, Edwin Lankester's book *The Uses of Animals in Relation to the Industry of Man* (1860/1876), cabinets, freezer, and fridge
Dimensions variable
Made with assistance from the UCLA Art|Sci Center and the California NanoSystems Institute



Together at the Edge:

Reflections on *Emergence*

Stacy Switzer

I don't know. They might be dead.

These aren't the words I wanted to hear, but I knew we'd taken a risk. The organoids had arrived overnight in a finger-sized tube. Dr. Marie Bannier Hélaouët was unpacking and inspecting them under a microscope as I looked on, gamely hoping for the best—healthy human tear glands that might eventually be coaxed to cry—but prepared for the worst: dead tissue, no crying for us. It was a rarefied drama at microscopic scale. I was elated when, a few moments later, Marie spotted signs of life under the lens. We had our organoids.

The original impetus for developing the organoids had been purely scientific: Lacrimal gland organoids are used to study treatments and cures for dry eye, among other biomedical applications. Marie first grew human lacrimal gland organoids and induced them to cry as part of her PhD research in Hans Clevers's lab at the Hubrecht Institute in the Netherlands, a pioneering laboratory at one of the most respected developmental biology and stem cell research institutes in the world. Now, half a world from home—and thanks to the collaboration of Dr. Albert Wu and his team at Stanford Medicine—Marie whirred briskly around the stamp-sized corner office that Fathomers had converted into a Biosafety Level II lab (aka media changing room) for the cultivation and care of living works in *Emergence*. The lab housed a cabinet with controlled airflow for the safe handling of materials, a CO_2 incubator to keep cells at human body temperature, a centrifuge, and a refrigerator full of growth media and nutrients. In a nod to David Lynch, LA's patron saint of liminal spaces, we'd installed a checkered vinyl floor in this "lab out of nowhere." Also being kept cool in the lab were several flasks of "immortalized" human cells; a slab of lab-grown salmon, hand-carried to us by its creator; and dozens of tubes of yeast-grown, indigo-like dye.

We had our organoids. Their rarity, mutability, and implausible journey to Los Angeles mirrored so much of the production and presentation of *Emergence* as a whole. Collectively, Marie, Albert and his team, and Fathomers considered a variety of enchanting ideas for this project—including fluorescing organoids and the attempted assembly of a "whole eye"—and their implications, both artistic and scientific. Yet we ultimately decided to make no attempts to bring the organoids further into the realm of art than they already were, these uncanny readymade entities—fellow *Emergence* artists Oron Catts and Ionat Zurr of the Tissue Culture & Art Project might call them "semi-living"—born as stem cells and cultivated to live in the actual and symbolic wells of our curiosity. This is how *Emergence* emerged, from moments of deep uncertainty—*I don't know*—paired with an earnest desire to learn more: *What is possible? Can we grow an eye? Moreover, should we? If so, on what basis? Poetic? Scientific? Both?*

• • •

Nearly all of the projects in *Emergence* were newly developed for the specific occasion of PST ART. In 2023, about a year in advance of the exhibition's opening, Fathomers organized a convening of possible collaborators: artist-scientist



The *Emergence* lab at the Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.

innovators in the fields of biological art and DIY or community biology; scientists using the tools and methods of synthetic biology in their laboratories for cancer research, medicine, biomaterials, and other applications; artists keen to learn firsthand about these tools and their uses as possible subject matter, methods, and materials to be incorporated into their work; and others with unique perspectives on the legal, ethical, and creative intersections between art and synbio. The framework of the convening was open-ended: We curated a group of people first, and let the guiding themes and principles of *Emergence* unfold from the conversations that developed among them. We wanted to keep the curatorial arc of the project open and flexible for as long as possible, to see what ideas surfaced as urgent, necessary, and top of mind for our collaborators. While the expansiveness of this framing sometimes proved challenging, it allowed *Emergence* to become, in a sense, its own organism—alert to its environment, responsive, and capable of evolving in relation to changing conditions.

Over time, three distinct but related zones of inquiry emerged. One is a set of questions around justice and ethics, considered at length in my excellent colleague Dr. Yewande Pearse's companion essay; another is the exploration of time and transformation, touched by all of the projects in the exhibition. The last is the curious state of liminality or contingency—of being between or on the cusp—in which we all inevitably find ourselves. Questions of liminality surface throughout the exhibition in works exploring hybridity and the thresholds between life and nonlife. These works ask: What is life? What is death? What separates them—and how do we make sense of that blurry boundary? In our era of artificial intelligence, gene therapies, synthetic cells, and xenobots, what remains uniquely human? Philosophical discussions of liminality, temporality, and



transformation have a natural home in art and artmaking, as we seek to fix our ideas about mortality and meaning in forms that can be conveyed to others. Synthetic biology, meanwhile, takes up these questions directly in the lab, through its various aims—medical therapeutics designed to enhance and prolong life, for example—and methods.

Among those methods are techniques for producing immortalized cells, such as those included in Eduardo Padilha's haunting sculptural installation for *Emergence*. Titled *Apoptotic Bodies* (2024), the work presents three living cell lines—"normal" human fibroblast, immortalized human fibroblast, and human melanoma—in individual vitrines equipped with incubator-style warming plates. Despite their name, immortalized cells can still die under certain conditions—just as "normal" fibroblast and cancerous melanoma cells do—by undergoing a programmed form of cell death known as apoptosis. All of these cells are thus fragile. As Padilha writes in his essay for this catalog, "A dichotomous approach to life and death is insufficient not only at the cultural level but at the biological one as well. Although it is accepted that there is indeed a point beyond which living beings can be considered permanently dead, meaning that life can never again animate their structures, there seems to be much less certainty regarding the stages preceding this final, definitive state." His

Visitors tour the *Emergence* lab during The Lab Behind the Artworks, a PST ART Weekend event in Downtown Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.

These works ask: What is life? What is death? What separates them—and how do we make sense of that blurry boundary?

work attempts to parse this uncertainty, creatively deploying scientific tools to probe the liminal space between life and death. Revealingly, one of the vitrines in *Apoptotic Bodies* is connected to a mortician's embalming machine, gesturing toward the stakes of both preserving living cells destined for death and the still-developing use of those cells in cancer and other medical research.

Michael Jones McKean's *of kin and bone* (2024) also meditates on birth and death as well as ritual and transformation. The large-scale diorama assembles materials and moments from across timescales and species, embedding engineered life as one story among many in the multispecies history of life on Earth. One of several tableaux embedded in *of kin and bone*s is a set of bones based on the twenty-eight-thousand-year-old remains of a child who possessed both *Homo sapiens* and Neanderthal ancestry. The 1998 discovery, in Portugal's Lapedo Valley, of the original remains, now known as the Lapedo Child, called into question existing understandings of the group migrations and convergences that gave rise to modern humankind.



To recreate the child's skeleton, McKean enlisted the help of synthetic biologist Dr. Stephen Fong, a fellow professor at Virginia Commonwealth University, who experimented with existing protocols for growing synthetic nacre, or mother-of-pearl, in the lab, altering them to adjust for material qualities such as color, sheen, and strength. The bones that emerged through Fong and McKean's committed trial and error appear in the work as mysterious objects imbued with an aura of the sacred. On the reverse side of McKean's diorama, a ribbon of mottled gold flows between a nativity scene and a shallow basin from which various forms of nonhuman life spring, all of it hand-sculpted and covered in gold leaf. On one shallow side of the sculpture, the artist has embedded material specimens—coral, fossilized whale bone, and basalt among them—from each of the twelve sites in his ongoing planetary-scale sculpture, *Twelve Earth*s (c. 2017–28 | 2029–40). These found relics condense the mysteries of vast geologic time to the size of pebbles; they seem to be grouped as kin, evoking the sculpture's title. And what of the bones in McKean's work? Though grown in the lab in 2024, they replicate those of a child from the Upper Paleolithic Period, and their substance, calcium carbonate, chemically predates humanity by some eighty million years. Are they also our kin?

McKean's *of kin and bone*s seems to be in natural conversation with Henry Tan and Masato Takemura's *Pillars of Creation* (2024), installed

The *Emergence* fabrication and installation team unpacks Michael Jones McKean's *of kin and bone*, 2024. Courtesy of Fathomers.

nearby in the exhibition. Materially and visually, the gilded components of both works echo each other. *Pillars of Creation* is also coated in gold leaf but draws on distinct religious and artistic referents, including the Erawan Shrine in Bangkok. Conceptually, both works seek to absorb and distill thousands of years of evolution and inquiry into precisely calibrated gestures for meditative reflection. *Pillars of Creation* represents Brahma, the Hindu and Buddhist deity, adapted to the age of CRISPR gene editing and artificial intelligence. Traditionally, Brahma's four arms hold a scroll, a rosary, a scepter, and a water vessel, symbolizing knowledge, time, sacrifice, and cosmic energy, respectively. In Tan and Takemura's depiction, each of Brahma's arms cradles a built-from-scratch technology or symbol representing the immense power unleashed by modern research into memory, longevity, and the authoring of life in the lab.

In the spirit that inspired *Emergence*, *Pillars of Creation* emerged—and continues to emerge—as an artwork and locus of transdisciplinary research through and beyond the exhibition opening. To complete and install the work, Tan and Takemura arrived in Los Angeles weeks in advance. Takemura, a mechanical engineer by training, spent hundreds of hours refining the kinetics of the sculpture, which include a hand-built clino-stat for simulating zero gravity experiments in space, a 3D-printed tourbillon inspired by the clock drawing test used to screen patients for dementia, and a mechanism to slowly rotate the four arms of the sculpture. Tan and Takemura also connected with local synbio researchers at CalTech and UCLA to deepen their understanding of organoid biology, with the goal of eventually employing electrical signals from human brain organoids to power parts of their sculpture. After the exhibition closed, *Pillars of Creation* traveled with Tan to Abu Dhabi, where he is the inaugural artist-in-residence at NYU Abu Dhabi's Center for Genomics and Systems Biology. There, Tan is continuing his brain organoid research and, with fellow *Emergence* artist Dr. Pat Pataranutaporn, beginning to explore how organoids might become wearable devices, further blurring the boundary between technology and human life.



Pataranutaporn, a technologist and researcher at the MIT Media Lab, is a polymath shapeshifter who wears a dinosaur costume in his frequent public appearances at conferences and symposia around the world. He has become a sought-after speaker on artificial intelligence, addressing topics like the addictiveness of chatbots and the ability of AI to implant false memories. I first approached Pataranutaporn after learning about his work on *Wearable Lab* (2019), a seamless human-computer interface worn on the body to perform real-time monitoring of biochemical health markers such as cortisol, glucose, and nitric oxide.

For *Emergence*, Pataranutaporn suggested two more recently prototyped projects: *CyberBiome* (2021), a smart spacesuit that builds on ideas and technologies from *Wearable Lab*, and *MicroPET* (2023), named one of *TIME*'s "200 Best Inventions of 2023." Like his earlier work, *CyberBiome* may sound like science fiction but largely isn't. Fabricated from a self-healing biomaterial, the spacesuit continuously monitors its wearer and

Masato Takemura and visitors view *Pillars of Creation* at the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.

triggers the production of personalized drugs and therapies in response to their biomarkers. Meanwhile, *MicroPET* aims to help mitigate the effects of human intervention both in space and at home. The compact device programs bacteria and enzymes to break down PET plastic for reuse. *Wearable Lab* and *CyberBiome* are truly cyborgian in both form and function, a characterization Pataranutaporn embraces. They call into question the limits of the human while making a case for pressing beyond them. In contrast, *MicroPET* responds to a crisis born of our imprint upon the planet: What do we do with all those plastic wings we wear as we fly closer and closer to the sun?

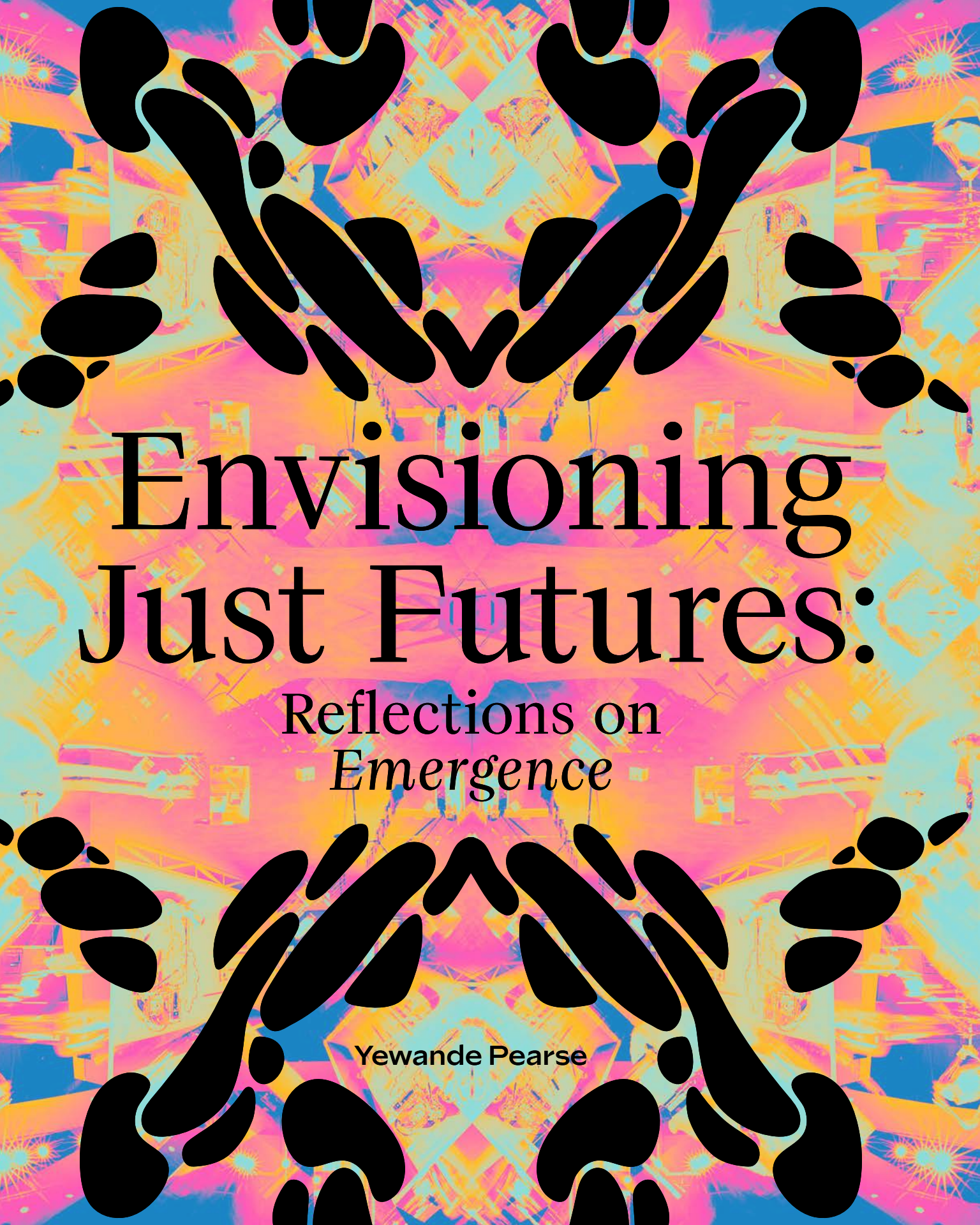
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Even with hindsight, it is difficult for me to disentangle the process of making *Emergence* from the public experience of the exhibition and the extended network of connections it fostered, as well as from the awareness that the version of *Emergence* we created for 2024 probably couldn't happen in the United States in 2026. So much of *Emergence* existed in its margins, its liminal spaces: in the relationships and trust-building among artists, scientists, and our brave partners at the Japanese American Cultural & Community Center; in the background zones of biosafety, permissions, and procurement of everything from human cell lines to tiny glass elephants; in the conversations still unfolding among many of us, catalyzed by the exhibition. This catalog continues those ongoing conversations, offering another window into what emerged from *Emergence* in order to archive and extend them—and, I hope, to inspire.



Stacy Switzer is the curator of *Emergence* and a cofounder of Fathomers, where she has served as curator and executive director since 2015. Her ongoing projects with Fathomers include Michael Jones McKean's *Twelve Earths* and Sage Ni'Ja Whitson's *Trans Trappist the Extraterrestrial: Flight of Seven Planets*. With Whitson and Dr. Jessie Christiansen, Switzer is a 2025 awardee of the Simons Foundation's Open Interval program, and in 2022, she received a curatorial research fellowship from the Andy Warhol Foundation for the Visual Arts for her work on *Emergence*. Switzer was the artistic director of Grand Arts in Kansas City from 2004 to 2015, where she curated dozens of major projects by artists including Sanford Biggers, Cody Critcheloe, Glenn Kaino, William Pope.L, Mariah Robertson, Tavares Strachan, and Sissel Tolaas. With Annie Fischer, she coedited *Problems and Provocations: Grand Arts 1995–2015* (2016). She has been a visiting lecturer, critic, and consultant for Creative Capital, the Jerome Foundation, and the Philadelphia Exhibitions Initiative, among others.

Stacy Switzer speaks at the opening of *Emergence*, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.



Envisioning Just Futures:

Reflections on *Emergence*

Yewande Pearse

I've been thinking a lot about the future recently—about the kind of future that might await us. Perhaps it's the inescapable social and political backdrop of 2025, or the fact that I'm expecting a baby as I write this, or perhaps it's a response to turning forty last year and being confronted with the new shape time takes as we age. I've also been thinking about the future as I coedit this catalog for *Emergence*, an exhibition that brought together an eclectic mix of works exploring synthetic biology through art. After almost a year of absorbing these works, I'm still uncovering new thematic tissues connecting them.

A number of the works in *Emergence* converge on the theme of just futures. Though they take strikingly different forms, they all reflect on recent shifts in synthetic biology and suggest that by interrogating these changes through an artistic lens, we can uncover a glimpse of what c*ould* happen in the future. Projects by Dr. Callie R. Chappell and Dr. Nasa Sinnott-Armstrong, the Tissue Culture & Art (TC&A) Project, Dr. Marie Bannier Hélaouët and Dr. Albert Wu, Corinne Okada Takara, AfroRithm Futures Group, and others envision and raise questions about alternative futures in which justice sits at the center. They remind us that science is more than methodology and data; it's worldbuilding. Through their engagement with science, these works provide something beyond aspirational impressions. Instead, they offer actionable visions of how we might actually create a more just future.

• • •

In 2020, catalyzed by the Black Lives Matter movement, the term "decolonize" seemed to emerge (or rather reemerge) as a powerful directive across politics, environment, economics, and culture. Decolonization, at its core, aims to dismantle colonial structures and ideologies; it is a multifaceted, dynamic process that continually evolves as society shifts. Among those with a shared intention, decolonizing fields like



education, healthcare, and science became an urgent priority, demanding a dedicated process of acknowledging and dismantling the Western biases and power structures that have historically dominated scientific research.

Yet as a graduate student and postdoctoral researcher, I had found there wasn't always time for the intentional pause, processing, and action that decolonizing science demands. Academic life emphasizes the relentless need to produce data, which can work against many researchers' inherent passion for their research and the noble goal to move science forward. I worked on rare childhood brain diseases during my PhD, in a lab that welcomed parents of affected children into the ivory tower and behind the veil. The urgency could not have been more real than when meeting the actual beneficiaries of your research. Yet educational structures that link data generation to funding also make competition and tunnel vision commonplace. Confronted with academia's cumulative failings more intensely than usual, I started reflecting on what I'd known and experienced throughout my academic career: that science is saturated with colonial detritus, and that Western frameworks dominate not just humans but all living systems. In the middle of completing my postdoc, amid the loud quiet of the early Covid-19 pandemic, that colonial detritus smelled more rotten than ever.

A visitor examines a flask containing living cells under a microscope in the *Emergence* lab as part of The Lab Behind the Artworks, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.

These works provide something beyond aspirational impressions. Instead, they offer actionable visions of how we might actually create a more just future.

For some works in the exhibition, too, that colonial detritus is impossible to ignore. Instead, they sit right at the center of colonial doctrine, ready to disrupt and reconfigure from the inside, offering new perspectives on the relationship between humans and other living organisms. These works boldly and unapologetically confront colonial legacies. In doing so, they inspire hope and a sense of possibility for a more just future. In particular, scientist-cum-artist duo Callie R. Chappell and Nasa Sinnott-Armstrong's *IndiGROW* (2024) presents a compelling intervention into the violent colonial histories of indigo production while interrogating the potential futures of synthetic biology. Through an installation featuring jeans and cushions dyed with bioengineered indigoidine alongside an interactive dyeing station with a large flask of the blue dye, the artists document indigo's trajectory from ancient craft traditions across diverse global cultures to its exploitation under European colonialism.

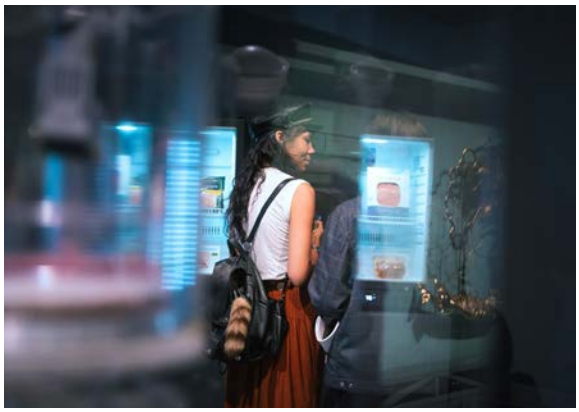


IndiGROW also showcases how synthetic biology has been cleverly harnessed to produce indigo. On first reflection, this technological development might seem to represent significant progress from a time when enslaved and Indigenous populations suffered decimation in the service of producing what was then called "blue gold." But Chappell and Sinnott-Armstrong confront the colonization of living organisms directly and fearlessly, using our relationship with microbes as a mirror to human power dynamics. Their central provocation lies in their concept of "abioticizing" microbes. Reducing genetically engineered bacteria and yeast to machines, they contend, recapitulates the dehumanization that justified colonial exploitation. This reframing challenges synthetic biology's tendency to reproduce colonial patterns of domination and extraction, instead urging us to embrace the complexity, reciprocity, and intrinsic value of all life forms, no matter how tiny. In this way, *IndiGROW* ideates a just future in which biotechnology enables us to recognize life's inherent worth.

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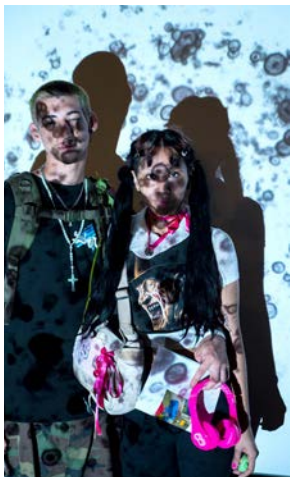
As a former cell biologist, I spent the good part of fifteen years culturing various cell types, from fibroblasts to stem cells to neurons and glia and brain organoids. I even tried my hand at culturing cardiac cells, known for their ability to visibly beat under a microscope. When I think back to the casual act of separating something so momentous from its whole to interrogate its function in a dish, I still marvel at the brilliance of technology to help us better understand our own

Callie R. Chappell and Nasa Sinnott-Armstrong at the opening of *Emergence*, 2024. Photo: Jordyn Doyel.



complexity—yet it also strikes me as somewhat diabolical to consider something as intricate and ineffable as human thought, a beating heart, or the act of crying in such a simplistic, detached way. I wouldn't be a very good scientist if I didn't acknowledge that the scientific method usually requires this kind of reduction—breaking complex systems into manageable parts to understand the whole—but we tend to lose focus on the bigger picture as we become accustomed to the daily minutiae of manipulating life. Seeing the same kinds of cells and tissues I'd worked on for years recontextualized as art in *Emergence* has forced me to confront what I'd gotten comfortable overlooking, pushing me into more unsettling moral territory than the ethical frameworks that typically govern laboratory practice ever demanded.

Unlike the term "decolonize," scientists are used to thinking about ethics. Given science's power and potential, ethical frameworks are integral—in fact mandatory—to most scientific research. These frameworks are meant to ensure that scientists conduct research wisely and responsibly, in a way that serves humanity's best interests, yet they rely on Western ethical systems that have historically marginalized Indigenous, non-Western, and colonized worldviews. *Emergence* takes an alternative approach to thinking about ethics, disrupting these hegemonic standards by recontextualizing biological processes outside their natural environments. Works such as the Tissue Culture & Art Project's *The Use of Life (in Relation to the Industry of Men)*, Eduardo Padilha's *Apoptotic Bodies*, and Marie Bannier Hélaouët and Albert Wu's *Crying Organoids* (all 2024) use science that has undergone and "passed" rigorous ethical inquiry, yet compel us to reconsider the morality of extracting biological functions from their living contexts. Among these works, ethics becomes more akin to deeper spiritual questioning: What do we owe to the life we create in isolation?



TC&A's *The Use of Life* pulls at this ethical yarn, presenting isolated, lab-dependent "semi-living" cells and tissues that are neither fully alive nor completely dead. The installation reflects on how biotechnology creates new biological entities that existing ethical frameworks struggle to fully address. By displaying traditional animal products alongside their cellular counterparts, the artists expose the irony inherent in biotechnology's promise of "victimless" production. This juxtaposition unravels our moral assumptions, revealing how existing ethical frameworks lag behind our technological capabilities and leave us underprepared for a world increasingly populated by engineered life-forms that are designed solely to serve human industry.

Eschewing the pointed critique of TC&A's work, Bannier Hélaouët and Wu's *Crying Organoids* instead invites viewers to simply observe the functional lacrimal glands on display. Yet within this artistic context, their project inevitably invites similar ethical contemplation. These lab-grown lacrimal glands, developed

Top: A visitor views the Tissue Culture & Art Project's *The Use of Life (in Relation to the Industry of Men)* at the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Photo: Jordyn Doyel. **Bottom:** Visitors view Marie Bannier Hélaouët and Albert Wu's *Crying Organoids* at the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Photo: Jordyn Doyel.

Altogether, the works in *Emergence* caution me toward the truth that a just future is not the inevitable outcome of technological progress but the result of deliberate choices we must make about how we relate to life itself, both human and nonhuman.

to help cure serious eye diseases, seem to carry a more profound meaning through their very function: producing tears. The emotional weight of crying, and the mystery surrounding this uniquely human expression, imbue the cells with poetic significance even though they were not cultivated to study the emotional production of tears. Whether deliberate or incidental, the act of biological separation at the heart of *Crying Organoids* reinforces TC&A's argument that the ethical considerations of biotechnology extend far beyond conventional frameworks, demanding we grapple more seriously with our moral obligations to the isolated fragments of life we create and manipulate. How, they prompt us to ask, might a more expansive framework of scientific ethics contribute to a more just future?



Eduardo Padilha, Corinne Okada Takara, Fathomers programs manager Annie Zeng, and Yewande Pearse at the opening of *Emergence*, 2024. Photo: Jordyn Doyel.

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Not long ago, a pop star flew to space. Like many people, I wondered why. Was the purpose of this stunt to represent the boundlessness of human endeavor, or might we all soon need an exit plan? Several works in *Emergence* take up increasingly urgent questions about human life beyond Earth in relation to synthetic biology. How can synthetic biology help us get to space—and more importantly, should it? Embracing new technologies, Dr. Pat Pataranutaporn's *CyberBiome* (2021) innovates adaptations for life beyond Earth, inviting us to reflect on our potential future as hybrid beings, as my coeditor Stacy Switzer writes in her companion essay. For Corinne Okada Takara, the question of survival beyond Earth is inseparable from the preservation and evolution of cultural practices. Takara creates spaces where synthetic biology converges with Indigenous knowledge systems, positing ancient practices of biodesign as blueprints for off-world cultivation. In her *Floating Future Gardens* (2024), cutting-edge synthetic biology meets traditional ecological wisdom in installations that encourage collaborative worldmaking through the act of play.

The AfroRithm Futures Group's *MultiPlanetary Garden* (2024) offers perhaps the most radical reimagining of synthetic biology's role in humanity's cosmic future. Born from the collaborative



worldbuilding game AfroRithms from the Future, which centers vibrant Black and Indigenous perspectives, this work transforms speculative storytelling into embodied performance. I first got to take part in AfroRithms from the Future in 2022. I and twelve other participants from various fields—including arts and culture, accessibility, and economics—spent a daylong retreat at the Interval, a cozy cafe, museum, and bar at the Long Now Foundation in San Francisco, grappling with the exciting possibilities and challenges of the virtual landscape through the medium of gameplay. Framed as an opportunity to explore the potential of Metaverse and similar virtual platforms as liberatory spaces for Africana and Indigenous people, the retreat provided a fun and intellectually stimulating visioning exercise that also felt surprisingly viable. I think this is the beauty of the AfroRithm Futures Group's work: It starts with the seemingly impossible, then helps us navigate how to make it possible.

Through a cycle of dances that progress from individual movement to communal celebration, *MultiPlanetary Garden* presents a future in which synthetic biological advancements have enabled egalitarian abundance across multiple worlds. While this may seem pretty out there, the group's collaboration with synthetic biology pioneer Dr. Drew Endy grounds their Afrofuturist visions in scientific possibility, allowing them to consider how biosynthesis could make scarcity obsolete and allow all kinds of life to flourish responsibly and respectfully throughout the galaxy. As major corporations stake claims in both virtual metaverses and actual space, *MultiPlanetary Garden* offers a vital counternarrative that centers justice over profit. Rather than providing escape plans for the privileged few, AfroRithm Futures Group creates road maps for transformation rooted in community-centered, Afrofuturist egalitarianism, using bioengineering as a vehicle to achieve abundance for all.

Like *Floating Future Gardens*, *MultiPlanetary Garden* frames ancestral practices like dance, storytelling, and agronomy as sophisticated rather than primitive modes of imagining how bodies and environments might interact across worlds. In using play to bring together art and synthetic biology, moreover, both works envision a future where disciplinary boundaries dissolve,

AfroRithm Futures Group during the live performance of *MultiPlanetary Garden* at the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.

and in those smudges, something genuinely new emerges. The tension between play and the seriousness of synthetic biology and biotechnology—and the high stakes represented by our intergalactic human footprint in both these projects—makes for a hopeful view of the future. Instead of replicating existing power structures across worlds and erasing cultural heritage in the name of technological advancement, they show us how capable we are of creating something not only new but inclusive, fair, and just.

Altogether, the works in *Emergence* caution me toward the truth that a just future is not the inevitable outcome of technological progress but the result of deliberate choices we must make about how we relate to life itself, both human and nonhuman. Whether confronting synthetic biology's potential to replicate colonial patterns of exploitation, wrestling with our moral obligations to the entities we create, or envisioning multiplanetary societies rooted in equity rather than extraction, the artists and scientists in *Emergence* demonstrate that the future of synthetic biology and biotechnology depends not on what we can do but on who we choose to be in the process of doing it. Science is cool, and the scope of human ambition and achievement is mind-blowing. But these works remind us that in a world where we increasingly engineer life, the coolest and most radical thing might be to recognize that every organism, no matter how small or how engineered, deserves careful consideration. As I prepare to welcome new life into this world, I find myself meditating on the idea that the future is not something that happens to us; rather, it is something we can build together—one discovery, one act of recognition, one choice at a time.



Dr. Yewande Pearse is the director of science editorial and content for *Emergence* and the coeditor and scientific editor of this catalog. She translates science as an expert advisor, speaker, moderator, and writer, driven by the belief that science has the power to connect people and communities. A neuroscientist with over fifteen years of research experience at King's College London and Harbor-UCLA Medical Center, Pearse has brought science storytelling to the Natural History Museum of Los Angeles County, Sundance Film Festival, the LA Phil, Headspace, TEDMED, and Science Gallery. She produced and hosted the Sound Science podcast on Dublab Radio and was an account supervisor at Stellate Communications, helping some of the greatest minds in science translate their discoveries into meaningful public impact. She currently serves as an advisor to the California Science Center and a community fellow at the Center for Diverse Leadership in Science at UCLA.

Yewande Pearse coleads a guided gallery tour of *Emergence*, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.





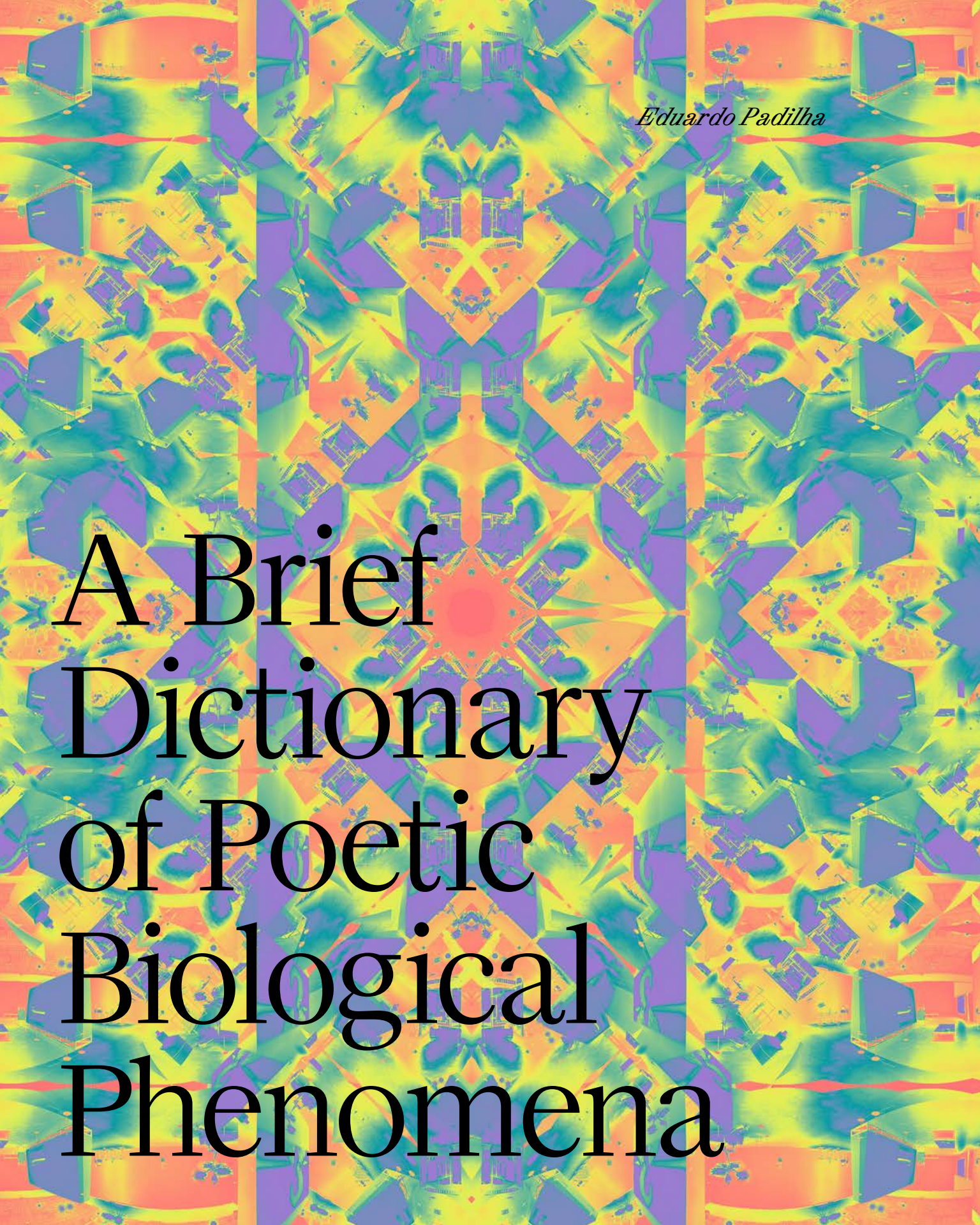


Top left: The Fathomers booth at the PST ART DTLA Street Fest, Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel. **Top right:** Ionat Zurr and Masato Takemura in the *Emergence* lab, 2024. Courtesy of Fathomers. **Bottom:** Members of the extended *Emergence* team, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.



Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.





Eduardo Padilha

A Brief Dictionary of Poetic Biological Phenomena

Preface

The reader should be warned that, unlike conventional dictionaries, this work does not intend to be comprehensive. Although it provides accurate definitions of specialized terminology, in this case from the field of biology, that is not the sole or final goal of this effort. The list of terms is far from exhaustive and does not broadly cover biological vocabulary. The reader will notice that the entries have been curated to reflect a series of phenomena characteristic of the living world. The main criterion for inclusion was the poetic potential inherent in each phenomenon—"poetic" deriving from the Greek *poiein*, meaning "to create" or "to produce," the root of the word *poetry*—as this dictionary was the work of an artist. Such an unexpected origin for a dictionary, however, should not raise suspicion but, if anything, spark curiosity, since the entries were chosen to expand and dislocate interpretation. From the scientist readers, I ask for understanding, for although I deal with jargon here, pragmatism was not quite the compass guiding my effort. From the artist readers, I ask for imagination, for the living world is poetic by essence.

São Paulo, 2024

Amber

/ˈæm-bər/ | (am·ber)

Fossilized resin, commonly used for jewelry- and ornament-making. The protective resin is exuded from tree bark in response to threats such as insects and fungi, filling gaps in the bark, hardening and sealing it. Organic in composition and inorganic in appearance, these vegetable secretions sit at the boundary between living and inanimate worlds. Time capsules, they imprison and preserve witnesses of older times.

Apoptosis

/ˌæp.əpˈtoʊ.sɪs/ | (ap·o·pto·sis)

Apoptosis, from the Greek *apo*, "away" or "off," and *ptosis*, "fall," is programmed cell death. In circumstances where the amount of aggression or damage is so great as to compromise the processes normally performed by a cell, the cell can initiate a precise and organized series of biochemical events that culminate in its death. This death, however, is triggered in a way that causes the least possible damage to the surrounding tissue. As a result, apoptosis is commonly referred to as a "clean" and "organized" death. It is the choreography of death danced to no music.

Autophagy

/ɔːˈtoʊˈfæ.dʒi/ | (au·toph·a·gy)

A cellular mechanism employed to degrade cytoplasmic proteins and organelles, recycling cellular components for homeostasis, survival, and the production of energy and metabolic precursors. This ubiquitous process is also involved in the control of cell growth, aging, and death, and is characterized by an elongation of the cell membrane in order to sequester cytoplasmic material in a structure called *autophagosome*, from the Greek for "self-eating body."

Autopoiesis

/ɔːˈtəˈpɔɪ.iː.sɪs/ | (au·to·poi·e·sis)

From the Greek *auto*, "self," and *poiein*, "to make," as in "poetry." In *What Is Life?* (1995), biologist Lynn Margulis and writer Dorion Sagan define autopoiesis as "life's continuous production of itself. Autopoietic behavior, characteristic of all living matter, refers to the chemical activities (metabolism) of identifiable organic beings as they self-maintain."

Cancer

/ˈkæn.sər/ | (can·cer)

Cancer is a group of diseases characterized by the uncontrolled proliferation of cells. These cells lose their biological identity, cease to function like their tissue of origin, and acquire the ability to invade other tissues of the organism. Commonly associated with imminent death, cancer is ironically an excess of life, given that malignant cells no longer respond to growth-suppression stimuli and can reproduce ceaselessly. Thus cancer reflects a paradox of life and death, a blow to the dichotomy between self and nonself.

Death

/dɛθ/ | (death)

The opposing force to life. Biologically, death is the irreversible failure of vital functions that sustain an organism, marking the end of life. In the history of medicine, death was a condition less obvious than initially believed, making it a challenge to declare a human truly dead.

Decomposition

/ˌdiː.kəm.pəˈzɪʃ.ən/ | (de·com·po·si·tion)

The action of decaying or causing something to decay, breaking something into its constituent parts. For living bodies, the process of decomposition begins after death, when vital forces no longer operate to construct and maintain structures, leaving them subject to dismantling and disintegration.

Differentiation

/ˌdɪf.ə.ˌrɛn.ʃiˈeɪ.ʃən/ | (dif·fer·en·ti·a·tion)

The process through which cells from the same source produce cell groups with different morphological structures and functional characteristics. By means of differentiation a cell reaches its specialized and mature phenotype, losing developmental potential. There is a price to be paid for the specific functional capabilities acquired; this price is forfeiting stemness. Thus differentiation suggests a suspension between potentiality and action.

Efferocytosis

/ˌɛf.ə.roʊ.saɪˈtoʊ.sɪs/ | (ef·fe·ro·cy·to·sis)

The process that mediates the removal of apoptotic cells by phagocytic cells. This anti-inflammatory process removes billions of apoptotic cells in the human body daily and is crucial for maintaining homeostasis.

Ferroptosis

/ˌfɛr.oʊpˈtoʊ.sɪs/ | (fer·rop·to·sis)

Originally defined as cell death that can be activated by small molecules such as erastin, ferroptosis is mediated by iron-dependent lipid peroxidation. It differs morphologically from apoptosis and necrosis and does not involve the cellular machinery that mediates apoptosis or necroptosis.

Hematopoiesis

/hɪˌmæt.oʊ.pɔɪˈiː.sɪs/ | (he·ma·to·poi·e·sis)

The process through which the body produces blood cells. It takes place in the hematopoietic system, a self-renewal system comprising organs and tissues involved in blood production. All the cellular components of the blood are derived from hematopoietic stem cells.

Homeostasis

/ˌhoʊ.mi.oʊˈsteɪ.sɪs/ | (ho·meo·sta·sis)

Homeostasis, from the Greek, *hómoios*, "similar," and *stásis*, "standing," describes the ability of living organisms to maintain internal balance and stability in response to changes in the external environment. This dynamic equilibrium, conserved despite fluctuations and oscillations, is seen as one of the defining aspects of what we call "life," an indispensable attribute of living beings. "Standing similar" refers above all to the being itself, its sustainment of internal metabolism and processes despite the vicissitudes of the exterior world. Homeostasis hinges on the balance of discrete entities.

Immunosuppression

/ˌɪm.jʊ.noʊ.səˈpreʃ.ən/ | (im·mu·no·sup·pres·sion)

The suppression of the immune system and its capacities, whether intentional or not. Immunosuppression may be induced by drugs, for example, in preparation for bone marrow or organ transplantation, in an attempt to prevent rejection of the donor tissue. In this case, it is a strategy to suppress the mechanisms of the immunological self, depleting the organism's guard against the "other," the nonself.

Inflammation

/ˌɪn.fləˈmeɪ.ʃən/ | (in·flam·ma·tion)

A biological response of the immune system to harmful stimuli (e.g., pathogens, damaged cells, irritants) characterized by the key signs of pain, heat, redness, swelling, and loss of function. Inflammation is a protective mechanism that, when dysregulated, may contribute to the pathophysiology of many diseases. It is usually referred to as "inflammatory response," as if to imply that the organism or tissue is being interrogated, challenged. Cells may undergo apoptosis—a "clean" death that does not trigger inflammation—in order to avoid such interrogation and trial.

Metabolism

/məˈtæb.əˌlɪz.əm/ | (me·tab·o·lism)

From the Greek *metabolē*, meaning "change" or "transformation," metabolism is the entirety of biochemical reactions taking place within living organisms: the changes of molecules carried out by enzymes, involving the production and consumption of energy and macromolecules and the elimination of toxic wastes. The permanence of life rests on the impermanence of nonliving entities.

Metastasis

/ˌmɛt.əˈstæ.sɪs/ | (me·tas·ta·sis)

The spread of malignant cells from the primary tumor site to distant parts of the body. The cells acquire the capacity to invade surrounding tissues and travel through the bloodstream or lymphatic system, originating secondary tumors in different organs or tissues.

Mitosis

/maɪˈtoʊ.sɪs/ | (mi·to·sis)

The tightly regulated biological process through which a cell divides into two daughter cells. Mitosis includes the division of both the cell nucleus and the cytoplasm, with the resulting cells genetically identical to the parental one. This *poietic* process is at the root of the generation and maintenance of the organic structures necessary to life. It is a means of transcending the limitations of unity by becoming many.

Mutation

/mjuˈteɪ.ʃən/ | (mu·ta·tion)

A change in the nucleotide sequence that makes up the DNA strand, leading to genetic variation. A mutation may result from different causes, such as radiation, chemicals, or spontaneous mistakes during DNA replication, and its implications range from completely harmless to potentially fatal.

Necroptosis

/nɪˈkrɒp.toʊ.sɪs/ | (ne·crop·to·sis)

Necroptosis, a necrotic programmed cell death pathway, was the first discovered programmed cell death mechanism to mediate necrosis. It can be promoted by the activation of death receptors by their cognate ligands in cells under apoptosis-deficient conditions.

Necrosis

/nɛˈkroʊ.sɪs/ | (ne·cro·sis)

A form of cell death triggered by an acute insult, in which the cell undergoes unregulated digestion of its internal components. This process elicits inflammation and affects neighboring cells—a critical difference between necrosis and apoptosis. Present in different human pathologies, this dramatic way of dying involves the swelling of the cytoplasm and the disruption of the cell membrane, a conspicuous implosion that releases the cellular contents into the intercellular milieu.

Phagocytosis

/ˌfæg.oʊ.saɪˈtoʊ.sɪs/ | (pha·go·cy·to·sis)

The engulfment and digestion of entities (e.g., particles or another cell) by an individual cell. Phagocytosis is a fundamental activity for host defense against pathogens and cleanup of dead or damaged cells and debris.

Pyroptosis

/paɪˈrɒp.toʊ.sɪs/ | (py·rop·to·sis)

A type of programmed necrotic cell death regulated by dedicated genetic pathways in mammalian cells. Pyroptosis is a lytic and inflammatory type of death that involves cell swelling, membrane perforation, and the release of cell contents.

Secretion

/sɪˈkriːʃən/ | (se·cre·tion)

A vital biological process by which cells segregate, elaborate, and release some substance, such as saliva or urine. Secretion enables cells to communicate, transport nutrients, and eliminate waste products.

Semipermeability

/ˌsɛm.iˌpɜr.mi.əˈbɪl.ɪ.ti/ | (semi·per·me·abil·i·ty)

Semipermeability refers to the characteristic of a material or membrane that allows certain molecules or ions to pass through it while blocking others. This selective permeability serves an important role in various biological and chemical processes. For example, cell membranes are semipermeable, permitting essential nutrients to enter the cell while keeping harmful substances out. The semipermeable nature of these membranes is crucial for maintaining homeostasis within the cell.

Transcription

/trænˈskrɪp.ʃən/ | (tran·scrip·tion)

The process by which the "text" of the genes, stored in the deoxyribonucleic acid (DNA) molecule placed in the cell nucleus, is transcribed into another species of nucleic acid, ribonucleic acid (RNA), a messenger that can reach the cell's cytoplasm and be used for translation into proteins.

Transformation

/ˌtræn.sfərˈmeɪ.ʃən/ | (trans·for·ma·tion)

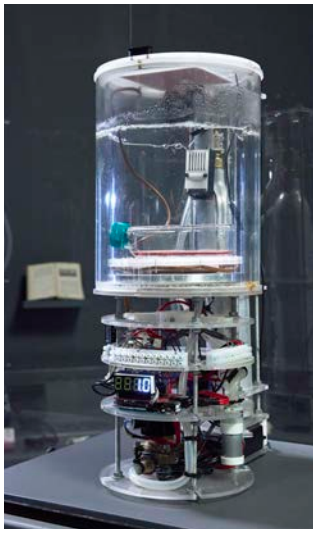
In cell biology, transformation refers to the transition of a normal cell into a malignant, tumorigenic state. It involves loss of homeostasis, mainly loss of control over cell reproduction and proliferation. A "transformed" cell is not necessarily a fully malignant cancer cell, highlighting the gradient between normal and pathological—a continuum rather than poles in a binary system.

Translation

/trænˈsleɪ.ʃən/ | (trans·la·tion)

The process of synthesizing proteins from messenger RNA by translating the language of RNA (an alphabet composed of nucleotides) into the language of proteins (an alphabet composed of amino acids). This "univocal correspondence between . . . alphabets," in the words of biologist François Jacob, is a central process in molecular biology and, most importantly, a semiotic occurrence, ensuring the flow of information and the perpetuation of being(s).

Long *in the* Tooth *and the* Shadow



Dan Samorodnitsky

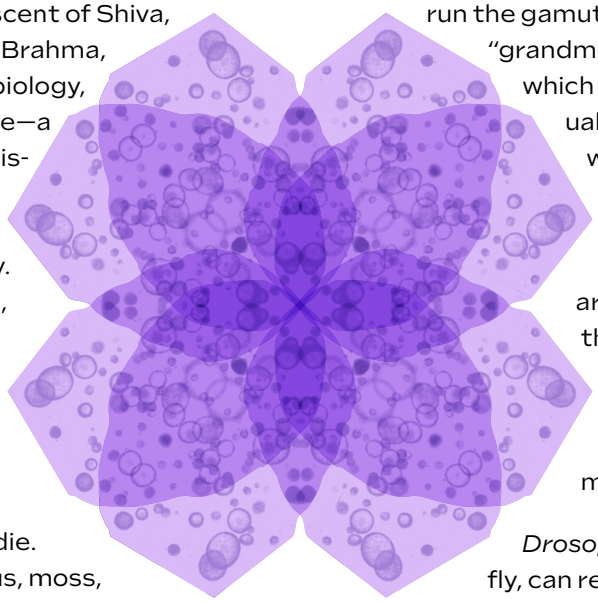
At the Japanese American Cultural & Community Center in Los Angeles stands an unusual figure of Brahma. He has four hands: One of them holds a water pot, a receptacle for cosmic energy; another a lotus flower, a symbol of rebirth. Brahma was born from a cosmic golden egg, but in this iteration, he is made of plastic, and his tools of creation are modern and biological. As the writer Matthew Herper puts it, the twenty-first century is "biology's century," in the same way that the twentieth was dominated by physics and physicists, the space race, the atom bomb, death and destruction.[1] In biology's century, we are increasingly obsessed with life and its careful study and deconstruction. We synthesize DNA in mass quantities like a scroll of infinite knowledge. Scientists can grow individual organs in miniature in a laboratory—called *organoids*—a significant advancement over 2D cell cultures, opening new doors to understanding how the brain functions and responds to drugs.

The artists Henry Tan and Masato Takemura had many inspirations for their installation, titled *Pillars of Creation* (2024). One inspiration was the Pillars of Creation themselves: "It's the birthplace of stars seven thousand light-years away," said Tan. "But what we see has already been destroyed; we just see the image because light just got here." These galactic "elephant trunks"

Tissue Culture & Art Project, *The Use of Life (in Relation to the Industry of Men)*, 2024. Detail: custom-made bioreactor and cellular agriculture. Courtesy of Fathomers. Photo: Carson Davis Brown.

(so named because they bear an uncanny resemblance to elephant appendages) pushed Tan and Takemura to draw connections among the sites of stellar creation, the tree of biological life here on Earth, and the creations of Brahma. Another inspiration was the statue of Brahma at Erawan Shrine in Bangkok, Thailand; while Brahma figures in both Hindu and Buddhist traditions, the Brahma at Erawan is the object of broader, syncretic worship, attracting devotees of diverse faiths and none. Many ask the god for a favor and promise an offering if their wish is granted.

The PVC piping that makes up Tan and Takemura's golden Brahma, the creator, was originally a brilliant blue, reminiscent of Shiva, the destroyer. This modern Brahma, carrying tools of synthetic biology, biotechnology, and medicine—a sensor readied to house a disembodied brain, a machine for printing DNA, a dementia clock—haunts the gallery. It is a specter of both death, the legacy of the twentieth century, and eternal life in biology's century, the twenty-first.



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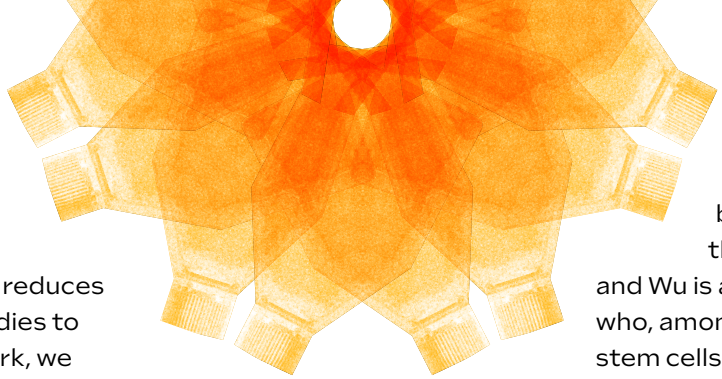
It is critical that organisms die. Every cell, bacterium, fungus, moss, plant, mouse, bird, bear, and human must die. Life on Earth cannot grow or evolve, let alone persist, without every previous generation having its limited time in the sun and then bowing out. Immortality is not an option.

But why any one individual organism must age and die is a mystery. Aging is the great "unsolved problem of biology," as the Nobel laureate Peter Medawar put it. One prominent idea—which biologists call the "selection shadow"—suggests that mutations simply build up over time: Early on in a creature's life, they are few and harmless, but in its twilight years they become an avalanche of late-acting derangements.[2] The genome is too big, cells too numerous and fragile, to withstand time's assault. Cells have shadows, as forests do, that grow long as the day goes on, as we grow long in the tooth.

Often, the lifespans of many organisms far exceed the periods of their lives when they reproduce. Explanations for this phenomenon run the gamut: the selection shadow; the "grandmother effect," according to which post-reproductive individuals help with child-rearing; a wise shrug suggesting that not everything in biology is evolutionarily adaptive, that sometimes things just are the way they are; the belief that a person's tics and habits are actually biologically beneficial, and so having a cup of tea every morning will mean living to one hundred.

Drosophila melanogaster, the fruit fly, can reproduce on the fifth day of its life but its lifespan can last up to forty days. If their lives are artificially curtailed to five days for many generations and then allowed to unfold normally, fruit flies still may live up to forty days. This persistence of longevity, even when not realized for many generations, raises the question, Why must life go on so long?

Cells have shadows, as forests do, that grow long as the day goes on, as we grow long in the tooth.



Ionat Zurr and Oron Catts's *The Use of Life (in Relation to the Industry of Men)* (2024) reduces Earth's collection of bodies to the minimum. In this work, we face life reduced to bits, often just the parcels the economy deals with: textiles, foodstuffs, ornaments, personal items. *The Use of Life* functions as a biologically closed system: temporary, limited in scope, all life within it eventually doomed to die once its life support is withdrawn. Planet Earth—light-years from the nearest solar system or any other source of natural resources—resembles a closed system, like Zurr and Catts's piece writ large. Here, life itself is instrumentalized: Cell cultures are designed to die, with their membership in an organism and thus their sentiency lost, their connection to previous and future generations cut off. Mammary tissue grown in isolation, without children to nurse, turns the concept of life itself on its ear. The cells still live in the shadow—no human intervention can undo that—but in a lonely dish, disconnected from all other forms of life.

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Death, then, is an invention of life; it is a phenomenon that had to be brought forward by evolution. Atoms and molecules do not themselves die. They spin, merge, collide, and annihilate one another. Photons pop in and out of existence. DNA, RNA, and proteins—just molecules—do not "die" according to the common usage of the word. Given an infinite food source, many types of cells can keep dividing infinitely. If you start with one bacterial cell that divides into two and then four and eight and on and on, you end up with the Ship of Theseus in reverse, one cell splitting an infinite number of times into an infinite number of daughter cells. Where did the original cell go? Did it die?

Crying Organoids (2024) by Dr. Marie Bannier Hélaouët and Dr. Albert Wu reiterates the ghost of sentience that hovers near *The Use of Life*. Bannier Hélaouët is a biologist who studies the surface of the eye and Wu is an ophthalmologist who, among other things, uses stem cells to regenerate damaged parts of the eye. Bannier Hélaouët and Wu cultured tear gland organoids, which swell with tear fluid when exposed to adrenaline. Akin to miniaturized organs, organoids are groups of specialized cells growing in a dish, mimicking their organ of origin. Henry Tan's plastic Brahma will eventually hold an organoid version of a brain—the seat of consciousness and sentience—in his hand.

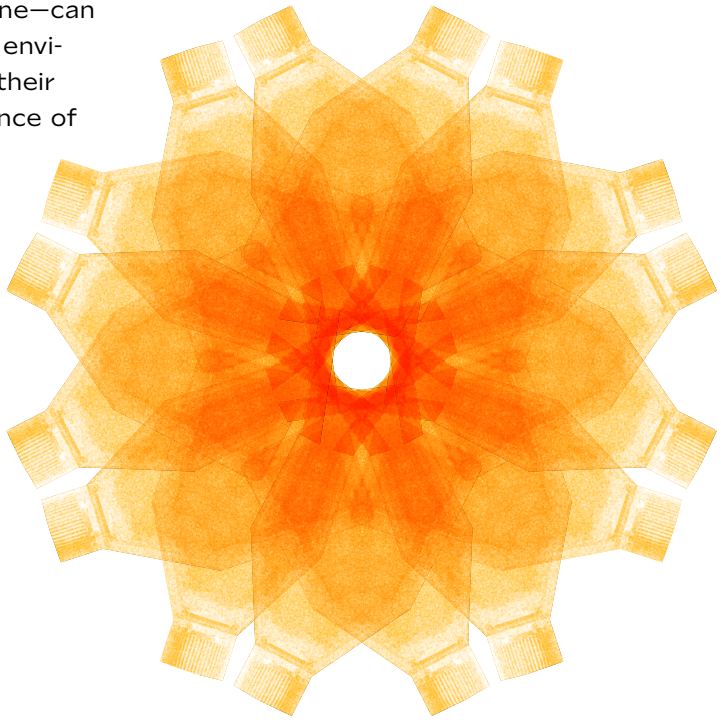
Emotionally generated tears contain chemosignals that directly alter brain activity in other humans; they can induce stress responses or even tamp down arousal.[3] Over the course of a human life, the eye's ability to cry and to protect and lubricate itself can decrease significantly, regardless of gender or life experience.[4] Yet Bannier Hélaouët and Wu's artificially created lacrimal gland organoids are disconnected from a controlling brain, disconnected from our thoughts, devoid of the motivations that drive one to cry: fear, grief, joy. Separated from the rest of the body—like Zurr and Catts's disassembled pieces of life—and even from the eye they are meant to lubricate, what value do these isolated tears have? Severed from their source of human sentience, will these tears still induce a response in others?

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Immortality, for any of us, is not an option. The individual components of life, the things that make up any organism—whether it be limbs, tear ducts, cells, or DNA—still suffer under the same regime of mortality when separated from the whole. Death comes for us all, completely or in parts. Even the individual molecules that drive life—DNA, RNA, proteins—accumulate mutations in the selection shadow and cease to function. That, in a sense, is a type of death.

If a molecule can "die," then what is life to begin with? Surely something imbued with life must have a lifespan, as much bounded by birth as by death. Does Brahma, a god, have a beginning and an end? Is Brahma alive or dead? Do body parts cultured in a lab, bristling with living cells but not connected to any organism and unable to reproduce, have a lifespan? We have ripped the molecular stuff of life out of its normal dwelling place, turning it into dispossessed pieces of organic material. By artificially growing and perpetuating these pieces, scientists create beings without origin, disconnected from the larger course of organismic life and death. They are not born from a womb or an egg or a sac. They are *perpetuated*, like a cutting from a fruit tree, grafted into a new growing place. Nonetheless, they are cared for, they are nourished—but are they loved?

These pieces of DNA, these cells swimming in culture, these brain organoids sending neural impulses to nowhere, exist somewhere in the limbo between life and death, neither a creature of the wild nor an unmoving, inanimate object. Some—like tear gland organoids injected with adrenaline—can even respond to their environment and change their behavior. In the presence of these organoids, it may become easier for us to see that life—all we see and do—is infinitely more than the sum of its parts—*all lives*, our environments, flora and fauna, the whole Earth.



1 Matthew Herper, "Here's Why We're Not Prepared for the Next Wave of Biotech Innovation," *STAT*, November 23, 2022, https://www.statnews.com/2022/11/03/why-were-not-prepared-for-next-wave-of-biotech-innovation/.

2 Alexei A. Maklakov, "Aging: Why Do Organisms Live Too Long?," *Current Biology* 23, no. 22 (2013): R1003–R1005, https://doi.org/10.1016/j.cub.2013.10.002.

3 Min Hooi Yong and Ted Ruffman, "Emotional Contagion: Dogs and Humans Show a Similar Physiological Response to Human Infant Crying," *Behavioural Processes* 108 (October 2014): 155–65, https://doi.org/10.1016/j.beproc.2014.10.006; Shani Gelstein, Yaara Yeshurun, Liron Rozenkrantz, Sagit Shushan, Idan Frumin, Yehudah Roth, et al., "Human Tears Contain a Chemosignal," *Science* 331, no. 6014 (2011): 226–30, https://doi.org/10.1126/science.1198331.

4 Murat Özdemir and Hasan Temizdemir, "Age- and Gender-Related Tear Function Changes in Normal Population," *Eye* 24 (January 2010): 79–83, https://doi.org/10.1038/eye.2009.21.



Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.



Corinne Okada Takara, *Floating Future Gardens*, 2024. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.

1,000 Days

Drew Endy and Jennifer Willet in Conversation with Yewande Pearse

In June 2022, Dr. Yewande Pearse, the director of science editorial and content for *Emergence*, spoke with synthetic biologist Dr. Drew Endy and artist Jennifer Willet in a public conversation at the Japanese American Cultural & Community Center in Los Angeles, as part of the Fathomers event *1,000 Days*. Inspired by Endy's provocation that a world that includes fully synthetic living cells is already within one thousand days' reach, their conversation touched on intersections of synthetic biology and creative practice, ways of engaging diverse communities and forms of knowledge within the lab, and the ethics of creating new life.



Drew Endy I want to start with the word synthesis. What does that mean at its root? It's a putting together, a composition. We're familiar with synthesis in the world of art and in music, and in everything in which we have agency. Throughout the history of life, life synthesizes itself, but our relationship to it is that it happens *to* us. When we take the perspective of intentionality and the responsibility that comes along with synthesizing life—when we're putting together life—is it sublime? Is it beautiful? Is it scary? It's probably mostly scary or just doesn't work. But sometimes it's sublime and beautiful. At the root of what's happening, I hope you might see a connection between the making of these different things, whether it be art or living systems.

Yewande Pearse Jennifer, your work as a bioartist and director of the INCUBATOR hybrid laboratory is grounded in the connections between art and biotechnology but also challenges synthetic biology and its applications.

Jennifer Willet I'm a bioartist: I work in art and biotechnology. I have no scientific background or training. I read a lot of scientific papers and I often adopt scientists and get them to teach me what they know how to do. For many years, I would travel the world and go into labs and try out what they did, and then I would make some art projects out of that. And I found that I was kind of a disrupter but also a friend and provocateur. At the end of those residencies, the scientists would often say to me, "You know, I got a lot more out of that than I thought I would. I learned something new about my practice." Maybe what I have to offer is that over the years, science itself has become my topic of interrogation—and not just big capital-s Science, but all the little minutiae too, like the bureaucratic processes, the hiring processes, the methodologies that go into making science. I suspect I'm here to talk with you a little bit about some of the processes that are involved in these large collaborative projects that seem to bring together all different kinds of scientists but also thinkers of different kinds.

In the *Emergence* lab at the Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.



YP One frame for this conversation is the question of creating living cells from scratch. What are the goals of doing this? What could humanity do with it?

DE We live in a life well—in a basin of attraction that holds the forms of life that we are and that we're familiar with—and we're at the bottom of the well because we're trapped. We're constrained by lineage, our parents, the life that came before us. We're constrained by the requirement that if life's going to continue, it has to reproduce. We're thirdly constrained by the fact that if the environment is changing in our well, then life better be able to change too. Being within a well is wondrous and sacred and safe and protected, but it's also like we're trapped down here, and the possibility of constructing life is like climbing and clawing and scooching up to the top, to the lip of the well. And what's up there? I don't know. But what I do know is that possibility is up there, because it lifts us up out of these three constraints of lineage, requirement to reproduce, and requirement to evolve. I give you the utilitarian dream, but . . . that's like a bonus.

YP Jennifer, as a bioartist, I think you're interested in a concept like this. How would you approach it? What would your perspective be?

JW Drew, your metaphor of a well feels a little religious. It feels like this really progressive reaching toward a transcendent goal, and I think that could be a useful or motivational metaphor, but I'm not sure it's accurate. I'm still just reveling in this story of us in a biological well, aiming for the future. I get a lot of questions from people asking me whether biotechnology is incredibly unnatural, and the implication of that is whether it's evil or harmful, all of those things. I often argue that actually it's quite the opposite. It's incredibly natural. If you look from an ecological standpoint, organisms consume resources, they excrete resources, they produce waste, some other organism eats the waste, right? And through doing that, they build domiciles for themselves or they gain more energy or they transform in different ways.

So when I hear this story, I don't think that it's unnatural, and I *love* your engineering description of constructing versus a sort of Genesis story. You are constructing these molecules together. But I think that if you take it to its logical extent, what we're doing in the lab today is natural and is just this ecological thing that organisms tend to do, which is to consume all of the resources around them until there's nothing left, and then they die. That's the way I read what you're saying, that what we're doing is exploring the parameters of what is possible in the lab, and one of the ultimate goals might be making new life rather than reproducing existing life.

Opposite page: Buddhist priest and artist Hirokazu Kosaka performs a traditional *kyudo* ceremony to open *1,000 Days*, Japanese American Cultural & Community Center, Los Angeles, 2022. Courtesy of Fathomers. Photo: Alicia Afshar.

DE My moral compass is, "Am I contributing to improbability?" By my decision, if I am making things more improbable, directly or indirectly, then I am contributing to the good. And if I am destroying or reducing this improbability, then that's a bad thing to do. By this frame, I find myself through my actions. I don't see any distinction between human or nature at all. I am just part of life, and I am realizing and contributing to life by this type of action. Getting to the capacity of being able to construct life from scratch, without these constraints, is like the ultimate platform or starting point for producing improbability. I'm attracted to it because it feels like the fundamental good that is at the core of my moral compass. Does it mean that everything that will happen with this will be good? No way.

JW I'm feeling 95 percent of what you're saying.

DE What's the 5 percent?

YP Yes, let's talk about that 5 percent.

JW The 5 percent is the part where you say, "And then, that's good." Right? For example, contributing to biodiversity . . . I'm interested in contributing to or being part of the unfurling of the universe, which I think is a very similar sensation to what you're talking about. There's an entropy . . . and the unfurling of the universe for me is neither good nor bad, and the outcomes are not good or bad, but I enjoy the sensation of participating in that unfurling. It's just the part where you say, "And that's good." But that's okay. We can be different.

YP We don't know if it's good, and that's the point of contention, because it's all about relationships. It sounds like we can create these synthetic biological systems that fit into our living systems, and as long as it's all in harmony, that would be good—but there's the improbability and unpredictability.

JW But harmony is impossible. That's not going to happen either, right? If everything goes well, there are still always going to be challenges; there's going to be suffering and the end of life. That's also part of the natural world. I think I'm just really puzzled that I'm sitting next to a world-renowned scientist who is emphasizing this *goodness* when I would expect that from me as the artist. It's a really interesting inversion of the descriptions of our disciplines.

YP What needs to be built in when we're building, to control for some of that disharmony?

DE That's a great question. We don't know. We're figuring it out as we go along, and we would take upgrades happily. We learn as much as we can from what we can study. For example, the Apollo program that got a person to the moon and back a couple times—that's interesting, but note that it didn't routinize bringing people to the moon and back. It was a moonshot project, and no infrastructure was built along with it. We just did it and then we stopped doing it. So that's one choice we're making, and that changes how we go about the work. We might not be the first to do it, but we're doing it in a way that allows us to continue to do it on a sustained basis. Another choice we've made is—you could go and say, "I've done it! Ha ha ha! Not you! Good luck catching up!" or you could say, "Well, let's climb up the well together, leave some handholds." (Sorry for the metaphor, I'm going there.) We've adopted the phrase, "How we organize ourselves will impact how we organize our cells, and vice versa." We're trying to build architecture that enables community, even though the community doesn't exist in this way right now.

JW I have some suggestions. I have a laboratory research group, and we have team members from all different backgrounds. We've been thinking about the idea that biotechnology might be a technology of love. What would it be to practice interspecies relationships in the lab with the notion of love as a motivational factor? I would like to first say that I do not mean romantic love or Hollywood love. I mean what bell hooks meant: committed, political, durational commitment and inter-exchange love. Then the idea grew and I got to thinking about the relationships we have not just with the organisms but with each other: Who is allowed in that lab? What backgrounds do they come from? What knowledge are they bringing to the table? I have artists and scientists, but I also have philosophers, and I have nurses. I have people from very diverse cultural backgrounds all working in my lab. The age range in my lab is from nineteen to sixty-nine. And what happens is we have this chorus, this cacophony of interrogation around ideas. The outcomes and the community that we build in that space are really profound.

When I read about your work in this paper, and listening to you now, I'm thinking about the pandemic; I'm thinking a lot about how in less than one thousand days, we came up with a vaccine internationally. On the one hand, for me, this example is an epitome of what science can do when we break down international borders, boundaries between corporations and governments and these types of things. But the rollout of that vaccine also made visible to us the areas where we are failing. There were all sorts of communities who did not feel a trusting, loving relationship with those vaccines and were unwilling to try them. I think what we can learn from



JW that, and what might be really valuable for your project, would be to widen the scope of who is involved in the production of this research and what the discussions are—not just a technical discussion of how to build this cell but the cultural discussion at the front end of the production of the cell. Think about what communities are going to have access to this cell. How will it benefit them? How would *they* like it to benefit them, as opposed to how you think it might benefit them? There's a real opportunity here to learn from what we saw as the successes and failures of the pandemic, and to think about how that could transform scientific methodologies to be more inclusive and more polyphonic in terms of the number of voices that are involved.

YP Scientists are taught that science is objective, and it's not. I don't think we're free from bias, and our ideas are only going to be as good as the assumptions of the people involved. Jennifer mentioned inclusivity and having a lot of diversity, so I wonder if you could comment on how we might redefine the disciplines and individuals that are included, Drew.

DE At the end of the day, a lab is a relatively tiny place, and as much diversity as you might bring into it, it's always going to be selective. I would respond by sharing the following set of questions: How many people should have the option of learning to read and write? Basic primary education? The United Nations says that's a human right, so we think it's everybody. How come? It's related to your question, right? Everybody should have

Yewande Pearse, Drew Endy, and Jennifer Willet in conversation during *1,000 Days*, Japanese American Cultural & Community Center, Los Angeles, 2022. Courtesy of Fathomers. Photo: Alicia Afshar.

DE that optionality. How many people should have the option of learning to read and write a computer language like Python or HTML? Apparently, we're trending toward everybody, because we have things like Computer Science for All in the US. Let's give everybody the option of learning to become literate with respect to expressing intentions with electrical computing machines. So then the third question and last one in the series is, How many people should have the option of learning to read and write DNA? I'm going to say everybody. And I practice that behavior within a context that doesn't necessarily support it—that's not the starting point. The starting point of the practice of reading and writing DNA goes back to, in my amateur understanding, the fear of being bad parents, captured in one form by Mary Shelley with *Frankenstein*—that inevitably, as parents, we will fail our creations or constructions sometimes. That fear is so profound that when genetic engineering got invented fifty years ago, it came into the world with that current of fear carrying it along. And the nerds, all they could respond with was, "Utility! We're going to cure disease!" That's a good thing to do, right? But they just tried to counterbalance or push back fear with utility, without ever really resolving the fear. There's this coupling between fear and diversity and accessibility and optionality and citizenship. . . . Are people going to be citizens of the biofuture, or are they just going to be patients and consumers or subjects or . . . ? I'd prefer citizens.

JW I think we really align in a lot of different ways, but the thing that I offer and that my community can offer to your community—it's not just that the people who read and write DNA should be in the room to determine how to read and write DNA going forward. You want people in the room who do not know how to do that, but who have other knowledges, experiences, and goals to offer your project.

DE Yeah!

JW You know, I read a lot of scientific papers, and sometimes I understand them, but sometimes I don't. I read them like concrete poetry. It just sounds like sounds. But there's something about having those other communities and those other people in the room that might not only transform it for the better in terms of ethics or those types of things, but might also improve the research that happens in scientific labs. That is what a lab like mine is trying to do.

DE Amazing, amazing.

YP This has been a beautiful conversation. I love the tensions and the overlap. Thank you so much, Drew and Jennifer.

Disciplines and Interdisciplinarity

Remarks on the Opening of *Emergence*

These reflections by a number of *Emergence* contributors, introduced by Fathomers associate director David Kim, have been compiled from their public conversation on October 13, 2024, as part of the opening celebration for the exhibition at the Japanese American Cultural & Community Center in Los Angeles. The conversation has been condensed and edited for clarity.



David Kim Our show, *Emergence*, is part of the wider initiative PST ART: *Art & Science Collide*, sponsored by Getty. The idea of cross-disciplinary collaboration is very much in the air, even beyond the context of this periodic initiative. And this idea has led me to think a bit about the relationship between separateness and value. Often when we think about separateness, we think about it as a hindrance or an obstacle or a friction: Separateness is something to be overcome. It's something to be bridged. It's a distance to be eradicated. But what I might propose is that in some important ways, separateness is a constitutive feature of human existence and a necessary structural condition for so many of the things we think are good and important. Separateness is the cause of alienation, misunderstanding, conflict, and selfishness, undoubtedly, but it's also the necessary condition of forgiveness, solidarity, communication, recognition. Some of the most important moments in our lives are those in which we are able to overcome separateness, and the significance of those moments—saying "I love you" to a lover, saying "thank you" to a friend—is only possible because we are separate persons. So there's this strange entanglement at the bottom. There are many moments when I think, *Yes, absolutely, we should bridge the gap, we should reach across the aisle*—I very much believe in those things, and I think this show is a powerful embodiment of them. But I also want to pause and identify separateness as the wellspring of some things that we value very highly and feel very positively about.

One analogous way to think about the relationship between separateness and value is to think about disciplines—disciplines as traditions. *Science* is a very large term for a whole category of disciplines and *art* is a large term for all manner of disciplines—I'll just use them as placeholders. A discipline is a tradition that we step into. Many of them have existed for hundreds or thousands of years. Disciplines provide us with a set of questions that we endeavor to answer. They provide us with a sense of membership. They provide us with standards and conventions and collaborators and histories, even when those histories

Emergence contributors participate in a public conversation during the exhibition's opening weekend, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.

David Kim

are problematic, violent, or dark. In this sense, they provide the depth and the thickness that allow us to hone technique and knowledge, to make advancements, to progress. Disciplines also, of course, have their shortcomings; we feel them to be constrictive or oppressive or partial. In no small part, I think, we feel excitement and energy around an initiative like *Emergence* precisely because it gives us the opportunity to address those shortcomings and to try to move beyond what we experience as the everyday confines of our disciplines. These disciplines provide identity and tradition but also heavy constraints. This is akin to the way that we experience separateness.

With all that said, how do we think about the relationship between art and science, or between art and synthetic biology? How do we think about the mutual contact or exchange or whatever it is that's happening both in this exhibition and in PST ART broadly? First, an initiative like *Emergence* creates a kind of sociality, which is really important. We come together; we meet each other; we grow in the esteem of these other people. I meet some of the extraordinary scientists and artists involved in this exhibition and feel honored to be in their presence. And, I hope, some people here feel excited about their own work in a new way, because they've been able to share it with people who aren't familiar with it and who say, "Oh, what you're doing is really amazing and brilliant." That renewal, which might be at odds with twelve-hour days slogging through data or running another analysis, is important because it allows us to return to our own disciplines with a new sense of purpose.

Second, *Emergence* creates an institutional justification for a depth of exchange that wouldn't otherwise occur. I've learned a lot more about biosafety cabinets and biosafety measures and lacrimal gland organoids and human stem cell lines and their care than I ever would have without this exhibition. For example, I had the chance to meet with the head of the California NanoSystems Institute at UCLA some weeks ago and take a tour of that laboratory—it's extraordinary. The things they're doing there are just so marvelous to me. And I never would have had that access if I had not been able to say, "We are having an exhibition under the aegis of Getty. Please let me come and ask you some questions about what you're doing." Such exchange enables artists to make work about synthetic biology or climate science with a precision and subtlety that wouldn't otherwise be possible. In this paradigm, we're still basically sitting in our home discipline and creatively using the tools and standards of excellence from the other discipline.

Beyond this, there is a third possibility, a tantalizing one that we are reaching for but that to me remains rather underarticulated. This is the possibility that art might influence science as much as science influences art. As a starting point, Ionat Zurr and Oron Catts's practice as the Tissue Culture & Art Project is a powerful example of how serious science can enter into an artistic practice and create new possibilities for poetics, concepts, and materials. I will say—as a provocation—that in this instance, much of the movement is *from* science *into* artistic practice. For some in the arts, the strong hope is that there could

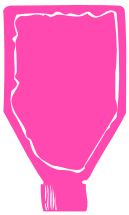
also be formative movement in the other direction. But what would it mean for scientific practice to take on artistic questions or concerns, techniques, and methods? Is it even sensible to talk about artistic standards of proof or validation? I don't know. In another moment, I would be excited to think a bit more about why the flow of deep influence is not usually bilateral.

Finally, I want to consider how we conceptualize and identify *new* disciplines. In what respects are these disciplines new? And to what extent do they rely on the standards of excellence from the cognate disciplines from which they've come? I expect that the degree of reliance is pretty significant, and I wonder whether truly new standards of excellence come into being very often. With all that said, it's my pleasure to introduce Eduardo Padilha, who has his own collection of questions emanating from his very rich scientific and artistic work. I'm really, really pleased to have the opportunity to discuss some of these things here with you today, with the extraordinarily accomplished people in this room.



Eduardo Padilha speaks at the opening of *Emergence,* 2024. Photo: Jordyn Doyel.

Eduardo Padilha



I'd like to build on these questions of separateness versus merging disciplines. We've been talking about interdisciplinarity over the past few days, and that reminds me of something I think is connected. Maybe some of you have heard of Umberto Eco; he was a novelist and a very prolific intellectual in semiotics, literature, and philosophy. In the 1980s, there was this very interesting event in a small city called Lucca, in the countryside of Italy, that brought together a bunch of linguists and theorists of language with immunologists and physicians, because in the '80s there were many new discoveries in immunology. Many new cell types were being discovered: lymphocytes, monocytes, and all kinds of receptors that they have in their cell surfaces. A lot of knowledge was emerging in the field.

In linguistics, they thought, "What if we connected with these immunologists who are discovering a lot about cellular communication?" They were having these discussions about whether or not the creation of meaning depended on consciousness, because up to that point, linguistics was predicated on the idea that creating meaning was tied to language, to human language. And then in immunology there were these new concepts of cell communication: What is the self? What is nonself? And cellular signaling: one cell touching another cell's surface and sending some kind of signal so this other cell would respond in a different way. The linguists thought they might learn something from the immunologists' work and vice versa. This is now considered a key event in the history of what came to be known as biosemiotics. Today, biosemiotics is an actual field of inquiry, and it has embraced the idea that creating meaning does not rely on consciousness; cells have been doing that. "Life is semiotic in essence," Umberto Eco writes in his preface to the annals of this conference.

I think that new things might emerge from these kinds of encounters. I've had the pleasure and honor of connecting with lots of interesting people over the past months, as we discussed what this exhibition would come to be. I think this was a very important part of the process, these connections and contaminations—even personally speaking, as part of my own process for my artwork upstairs. Each of us came from our disciplines, so there was still some integrity in terms of disciplines; on the other hand, we are trying to merge and create these hybrids, these monsters. Disciplines bring us tradition, familiarity: Even from elementary school, we know knowledge is somewhat divided into science and math and art. There are all these bodies of knowledge that we are used to organizing our minds around. How do you propose something new in the face of this familiarity? How uncomfortable is that? I don't know how uncomfortable it was for Umberto Eco and those immunologists to come up with a new field of inquiry.

Corinne Okada Takara

I think, as an artist, the most interesting space is that frisson between the familiar and the foreign. Sometimes things that seem strange or different become familiar after you encounter and process them through art, or you realize, "Oh, I actually have something to contribute to that, and I understand it in a way that's maybe unique to myself or my culture or my community." Conversely, sometimes we think, "Oh yeah I know that," but when we encounter the thing through art, we realize, "There are aspects of this that are foreign and I need to interrogate this more." We have a lot of this tension in the show, where something is familiar but aspects of it are foreign, and we go and create our own narratives of what we're seeing.



EP

Absolutely. We have a lot of that because we were questioning ourselves. This is also a personal question: When people enter the gallery, what are they going to see? What levels of engagement are they going to go through when they see these somewhat strange objects? What are they going to look at that's familiar, so they can actually start interacting with that artwork? I think people will come from different places and try to find these anchors of tradition in the middle of newness.

I had the chance to get to know Marie even before *Emergence*, and I remember she asked me, "How do you do it? How do you bring this aesthetic aspect to some scientific work?" Considering her background, our conversation was more about how art enters science, which is a bit what David is asking: What's the direction of this flow? I think one of the other things we are asking ourselves here is, Can it go the other way as well? Can contamination go both ways?

Marie Bannier Hélaouët



Actually, I see quite a lot of similarity between the ways we are working, how you have been creative in coming up with your art and how scientists have to be creative in order to discover hopefully new science. We also have to be groundbreaking. I had a question for Michael: Because all of what we are doing is built on conventions, and we're trying to break the conventions, to make something new, how do you break the conventions? Do you?

Michael Jones McKean



Your question speaks a lot to David's introductory remarks—thinking about traditions, thinking about conventions. As you were talking, I was thinking about the sensitivity that we learn through practice: As we go deeper into our disciplines, we actually gain more and more clarity—through sensitivity—about what the problem is, how to go forward. There's a term in environmental studies or ecology that has something to do with our ability to see what's already there. In ecology, there are lots of moments where two things butt up against one another. You might have a forest and a grassland, for instance. For the longest time, we looked at the forest as one entity and the grassland as another entity, but we didn't look at what happens when they touch—in part because we didn't have a word for it. One of those words is *ecotone*: this sliver of touch where a third thing emerges, where it's not the grassland and it's not the forest, it's something else. This was always there, but we had to see it. We had to be



MJM sensitized to its presence. In some ways, this speaks to conventions: We're working within a set of histories, with a predetermined set of languages and ideas and questions, but they actually start to produce a sensitivity that unlocks some other way of doing, some other way of seeing. Generally, it's hard to see that progress is even being made, that new things are happening, because the way that this sensitivity arises inside of us is so incremental.



MBH When I do science in the lab, sometimes it's good to completely switch topics, to work on something I didn't know before. Then I come to it with such fresh eyes that I can be creative; I become free from those conventions to some extent.

DK Marie, in that context, when you say "convention," what sort of thing do you have in mind? I have a better sense of what a "convention" might mean in painting or sculpture.



MBH We are building upon years and years of scientific literature. There's hundreds, thousands of papers now on organoids, on lacrimal glands. We're shaped by what everybody else around us has been researching before—and trying to build on that.

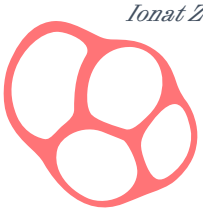


MJM There's also this question about directionality. This is a thought experiment: When you're working inside a specific discipline, you can imagine it as a bubble. Within that bubble, you're trying to force the questions outward. There's also this moment of contamination as you do that, which could happen from a few different directions. One possibility is that the bubble becomes porous, it becomes so stretched out that it starts to leak—this is that really curious and amazing moment when it leaks into another discipline. If you're working inside art and suddenly you leak into philosophy or you leak into semiotics, you see things through the specificity of your discipline and you generatively mistranslate what you're seeing. And this creates some other, really wild set of potentialities, where you might be misunderstanding semiotics entirely, or there's one aspect of some weird, outré thought that becomes really fascinating to you, that you take back inside of your discipline. That leakage becomes contaminated in a generative way.



EP I love that, because the imagery of pores, or a bubble leaking, is something many of us have talked about in terms of the literal and metaphorical permeable membrane that cells have. It's very interesting from a biological point of view but also a conceptual one. Ionat brought to my attention that in my questioning, sometimes I was being "too human." She said, "Maybe you could think more about membranes and how they actually allow substances or, in a cell, some specific molecules, to flow in and out." That also came up in my conversations with Corinne: Semipermeability is not complete openness; it's *semi*, it's partial. In a cell, not everything can actually permeate a membrane; there are some limits to the size of molecules that can do it. What gets lost in translation is also a very interesting part of it.

Ionat Zurr



I think a lot of what happens is fruitful misunderstanding. Let's celebrate it. The other thing Michael talked about is the poverty of language. This may be one of the reasons that artists go to other disciplines. They are kind of "philosophers in the wild," or "anthropologists." Part of our practice is actually to go to those unknown places and find that we still don't have the language to communicate, and we then use nonlinguistic language to try and create this kind of discussion to come up with a language we can all use, successfully or not successfully.

But I want to go back to David's provocation, because we actually talked this morning about how it's much easier to get artists into the science labs, but it's very difficult to get scientists to an artist's studio, and I've been thinking about why this is the case. There are a few reasons. One is, again, artists like to play with other people. That's part of their practice. Also, we are saying, "This is a scientist," "This is an artist"—but I am not sure what science is today. I'm not sure if we're talking about engineering, technology; I am not sure how much it makes sense to say "science." A lot of it is actually technology. And then there is frustration among the scientists themselves. They come to science because they are curious about how things work, about the world around us, and sometimes they don't have the opportunity to be curious: They're busy, and they are sometimes being punished for actually looking at other disciplines because they need to be productive. That's one problem. The other problem, I think, is that we live in a society that is all about creating products. From the beginning, artists have been used to pacify, to domesticate synthetic biology so that we accept it into society. We can learn from the history of genetic engineering that there was a backlash against that technology. With synthetic biology, which is basically glamorous genetic engineering, the idea was, "Let's get designers and artists to start with it, and through that we'll communicate that this technology is good."

Albert Wu



Coming from the scientist side, I do think that we're quite constrained. If you ask your average scientist, I don't think that they would say that they're an artist. How able are they to be creative? I think it's somewhat limited, largely because we follow the scientific method. If you go outside of that, you're maybe not claiming to be a scientist; you don't follow a hypothesis and you don't follow the proof. I think the emotional aspect, the passionate part, is taken out of science. You're actually not supposed to be passionate per se. You have a question, and you have a limited number of options to test it based on technology. You're supposed to be logical, follow the evidence, and so on. I do think that there is a creative aspect to it, but it's difficult to access.

Thinking about the question, How do we bring the art part into science?, I see a couple of ways that scientists are able to do that. One is maybe in terms of inspiration. What drives a scientist? What drives an artist? I think that scientists can be pushed to create beauty—I don't want to get into questions like, What is beauty in art?, What is the purpose of art?, etc. But I do think there are scientists who want to create something beautiful—like the initial in vitro fertilization: They created life. There's something beautiful about creation. I think there are

AW scientists who are driven and motivated by creation in itself, outside of aesthetic beauty. The other part is necessity. They often say necessity is the mother of all invention.

In addition to being a scientist, I'm a plastic surgeon. When you're operating on a patient, the skin and the muscles are in many ways the canvas that you work with. I think that is in many ways the closest a doctor will come to creativity. You don't necessarily want your doctor to be creative on you; you want them to be very evidence-based and compassionate and all those things. But I do think plastic surgery bridges art and science a little, because you're trying to achieve an aesthetic of what is considered, in society or for that patient, beautiful. One thing that I found interesting as a scientist going to art is that a lot of art, I think, does take a lot from science: for instance, the beauty of fractals. In many ways, artists capture science, the beauty of nature and, I think more and more, technologies—there are materials that are incredibly beautiful.



Callie R. Chappell Nasa and I are both trained as scientists but are also artists, and I think it's interesting how the incentives influence how people see what science and art are. Sometimes people see science or art as identities—"I am a scientist," "I am an artist"—as opposed to structures and organizations and traditions that we're put in. Something that I've been trying to put forward is that art and science are really one and the same. If you ask any scientist that I know, "What is your creative practice?," every person has one, but they don't always see that as part of their work. And the reason why that's not always encouraged in their work is because of the way science is structured.

My positionality here is actually not so much as a scientist or an artist but more of an activist for reimagining how those institutions and organizations flow: how art can be used by science to propagate its political agendas, how art itself can operate to extract or understand things that are happening in science, and how we can operate in spaces outside of the traditional canons of both science and art to put forward a different way power can flow through the creation of knowledge, through creativity. I think our piece is really asking how art—for example, with the denim jeans, in the production of indigo—is part of our culture, part of our community, part of our history, but can also be part of deeply colonial, deeply problematic processes of capitalism in the future. But there could also be points where we can bioticize, we can bring culture back to the production of technology, outside of the way power flows within these spaces. I wanted to provide this provocation as a different way of thinking about art and science—not as one and the same, or one and different, but as part of these broader sociopolitical structures that we all operate under.

Opposite page: Nasa Sinnott-Armstrong speaks at the opening of *Emergence*, 2024. Photo: Jordyn Doyel.



Nasa Sinnott-Armstrong

I agree, I think that there's a lot of potential to reconsider the differences between art and science relative to the differences within each one. Part of my academic practice is in genetics, and I think this offers a very strong analogy. When we think about differences between human populations, there are differences in the genetic basis of individuals who live and are from different populations, but they're minute, they're extremely small compared to the differences that we observe within populations. Something like 90 or 95 percent of genetic variation is within populations. I think the same is true of science and art. There are pieces of each of them that are slightly different from one another, and there's a push toward aesthetics and passion within art, like we've been talking about, and a push toward mechanism and some sort of engineering, numerical precision, within science—but in reality those are small compared to the differences within each field. It's really important to recognize that that overlap exists, and we should be exploring and understanding better what that overlap is in order to make the most of what we can learn from both.





Henry Tan

When I meet new friends who are scientists, I always try to learn about their personalities, their practices. Some of them, on their social media, mostly post things unrelated to science. And when artists start to learn new tools from science, we keep posting things about science. For me, it's about the hat that you're wearing. Maybe you have many hats, and you choose to present yourself in different hats when you're exposed to different situations. How deeply can you master the different crafts that you acquire? How do you bring in different tools and knowledge from the different crafts that you want to take on? And what urgencies do you want to address? Whatever your disciplines, your practice, your urgency is to make a living first. Perhaps as a scientist, you follow your scientific career to make a living, but maybe you have other activities that you want to explore; you want to express yourself. As an artist, I start to learn about new tools from science and I try to learn them more and more deeply—enough to understand the craft, the way the scientists are thinking. Hideo Iwasaki also shared with me that his scientific research is inspired by his artistic questions, so he became a professor of science because of his art practice. As artists and scientists, we always try to practice our craft, mastering our craft. At a certain point, perhaps you reach some blockage or limitations, then you start to find other things to fill in, to push yourself forward into different proliferations.

Henry Tan presents *Pillars of Creation* during a guided gallery tour of *Emergence*, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.



IZ We're talking here about art and science, and we were talking previously about creation. I just want to mention Frankenstein. You know, the beauty of creation—we engineer cells, we become masters—but these kinds of discussions can also raise questions of care and control. As in the story of Frankenstein, with creation, we also have the responsibility to what we create. And I would like to talk about beauty, because this is the hardest thing. Actually, artists hardly use the word *beauty*. I've found that scientists often say things like, "It's beautiful," "It's elegant," "It works really well," while artists—and especially artists working with life—say, "No, it's not beautiful; actually, there are elements of violence when you work with life." It's messy. We can't master life, you know. But maybe that's what we like about this medium. And also with beauty, yes, craft is amazing, but why do we think that this kind of nose or this kind of girl is beautiful? That's a question that artists will ask. As a surgeon, you just do what the conventions—we're going back to convention—or what the person wants. As artists, because ours is a different kind of discipline, we can ask, But why? What are the reasons for that? We look much more at the sociopolitical aspects of it.

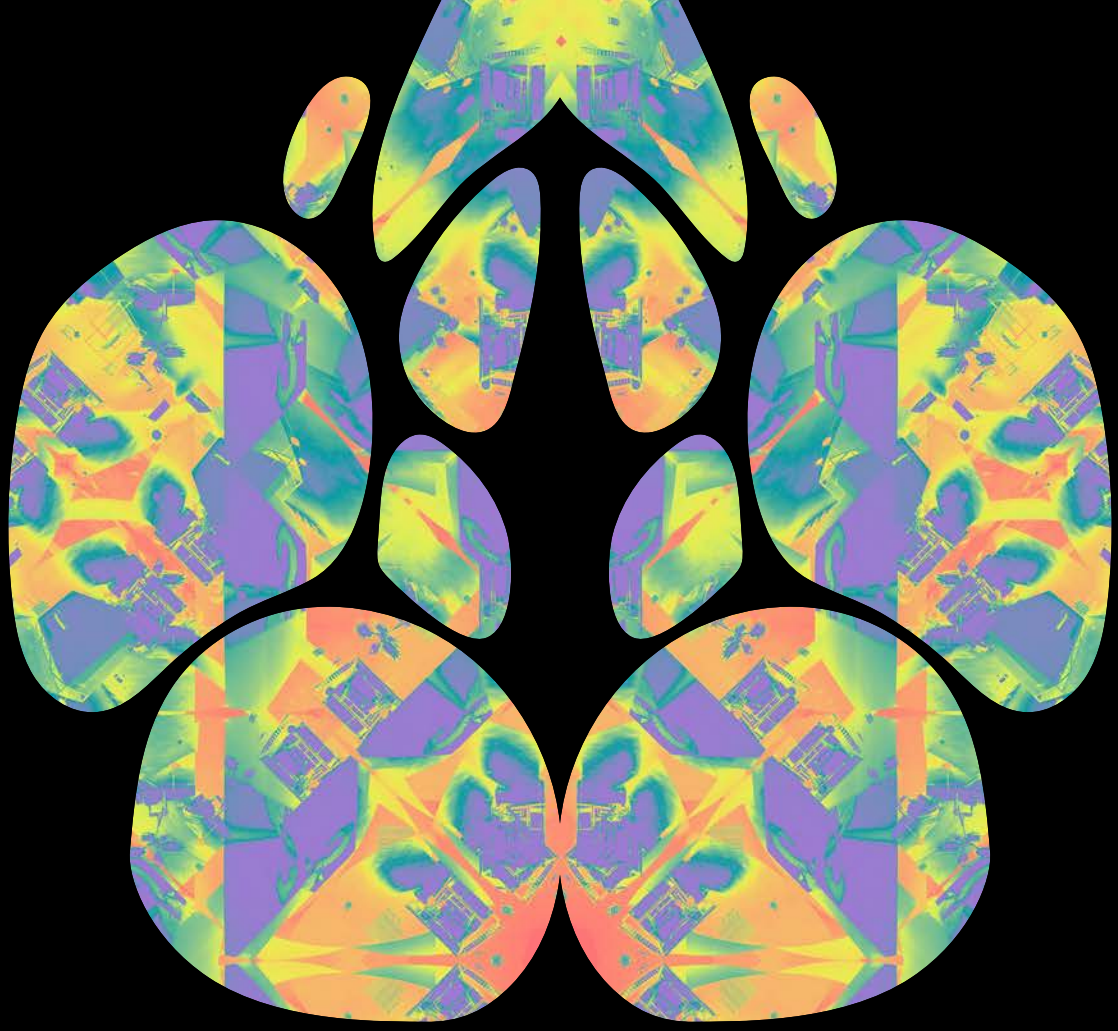


CRC Let's not be masters. Can we use different metaphors, please? I think this is what Ionat was getting at. If we're thinking about art and science, and we're thinking about our roles in society, perhaps we're doulas. Maybe we're mothers. How can we build relationships of reciprocity, of care, different ways that we imagine society could be? I think that is one of the many powers of combining art and science—and particularly with biology, synthetic biology: to break down the metaphors and the assumptions we have, and build new ones.

COT I love that. When we're engaging in storytelling through art or through science, the storytellers have the power in culture. How do we invite more people and more organisms into that storytelling space? I think all our art does that. I'm hoping that we create more platforms where we're thinking about who's not here in the room with us. How do we amplify those voices?



NSA There are definitely ways in which science has the potential to exist more in a space with art. One example of that, since we're talking about bringing in more storytellers, is cases in which we learn and build a world where we build collaboratively with various community members as scientists. That also exists in the context of connecting with art. The actual relationships that we build are key to the way that we think about both practices, and through that they overlap with one another more. I've seen that happen in the context of both science and art. I think there's a lot of potential there.



A *Feeling* for the *Organism:*

What It Means to Actually Work with Biology

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Claire L. Evans

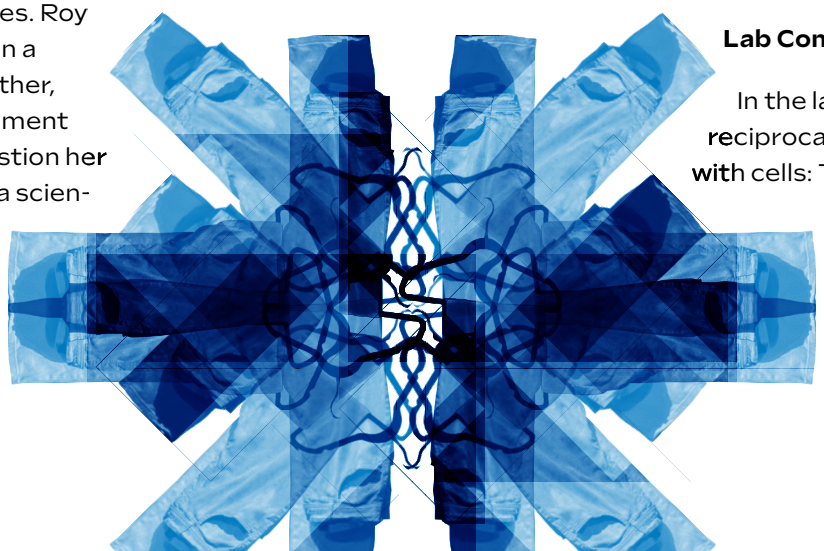
Deboleena Roy was working in the lab when something strange happened. A postdoctoral researcher at the Institute of Medical Science at the University of Toronto, she was standing in front of a sterile fume hood, her latex-gloved fingers on the door handle of a cell incubator. Inside were hundreds of well-fed rat cells, basking in temperatures of 37 degrees Celsius. In the course of in vitro lab work, it's a routine practice to dispose of extra cultured cells—which can multiply rapidly—while keeping a small portion alive for future experiments, a process called subculturing.

That day, Roy was halfway through a cell subculturing procedure, transferring small cultures of hypothalamic neurons to fresh plates and disposing of the rest, when it struck her: The neurons were currently flourishing in a warm nutrient bath, and she was about to kill them by removing them. "I held off on opening the incubator door for a few labored moments, then immediately considered the absurdity of the moment," she later wrote. The gravity of that decision, an ontological crisis Roy now refers to as "the pause," would determine the rest of her career.

A biologist is supposed to stand at some remove from her subject in the lab—be it a mouse, a bacterium, or a humble cell. But during the pause, Roy lost that footing. Part of it had to do with rhythm. Every six hours, she measured the neuronal cells' cyclic hormone secretions; every three to four days, she pruned back their proliferating growth. She had begun to feel these rhythms in her bones. Roy and the cells were in a kind of dance together, a whirling entanglement that made her question her own objectivity as a scientific observer and drew her to the lab at odd hours. "It was 2 a.m.," she remembers when I reach her for a conversation over Zoom. "Here I am, holding this incubator door—and I thought to myself, What am I doing?"

These days, Roy is dean of faculty at Emory College of Arts and Sciences in Atlanta, Georgia. Although she traded lab work for theory years ago—and now teaches women's, gender, and sexuality studies at Emory, with a dual appointment in neuroscience—she retains fond memories of her years as a working biologist. This experience, a formative moment in her thinking, figures prominently in her 2018 book *Molecular Feminisms*, in which she outlines a feminist philosophy of science, ethics, and the vast nonhuman world.

Roy's pause that day was about more than just guilt, she tells me. As a young scientist, she'd been adamant that she didn't want to kill animals, but she had made her peace with the process of subculturing, which was necessary in her thesis research. Her crisis at the cell incubator emerged from the sudden, disorienting realization that her relationship with these cells was not one-sided. The cycles of their growth, division, and death regulated her life. She was in their thrall. She acted on the cells, but they acted on her too—so profoundly altering how she spent her days that she grew unsure about who was doing what to whom. "I'm a scientist, I'm supposed to do all the knowing," Roy tells me. "But in fact, I think the cells were doing some of the testing on me."



Lab Conditions

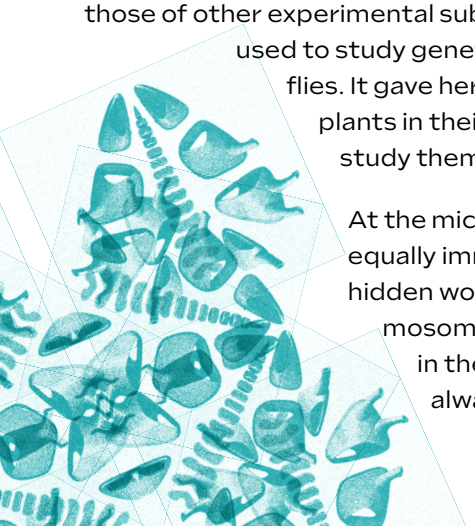
In the lab, scientists form reciprocal arrangements with cells: They provide, or withhold, those conditions that allow life to thrive, and in turn, the cells reveal their behavior under novel

circumstances. This is a relationship, although not a particularly healthy one.

In the social sciences, there's an emerging consensus that any account of existence that ignores our entanglement with other life-forms is incomplete. Anthropologists are already including nonhuman actors in their fieldwork—in sweeping multispecies ethnographies tracing the ecological and cultural relations of human beings and plants, animals, fungi, bacteria, and even viruses. Could a similar perspective be brought to bear in the more highly controlled ecosystem of the lab?

Roy is hardly the first biologist to feel a pang of empathy for her lab subjects, and this more complicated feeling of entanglement is not new, either. The cytogeneticist Barbara McClintock believed that nurturing what she called a "feeling for the organism" was a vital part of being a good scientist. McClintock's landmark work in the mid-twentieth century proved the chromosomal basis of genetics; her discovery of the fluid nature of genetic material, initially dismissed as fringe, was recognized with a Nobel Prize in 1983.

Her organism of choice was maize, whose colorful kernels visibly express the plant's genetic traits. Over the course of many years, she came to know—with "great pleasure"—each individual plant in the experimental cornfield at Cold Spring Harbor Laboratory, where she conducted research for more than fifty years. The cycles of life and death in her plants were slower than those of other experimental subjects commonly used to study genetics, such as fruit flies. It gave her time to know the plants in their fullness, and to study them closely.



At the microscope, she was equally immersed in the hidden world of maize chromosomes. Like her plants in the field, they were always changing and sensitive to environmental disturbances. She learned to notice different kinds of changes and the nuances between them. She chastised other scientists for attempting to "impose an answer" on what they saw, preferring to become "part of the system" and let the answers come to her. With the time to look, the patience to listen, and the openness to allow the plants to speak for themselves, McClintock developed an extraordinary sensitivity to minute changes in her nonhuman collaborators.

Such sensitivity is rare; it earned McClintock a reputation as a mystic. Of course, McClintock's only magic power was the patience to observe life's mysteries in their most mundane unfoldings. Many others have arrived at similar states of heightened perception by artificial means. The countercultural icon Elizabeth Gips, in an essay recounting her first experience trying LSD, described sitting transfixed for hours under a tree, examining an infinitesimally small insect. "The tiniest little green bug clings to a blade of grass, so small it makes aphids look like giants," she wrote. "Nothing so small ever let me see it before." This observation, although made far afield from the lab, dovetails with McClintock's understanding of her role as a scientist: The closer and more willingly you look at the world, the more it allows you to see.

As McClintock's biographer Evelyn Fox Keller notes, the profound intimacy McClintock developed with her maize over years of close association both literally and figuratively extended her vision, allowing her to see beyond human limitations, deep into the minute genetic changes occurring in maize across generations. This was not an abandonment of scientific objectivity—it was the consequence of a dedicated scientist's sustained observation. Another, perhaps unintended, consequence was an overwhelming sense of the interconnectedness of all things. Once she'd developed an affinity with maize, it became difficult to disentangle herself. "Basically, everything is one," McClintock told

Keller. "Every time I walk on grass, I feel sorry, because I know the grass is screaming at me."

In *Molecular Feminisms*, Roy expands on McClintock's line of questioning, exploring the very idea of scientific taxonomy and the practice, however useful, of drawing hard lines between organisms. Not only does taxonomy alienate human beings from the natural world, she argues, but it creates hierarchies where there are none. There is no great chain of being; everything alive is interdependent. "The question perhaps is not whether or not differences exist between humans, animals, plants, water, inorganic elements and more, but how we think about these differences," she writes. "Do we choose to see these differences as differences of degree, or as differences in kind?"

Reconsider the Hierarchies

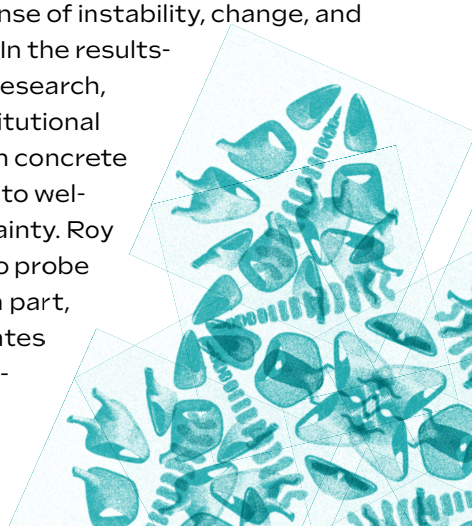
Assigning values to differences is a choice that we make. Rather than imagine ourselves at the summit of a hierarchy of life, we could just as easily place ourselves at ground level, along a continuous plane. A shift in vantage point may help us see our entanglements more clearly. We are different from corn, but many human cultures have relied on corn for survival. We are different from cells, but we are made of cells—to say nothing of the consortium of microbes that live in our guts, throats, and skin. As the feminist scholar and philosopher Donna Haraway observes, "To be one is always to become with many." Roy's call for continuity with the nonhuman world may be a philosophical provocation, but it's also a potent reminder that we are life acting on itself.

Rather than asking what an organism is, Roy suggests that taxonomically, we might benefit from asking what it can do. While science has historically relied on fixed identities and essences, working as a biologist brought Roy into contact with "material actants"—living things like genes, hormones, bacteria, and cells—that are more usefully described as processes. The deeper you look into the microscope, the squigglier the lines separating subject and observer become, and the more life itself appears to be defined by a capacity for change that we all share. Life, Roy writes, is an event.

Biology, however, is not. As Keller pointed out, the modern Western scientific worldview is rooted in the mechanistic visions of René Descartes—who compared the cries of a wounded dog to the sound of an improperly functioning machine—and Francis Bacon, whose rhetoric, Keller wrote in an influential paper, "conjoins the domination of nature with the insistent image of nature as female." This conception of science as a process for controlling and subjugating an unfeeling world has had lasting influence over the centuries. But as McClintock's work demonstrates, scientists can also choose to be in conversation with nature, listening carefully when it answers. This approach has long been central to Indigenous cultures, which see the world through relationships of mutual reciprocity.

We are all entangled with the living world, but those who study it are doubly so. Sometimes this entanglement can feel like communion: A sensitive enough scientist can begin to feel as though the very grass is screaming at her. Barbara McClintock was marginalized for decades, until her painstaking observations were validated by molecular biologists.

Dismantling the dominating impulses of science has been interpreted by many scholars as a feminist project, but it's as much about learning to face a feeling: a sense of instability, change, and mutual becoming. In the results-oriented world of research, or while under institutional pressure to publish concrete findings, it's tricky to welcome such uncertainty. Roy has the freedom to probe these questions, in part, because she operates as an interdisciplinary academic. But



making an effort to feel for organisms in their fullness is not only a philosophical position. It can have practical advantages, too.

Sarah Richardson is a molecular biologist whose bioengineering startup, MicroByre, tames wild-type bacteria for industrial use. Like McClintock, she prefers to let organisms speak for themselves, studying where bacteria come from, what motivates their behaviors, and what they need to thrive. Rather than dominate bacteria, she domesticates them—in the hopes that humankind and bacteria, in an improved symbiosis, can work together to produce useful materials, break down waste, and save the world.

As we talk over Zoom, her cat parades its tail back and forth across the screen like a sentinel. Domestication, she explains, gesturing at her cat, is a mutually beneficent arrangement. Biologists needn't abuse model organisms like *E. coli* and yeast, pushing them beyond their natural capacities, when there are so many wild bacteria in the world perfectly suited to the task. They just need to be coaxed with a little empathy, she says. Encountering wild bacteria is like brokering first contact with an alien species. "You have to learn its context every time. And you have to lose some ego to do that."

Richardson hopes to train wild bacteria to someday convert unused biomass into petrochemicals. McClintock discovered the existence of the transposon, a DNA sequence that can change its position within a genome, long before the invention of genetic sequencing. Roy's cell subculturing procedure helped her discover new forms of communication between estrogen receptors, estrogen molecules, and GnRH neurons in the brain. These scientists show that there are ways of encountering the nonhuman world, and even putting it to work for us, that emerge from a fundamental respect for life. It just requires a renegotiation of power and a willingness to approach our counterparts in the lab—be they cells or whole organisms—as collaborators.

Empathy is not only a question of life and death. It's an orientation to our nonhuman counterparts in the lab that can help us ask new questions. Richardson tells me she strives to be empathetic, but she doesn't want it to feel crippling. Instead, she wants empathy to drive her curiosity about the organisms she studies. "Empathy needs to be less, 'Oh shit, I'm killing them,'" she says, "and more, 'Why were they doing that thing in the first place?'"

I begin to make an observation about Barbara McClintock, but before I can finish my sentence, Richardson stops me. "The feeling for the organism," she says, nodding. She tells me that she was lucky to be exposed to McClintock's ideas when she was a high school student interning in a molecular biology lab at Johns Hopkins. Although her startup integrates automation and machine learning into its process, Richardson feels she's cultivating a feeling for each organism in her lab—just like McClintock did.

If you want to succeed in bioengineering, she says, it's easier to work with life than against it. In biology, after all, animosity often evolves into interchange, and many fundamental biological processes emerge from the gradual symbiosis of mutual antagonists. Evolution may be driven as much by cooperative relationships between organisms as by

competitive ones. And although we don't always fully understand the nature of that symbiosis, we've been making it work for us for centuries—from domesticating dogs and cats to breeding roses and transforming wild maize into corn.

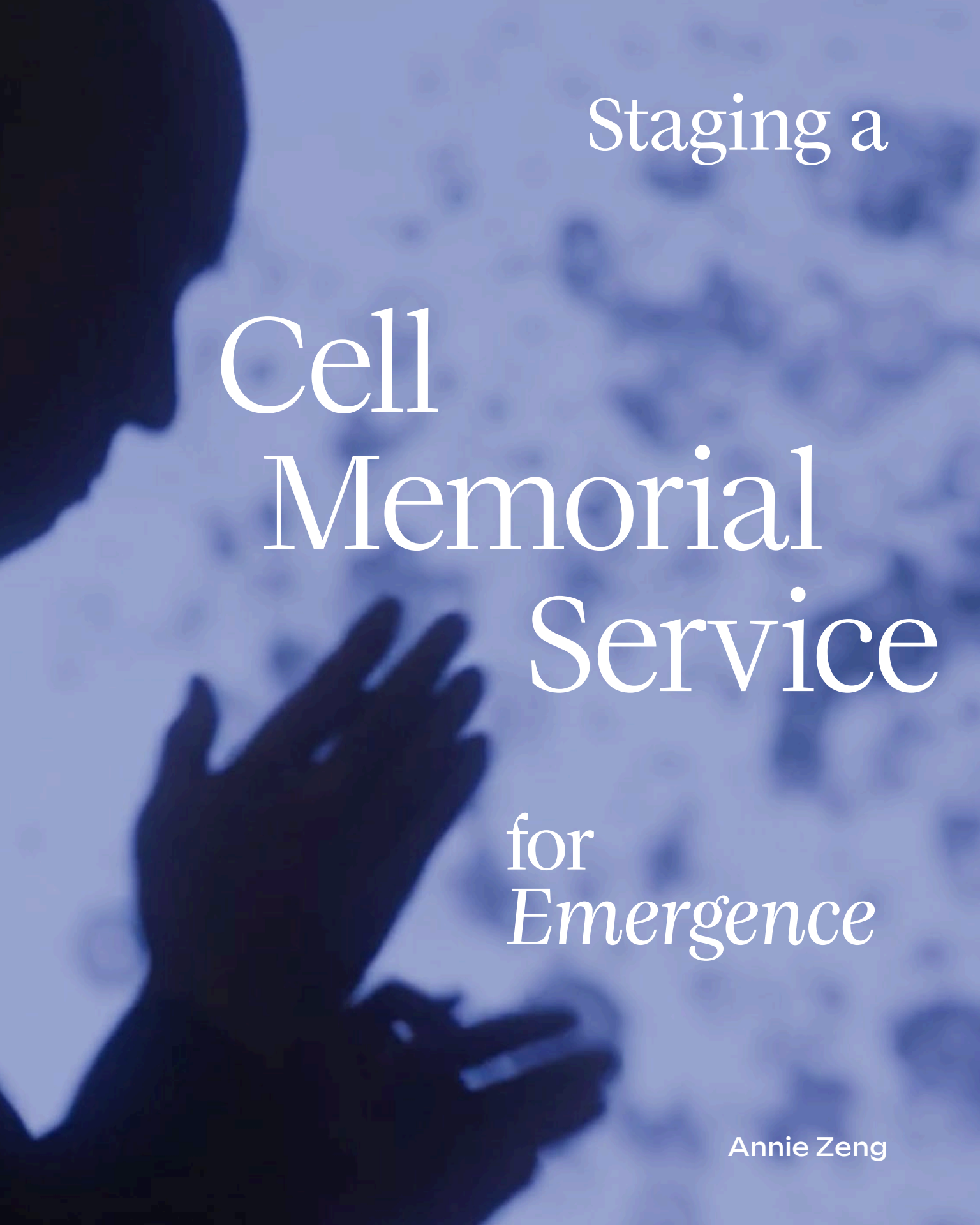
Richardson turns her laptop camera sideways so that her now-sleeping cat fills the screen. "When a dog wags its tail, it means one thing, and when the cat wags its tail, it means another, and you have to have a feeling for that," she says. "The people who figured it out the first time were bio-engineers. We need to think of the people who laid that down in our consciousness as biologists and bioengineers. They taught us the feeling for the organism." She gazes fondly at her cat. "That's how we got this idiot," she says.

When we domesticate other life-forms, we're brokering an agreement: room and board in exchange for affection, sustenance, or protection. But we're not defined by this transaction, and neither are our pets. As any cat owner can attest, even the tamest tabby contains mysteries.

Roy says the process of domestication can lead to blind spots. "In all of our labs, we have domesticated *E. coli*, thinking that we are going to use the machinery of this organism for our own means," she says. "What about the other parts of the life of these organisms that we're not paying attention to?" In her book, she points out that biologists, geneticists, and bioengineers have built their disciplines around the premise that life is a text that can be edited, rewritten, and translated by organisms like bacteria. In synthetic biology labs, *E. coli* is bred precisely for this purpose—to transcribe DNA and translate RNA. However, Roy says, "once bacteria have performed their tasks of transcription, recombination, or gene editing, they are promptly snuffed out for the valuable proteins they carry inside of them."

It's a missed opportunity, she argues, to approach our counterparts in the lab through such a mechanistic lens—to deem them worthy of our care and attention solely when they are productive. How we treat the microcosm is a reflection of our attitudes in the macrocosm. "We have deemed some humans to be better than others," Roy says, nodding to the history of molecular biology and its role in eugenics. "We have deemed some human traits as not being worthwhile, or not being productive, because we are unable to understand or appreciate their usefulness."

When we question hierarchies and taxonomies, even at the molecular level, we are engaging in a radical act of humility—one that manifests in our human relationships, too. It's the project of a lifetime, Roy says, to see yourself as one of many. Tame, wild, subject, observer: We are all carriers, in our own way, of the patterns of life. By deliberately decentering the human, we only become more humane.



Staging a Cell Memorial Service for *Emergence*

Annie Zeng

On a calm afternoon in the *Emergence* galleries, the drum of a wooden *mokugyo* echoes, resonating through bubbling bioreactors, encased microscopes, and vials of synthetic indigo. Incense burns next to white chrysanthemums as a monk's chanting fills the hall. Individuals holding recitation booklets gather before *Pillars of Creation* (2024), a sculpture with rotating golden arms that rise above its carpeted platform. What is happening here? And what is a "cell memorial service"?

When Henry Tan and Masato Takemura, the artists behind *Pillars of Creation*, were invited to participate in *Emergence*, they began planning a ritual that would honor the contributions of cellular life employed in the exhibition. Their artistic ritual was inspired by *aPrayer* (2016), a performance by Hideo Iwasaki and other members of the bioaesthetics platform metaPhorest that commemorated and problematized the lives of synthetic cells and microorganisms given to scientific research. As Iwasaki notes, *aPrayer* drew from the Japanese custom of commemorating the souls of nonliving objects and experimental animals: "More than 90 percent of universities and biomedical research institutions in Japan hold memorial services for experimental animals or experimental organisms every year." Tan and Takemura brought this practice—filtered through their own cultural awareness and ways of being, replete with practices of gratitude—to the novel context of an art gallery and satellite biolab in Los Angeles.



Tan and Takemura staged *Cell Memorial Service* on December 12, 2024, with the guidance of Sogen, a Zen Buddhist monk from the Rinzai-ji Zen Center of Los Angeles; they considered it "a farewell to the departed and celebration of the living." In typical biology labs, once an experiment is completed, cells are disposed of according to strict biosafety protocols. At the close of *Emergence*, cells were to be similarly rendered harmless and then discarded. Specifically, the biological materials in the exhibition—which included fibroblasts, epithelial cells, and organoids—were to be mixed with 10 percent bleach in a liquid reagent for thirty minutes before being safely poured down the drain. Technicians would perform this final act, ensuring compliance with Biosafety Level 2 (BSL-2) standards. Tan and Takemura's service began in the galleries; Monk Sogen had arrived in the morning to set up service stations in front of artworks containing cells, microorganisms, and even fluorescent plants. The service concluded in front of the BSL-2 lab on the fourth floor of the building. There, the artists offered up the cells, which had been stored and kept alive on a growth medium within an incubator, for ritualistic commemoration.

Cell Memorial Service created a space for artists, scientists, and religious practitioners to come together and discuss the implications of synthetic biology.

Above and opposite page: Henry Tan and Masato Takemura's *Pillars of Creation* during *Cell Memorial Service*, 2024. Courtesy of Fathomers. Video stills: Carson Davis Brown.

I had the privilege of working closely and learning with Tan and Takemura throughout the planning of the service. As part of our research, we visited religious spaces near Little Tokyo, where the exhibition was installed. We conversed with leaders and practitioners of various Buddhist lineages to understand their philosophical approaches to synthetic biology and to explore how we might frame such discussions for the local community. The artists were particularly interested in how religious traditions conceive of life and death, how these conceptions might change with the creation of artificial life via synthetic biology, and how synthetic biology can contribute to new philosophies of consciousness. We met Sogen at the Rinzai-ji Zen Center, where he greeted us with tea and an openness to ponder together. When we asked about how Zen Buddhist practice honors life and death, he responded with questions of his own about the nature of cells. After hours of conversation, warm matcha, and earnest drawings attempting to communicate intangible concepts, we recognized the rarity of such exchanges. We were humbled by the challenges of navigating religion, science, and art across diverse worldviews.

Commemorations of cellular life may seem unwarranted to some, especially since synthetic cells' reproducibility confounds our traditional understandings of death. Yet by honoring the contributions of cells to artworks, by even choosing to see organoids as collaborators, Tan and Takemura—whom we came to affectionately call Henry and Take—prompted us to reconsider how we use life in service of the industries of art and science. Their gratitude toward the life used in the exhibition extended beyond cellular organisms to the human bodies and minds performing creative labor to support their work. The artists honored their collaborators with an abundance of group outings, gifts, and shared meals. Before the exhibition opened, they invited curators, installers, lab technicians, gallery attendants, and others to be featured in images within the rotating clinostat in *Pillars of Creation*. As Henry put it, these were the many "eyes" of the exhibition's creators. On the opening night of *Emergence*, he raised a toast to "creatures, creators, and life," celebrating creative labor—human and otherwise.

Cell Memorial Service created a space for artists, scientists, and religious practitioners to come together and discuss the implications of synthetic biology. Further, by normalizing gratitude in the scientific and artistic industries, *Cell Memorial Service* showed us how we as workers might cultivate new relationships to both. In dedicating time, space, and resources to commemorate the labor of voiceless cells, the artists encouraged us to recalibrate our own senses, to develop a deeper appreciation for the labor of human and nonhuman life—from the smallest cells to our fellow workers. Many aspects of modernity make it easy to neglect our humanity, but perhaps taking the time to perform rehumanizing practices, like a memorial service for cells, can help restore an appreciation for our interconnectedness. Imagine if laboratories across the United States held commemorations for nonhuman life: Would the humble act of retraining our senses to recognize and express gratitude for varied forms of life and labor engender a different way of being within our own institutions of art, science, and technology?

To close with a personal practice of gratitude, I would like to especially thank Monk Sogen and the Rinzai-ji Zen Center, the Japanese American Cultural & Community Center production staff, Carson Davis Brown, Lukas Marxt, Eric Dobbins, Blessing Greer-Mathurin, and of course the cells, microorganisms, and plant life of *Emergence*. Without their invaluable labor, the service would not have been possible.

1 Hideo Iwasaki, "aPrayer: Memorial Service for Microorganisms and Artificial Cells and Lives," Hideo Iwasaki, accessed August 4, 2025, https://hideo-iwasaki.com/aprayer. See also page 66 of this volume.







Henry Tan and Masato Takemura, *Cell Memorial Service,* 2024. Courtesy of Fathomers. Video stills: Carson Davis Brown.

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Excerpt from

aPrayer:

Memorial Service for Microorganisms and Artificial Cells and Lives



Hideo Iwasaki

metaPhorest *aPrayer* team (Hideo Iwasaki, Hanna Saito, Shiryu Kirie, Mio Iizawa, and Noriko Toda), *aPrayer*, 2016. Detail: stone monuments to artificial cells and lives (left) and microorganisms (right), Ibaraki Prefecture, Japan. Courtesy Hideo Iwasaki.

Background: Aesthetics of Synthetic Cell Projects

One of the most ambitious questions related to synthetic biology is whether we can make a synthetic protocell in a test tube by combining biomolecules. Scientifically, this is very exciting because it makes us reconsider what life is, what cells are, what the boundary is between life and nonliving materials. . . .

Life can be considered to have at least two facets: One is life as a biological object, described as a biological complex or organism. The other is life as an intersubjective presence, perceived as a more emotional object or relationship—as "life with us," exemplified by the state of funerals and commemorations, for example. We are interested in the ambiguous border and complicated relationship between these two facets, that is, biological and intersubjective or even ontological. . . . Obviously, aesthetics is a good means of exploring such topics. Perhaps one reason for this is the intrinsic similarity between life and art.

Two Japanese Customs: Memorial Services for Experimental Organisms and Even Nonbiological Tools

More than 90 percent of universities and biomedical research institutions in Japan hold memorial services for experimental animals or organisms every year. Usually, biology attempts an objective description of life and tries to exclude ambiguous expressions as much as possible. But these memorial services held in scientific institutions show that such intersubjective and emotional experience is regularly formally organized within the halls of science. Officially, these services are supposed to be for the use of sacrificed animals, for educational and ethical purposes. But historically, they are also an extension of the Japanese tradition of holding memorial services for nonhuman species. For example, there are many old stone monuments to horses, fish, and many other organisms all over Japan. There is even a monument for snails, which were vectors for a serious parasitic infection. By 1983, the snails were eradicated in the southern part of Japan. The monument reads, "We hereby commemorate the Miyairi snails that have been artificially eradicated in the area of the Chikugo River, for the sake of the protection of our human society." Here, we can see the deep compassion of the eradicators even for the eradicated.

More importantly for our purposes, biologically nonliving materials and tools are also commemorated. Monuments for pens, brushes, needles, and dolls are often created, and memorial services are regularly held for these objects. These memorial services have all sorts of historical and ethical implications, such as a connection to local religions. However, we want to emphasize that the memorial services retrospectively acknowledge that s*omething was alive*. Here, it is important that the something being acknowledged is not limited to biological species, which are acknowledged as "life in the past" retrospectively. . . .

Our Project: Commemoration of Artificial Cells as a Thought/Artistic Experiment

Our project bridges the gap between the two facets of artificial cells, the biological and the intersubjective, by holding a memorial service and creating a monument. In doing so, it raises questions such as, What are death and liveness for such synthesized cells? and, Is artificial life worth commemorating? In 2016, as an artistic project, we installed a stone monument to the "souls" of artificial cells/lives in Japan and started holding annual memorial services for them. We also made a monument to innumerable microorganisms, as the area where we installed the project, Ibaraki Prefecture, is rich in fermented food culture. At the initial memorial service, we prepared a glass jar containing experimental tools that had been used for representative artificial cell/life studies at nine laboratories. The list of the tools is as follows:

1. In vitro translation system (PURE system), provided by Prof. Takuya Ueda (University



of Tokyo): The PURE system is a mixture of recombinant ribosome and translation proteins from *E. coli* bacteria, transfer RNAs, and adenosine/guanosine trinucleotide phosphates. It is a reconstituted system used to synthesize proteins in a test tube based on the template RNAs of your interest. . . .

2. Cell-size vesicles made with a synthetic lipid bilayer (liposomes), provided by Dr. Yutetsu Kuruma (Tokyo Institute of Technology): Some researchers consider membranes that discriminate between inside (self) and outside (environment) to be essential to the genesis of life. . . .

3. Artificial cells to mimic some microbial activities, provided by Dr. Kei Fujiwara (Keio University): In real cells, biomolecules are extremely concentrated. Thus, we usually cannot reconstitute such chemical solutions in a test tube. This researcher developed a clever method to condense cellular extract in liposomes using osmotic pressure.

4. Evolvable artificial cells, provided by Prof. Norikazu Ichihashi (Osaka University): Innumerable cell-sized water droplets are surrounded by oil in a test tube. The droplets contain a reconstituted genetic system (RNA, ribosome, and amino acids). Chains of biochemical reactions, spontaneous errors in the decoding process, the forced division of water droplets, and the isolation of mutated contents facilitate in vitro artificial evolution to enhance the cells' ability to survive in experimental conditions. . . .

5. Micro device compiling innumerable cell-sized bacterial extracts, provided by Dr. Kazuhito Tabata (University of Tokyo): The device holds millions of bacteria-sized pores on which bacterial extracts were loaded and then sealed with a thin lipid bilayer. Each pore is a hybrid cell, retaining at least some basic genetic activities, such as transcription and translation. This is a Frankenstein-like experiment to see if living bacteria can be regenerated after disruption of the cell.

6. Microrobotics formed in liposomes encapsulating proteins for muscle behavior, provided by Prof. Shin-Ichiro M. Nomura (Tohoku University): This synthetic membrane vesicle (liposome) contains proteins involved in cell motility and DNA origami. The latter is a three-dimensional microstructure made with DNA chains, which is used to control contact of the proteins to the membrane.

7. Mobile oil droplets surrounded by water phase, provided by Prof. Taro Toyota (University of Tokyo): These oil droplets are made of specific synthesized organic compounds. Some detergent effect on the surface of the droplet is likely important to generate its active mobility property.

8. Heated or Cobalt-60-irradiated amino acids, provided by Prof. Masashi Aono (Tokyo Institute of Technology): Proteins in organisms on Earth are composed of twenty amino acids. However, the origin of the polymerization of amino acids remains a mystery, since the production of amino acids requires a hydrophilic environment while polymerization (protein synthesis) requires hydrophobic

metaPhorest *aPrayer* team, *aPrayer*, 2016. Installation view: KENPOKU ART, North Ibaraki Prefecture, Japan, 2016. Glass jars containing the remains of artificial cells (left) and microbes (right) were each placed atop an altar, where visitors could also view video footage of the contents and read written explanations. Courtesy Hideo Iwasaki.

conditions. This researcher thinks it could occur under local and periodic alternations of hydrophobic and hydrophilic environments, such as a geyser or conditions of extreme heat or radiation in ancient Earth. He showed that the polymerization of amino acids occurred under artificial conditions that mimicked those environments.

9. Synthetic cells that are able to divide autonomously, provided by Prof. Tadashi Sugawara (Kanagawa University): Autonomous cellular division is one major issue in synthesizing cells. This artificial cell is composed of liposomes with a special membrane composition and contains DNA and an enzyme (DNA polymerase) to replicate it. When the DNA content inside is elevated by the standard technique known as PCR, physical contact between DNA and the membrane facilitates catalytic activity of some membrane compounds, thereby facilitating further polymerization of the lipid. This causes membrane growth. When the membrane expands beyond a threshold, the surface tension cannot be maintained and the membrane vesicle divides into two vesicles. This is one of the first demonstrations of artificial cells dividing autonomously. We also find it very interesting that DNA functions here not as genetic code but as a catalyst to mediate cell shape and division.

All these examples show broad-range activities in the field of cell synthesis research. It should be noted that a member of the project, Hideo Iwasaki, has also contributed somewhat to this field. Hideo reported the first reconstitution of a biological clock in a test tube (periodic enzymatic reactions within a period of twenty-four hours) by simply incubating three clock proteins from cyanobacteria (2005). One year after the initial memorial service, in 2017, local citizens and synthetic biologists buried the jar beneath the monument.

We interviewed fourteen researchers: the nine listed above, plus Profs. Takashi Ikegami and Shoji Takeuchi at the University of Tokyo, Prof. Daisuke Kiga at Waseda University, Prof. Makoto Hayashi at Kogakuin University, and Prof. Michio Tagiri at Ibaraki University. We asked questions such as:

- At what points do you feel liveness in your daily life?
- Do you experience feelings of liveness toward your artificial cells/lives?
- What is necessary in order to declare that you really make life?
- Have you joined a memorial service for experimental organisms? Do you think it makes sense to conduct such a service?
- Which organisms are worthy of commemoration, in your view?
- Are your artificial cells/lives worthy of commemoration?
- When and how do your artificial cells/lives die?
- Do you feel sorry when your artificial cells/lives die?
- What did you think or feel when you heard about our project, a memorial service for artificial cells?
- Do you have any idea what your parting words to your "dead" artificial cells/lives might be?
- How does your artificial cell/life project impact our future?

The researchers do not directly address these issues in their scientific articles. However, we believe their answers reflect their own ways of acknowledging liveness and the human aspects of the study of artificial cells and lives. . . .

> "If talking about sympathy, personally I can be sympathetic up to *E. coli* bacteria, as they are creatures just like us. However, I have a feeling that one would [only] hold a memorial service

for mammals. Perhaps genetic homology would influence that. If something is as genetically close to ourselves as mammals, perhaps we could have a ceremony for them." *Would it be possible to make artificial cells that make us feel sad when they die?* "Do you mean I would become sad? Yes, of course—even now, I devote my biggest affection to artificial cells! I can say I care for them like parents do for their kids." *As a parent, we would hold a memorial service for our kids, wouldn't we?* "Yes, we would have to!"

"When I heard about the memorial service for artificial cells, I thought, 'Oh, that's the way!' By creating a format to claim that artificial cells were alive, we make it so we need to hold a memorial service because they were alive . . ."

"Our purpose is to make something equivalent to or beyond a microorganism. Until then, actually, I feel a kind of sadness in making artificial cells, a similar feeling to when a baby is born unsuccessfully."

"When we consider the composition of lipid, we'd think, upon increasing chloroform from 20 to 21 percent, 'May the lipid not be spoiled!,' and that is a kind of prayer."

"Oh, this is the artificial monument! We too make artificial cells that still don't have souls, but we want them to be like real cells one day, to work better than real cells do, and later to put 'soul' in them. So the monument is interesting in enabling a meta look at our work."

To the question, When and how do your artificial cells/lives die? some researchers answered that they feel the cells/lives die when they see the reactions stop. In contrast, a researcher told us, "That's something I'm not quite certain about. They just stop responding when they are frozen, but if you take them out of a freezer and treat



them properly, they'll start responding again. In that sense, they might not die. As they are made artificially, they can be brought back to their original condition in one way or another. That could mean their death never occurs, though nonliving things couldn't die either." *Then what would be necessary in order to make an artificial cell that would die?* "Would that not be artificial, I wonder?" *Do you mean we are capable of making a living thing but not death?* "That's right. After all, artificial cells won't die as long as they are alive. Death means no reproducibility, but they are reproducible . . ."

But is anything lacking death truly alive?

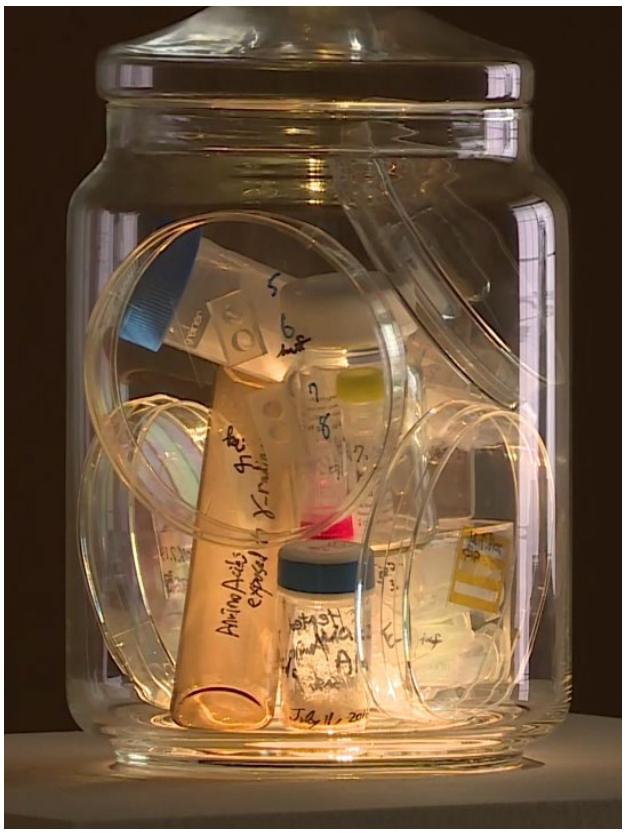
There are many other opinions. We also collected responses from local citizens and fermented food makers. In all cases, our memorial monuments and services likely functioned as a "narrative generator" about this issue, even among experts.

Upon the opening of *aPrayer*, a Shinto priest held a ceremony at the stone monument. However, it is unclear whether this satisfied accepted criteria for standard memorial mourning. It still remains at the stage of "artificial monument," as one researcher suggested above. The social and cultural reception of our monument would

A scene from the unveiling ceremony for the *aPrayer* monument, Ibaraki Prefecture, Japan, 2016. Following local custom, a Shinto priest from the area presided over the ritual. Local residents and artificial cell researchers continue to hold annual memorial services at the monuments, though they are not conducted in the Shinto style. Courtesy Hideo Iwasaki.

be determined by how people think about the "liveness" of artificial cells/lives in the future, while making artificial cells alone could relativize notions of death and commemoration. . . .

On the monument's surface, we inscribed four representative motifs related to synthetic cells: ribosome (a genetic decoder to interpret DNA and synthesize proteins), cells propagating in a flask, a DNA double helix, and lipid bilayer (cell membrane components). We also added the image of an eye, making the stone appear as the head of a human being. On the back side of the monument, we inscribed the following: "We hereby acknowledge this stone monument to commemorate artificial cells and lives that are still unseen, yet will have been synthesized before too long. We hope the monument will serve as a means of rethinking the conditions by which we are made to experience vitality, as well as the history of ideas of life."



metaPhorest *aPrayer* team, *aPrayer*, 2016. Detail: glass jar containing tools used for experiments on synthetic cells. One year later, the jar was placed in the space beneath the stone monuments. Courtesy Hideo Iwasaki.



Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.



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Art from Life

October 8–December 15, 2024

Japanese American Cultural & Community Center, Los Angeles

Featuring the work of

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Corinne Okada Takara

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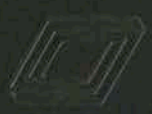






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Recipe



FATHOMERS





Embrace

This project is part of *Emergence*, an exhibition organized by Fathomers that ran from October 8 through December 15, 2024, at the Japanese American Cultural & Community Center in Los Angeles.

Emergence assembles artists, scientists, and artist-scientists working at the forefront of synthetic biology and contemporary art. Documentation of their projects as well as relevant writings and interviews, planning sketches, and other contextualizing materials are collected in this catalog. Some contributors draw from their work in medical or transdisciplinary research laboratories, where they confront new categories of life that destabilize our understandings of sentience, hybridity, and artificiality. Others engage the tools of synthetic biology as materials for creative experimentation and studio-based inquiry. Many contributors argue for decolonizing science and expanding access to biotechnologies through DIY and community science initiatives. Across *Emergence*, audiences and participants are invited to contemplate our human capacities for creation, destruction, recklessness, renewal, and hope. The exhibition prompts us to ask: Who has agency in this moment of making, learning, and living with? What forms of life are we choosing to cultivate? What will we nurture, and what might we leave behind?

Projects in the Exhibition

AfroRithm Futures Group
MultiPlanetary Garden

Marie Bannier Hélaouët and Albert Wu
Crying Organoids

Callie R. Chappell and Nasa Sinnott-Armstrong
IndiGROW

Michael Jones McKean
of kin and bone

Eduardo Padilha
Apoptotic Bodies

Pat Pataranutaporn
CyberBiome and *MicroPET*

Corinne Okada Takara
Floating Future Gardens

Henry Tan and Masato Takemura
Pillars of Creation

Tissue Culture & Art Project
The Use of Life (in Relation to the Industry of Men)

Fathomers is a creative research institute dedicated to producing sites and encounters that challenge us to live and act differently in the world. Fathomers cultivates the ideas of diehard dreamers, commissions projects that seem far-fetched, and collaborates with thinkers across disciplines to expand the limits of scale, scope, and support for artist-led projects.

Emergence was presented as part of PST ART: *Art & Science Collide*. PST ART is presented by Getty.

AfroRithm Futures Group

Multiverse Compendium

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Natasha Boyd

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Lonny J. Avi Brooks



MultiPlanetary Garden

AfroRithm Futures Group

Introduction by Natasha Boyd

The first conversation between Dr. Lonny J. Avi Brooks and Ahmed Best was supposed to be a fifteen-minute pre-lunchtime phone call. Instead, it lasted three hours. Best, a multihyphenate artist, actor, and educator, was looking to start a podcast on Black technologists. His brother-in-law suggested reaching out to Brooks, a scholar of Afrofuturism, which combines science fiction, history, and fantasy to explore Black identity, the Black diaspora, and African ancestry. At the time, Brooks was organizing a conference in Oakland for the Black Speculative Arts Movement, which had just published an anthology called *Afrofuturism 2.0: The Rise of Astro-Blackness* (2016). Brooks was supposed to talk with Best about these developments as the first guest on the podcast,

but it was clear to both of them that a one-time conversation was not going to cut it. So Brooks signed on as cohost, beginning a multimedia collaboration that has spanned a decade. Their ethos was radically direct: as Best put it, "Black people exist in the future."

Hosting the podcast introduced them to a plethora of different voices in the world of Afrofuturist thought, which was having a renaissance in the Bay Area at the same time as Silicon Valley was radically changing how people thought the future might look. To Best and Brooks, it was obvious what was missing in the imaginings of Silicon Valley giants: Black and Indigenous culture. Brooks, Best, and collaborator Eli Kosminsky began brainstorming an interactive storytelling game that could destabilize Eurocentric assumptions about utopian worldbuilding. They debuted AfroRithms from the Future at the Institute for the Future in Palo Alto, California. Players work together to think critically and problem-solve, designing unique "artifacts" that help them explore a future where Black, Indigenous, and other people of color thrive. Play, thought Best and Brooks, could be a valuable tool for thinking outside the box about how to drive transformative action for social justice. The game was a huge success at the Institute. Fathomers was among the audience—and became the next supporter of AfroRithms.

Best and Brooks formed the AfroRithm Futures Group to share the game with a wider audience, bringing on Jade Fabello as operations manager, game scribe, and poet. Originally created as an in-person, facilitated event, the game moved online in spring 2020 and has been presented as a workshop at the Institute for the Future, Dynamicland, the Black Speculative Arts Movement festival, Harvard Graduate School of Design, UNESCO Futures Literacy Summit, the University at Buffalo Humanities Institute, the

Community Futures School at the Museum of Children's Art in Oakland, Stanford University's d.school, and elsewhere. Hosting the game at Stanford brought Brooks, Best, and Fabello into contact with another important collaborator: Dr. Drew Endy, a member of the Stanford bioengineering faculty and one of the pioneers of synthetic biology.

In 2021 and 2022, Brooks and Best embarked upon the next stage in their vision: to create an Afrofuturist nation in the "pluriverse" of virtual reality, which they call the Astro Egalitarian Virtual Network, or AEVN. AEVN invites artists, scientists, writers, educators, and others to grapple with the possibilities and challenges of the virtual landscape for Afrofuturist thought. As human lives become increasingly cyborgian, AEVN seeks to help the world imagine (and survive) a future of rapid social and ecological change and increasingly blended virtual/reality by looking to ancestral intelligence, marginalized voices, and the rediscovery of lost Black and Indigenous stories.

MultiPlanetary Garden (2024) embodies this vision. Through a cycle of dances, audiences inhabit a future in which synthetic biological advancements have helped to create an egalitarian multiplanetary society. In collaboration with Endy, Best, Brooks, and Fabello imagine how biosynthesis could make abundance the rule rather than the exception, allowing life of all kinds to flourish across the galaxy. Los Angeles–based projection artist Jesse Gilbert and choreographers Raquel "Rocky" Horsford, Malaya, and Oguri depict the planting of gardens and the celebration of the harvest in a performance that begins with individual dancers and culminates in communal movement. AfroRithm Futures Group offers *MultiPlanetary Garden* as an opportunity to embrace how ancestral

and Indigenous technologies of dance, storytelling, and agronomy reframe Western assumptions about how body and environment interact. "Rather than colonize," they note of the project's multiplanetary setting, "we respect the dignity of all the life we encounter—life being a term we see as ever evolving and defining. Not life as we know it but life as we learn it." It's an ambitiously optimistic vision of the future. But what choice do we have other than to believe that the best outcome is at least a possibility?





Visitors view *MultiPlanetary Garden* during the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.





Lonny J. Avi Brooks

AfroRithm Futures Group

Ahmed Best





Jade Fabello

The **AfroRithm Futures Group** is an Afrofuturist storytelling collective led by Ahmed Best, Dr. Lonny J. Avi Brooks, and Jade Fabello, in collaboration with Dr. Drew Endy, Jesse Gilbert, Raquel "Rocky" Horsford, Malaya, and Oguri. **Ahmed Best**, a cofounder of the AfroRithm Futures Group, is a multihyphenate artist, educator, podcaster, and futurist as well as an award-winning actor, director, writer, producer, musician, and choreographer. Best is a senior fellow at the USC Annenberg School for Communication and Journalism and teaches at the USC School of Dramatic Arts and Stanford University's d.school. **Dr. Lonny J. Avi Brooks**, a scholar from Oakland, CA, cofounded the AfroRithm Futures Group with Best. Brooks is a professor in strategic communication and foresight at California State University, East Bay, and the former chair of the Communication and the Future division of the National Communication Association. He has authored and coauthored a vast array of futurist studies for publications including the *International Journal of Communication* and the 2016 anthology *Afrofuturism 2.0: The Rise of Astro-Blackness*. **Jade Fabello** is a Baltimore-based freelance writer and the operations manager for the AfroRithm Futures Group. A former political public speaker for US senate can-didates, Fabello now writes personal essays about politics, race, art, grief, and love. His work appears in *Texas Monthly*; *Thrillist*; StarWars.com; *Study Hall*; *Brown Journal of Philosophy, Politics, and Economics*; *Batshit Times*; and more. He is also the author of *I love words and you*, a newsletter on the craft of writing.

and Collaborators

Dr. Drew Endy is a professor of bioengineering at Stanford University and president of the BioBricks Foundation. His research teams pioneered amplifying genetic logic, rewritable DNA data storage, reliably reusable standard biological parts, and genome refactoring. **Jesse Gilbert** is a Los Angeles–based interdisciplinary artist working at the intersection of visual art, sound, and software design. He developed the software SpectralGL, an interactive listening instrument that generates real-time visual landscapes in response to sound. **Raquel "Rocky" Horsford** is a dancer and choreographer, and a graduate of Rutgers University's Mason Gross School of the Arts. Her work for film, television, and theater combines elements of jazz, ballet, African dance, Caribbean dance, and hip hop with influence from modern dance icons like Talley Beatty and Alvin Ailey. **Malaya** is an actress, choreographer, and classically trained dancer working in the United States and internationally. She has appeared in short and feature films, on television, and in music videos and concerts by artists such as Prince, Celine Dion, and Tate McRae. **Oguri** is a dancer exploring connections between the human body and nature, in particular the rhythms and cycles of traditional farming culture. Oguri started training in 1985 with famed dancer Min Tanaka's company, Maijuku, and cofounded Body Weather Laboratory with Roxanne Steinberg in Los Angeles in 1991.



Oguri

Photo: Ray Barrera



Raquel "Rocky" Horsford

Photo: Damu Malik Photography



Jesse Gilbert

Photo: Peter Adamik



Drew Endy

Photo: Earl Harper / Harper Studios

Malaya

Photo: Vince Trupsin





What don't biologists understand about biology?

SYNTHETIC BIOLOGY

Design and synthesis of a minimal bacterial genome

Clyde A. Hutchison III,[1]*† Ray-Yuan Chuang,[1]†‡ Vladimir N. Noskov,[1] Nacyra Assad-Garcia,[1] Thomas J. Deerinck,[2] Mark H. Ellisman,[2] John Gill,[3] Krishna Kannan,[3] Bogumil J. Karas,[1] Li Ma,[1] James F. Pelletier,[4]§ Zhi-Qing Qi,[3] R. Alexander Richter,[1] Elizabeth A. Strychalski,[4] Lijie Sun,[1]|| Yo Suzuki,[1] Billyana Tsvetanova,[3] Kim S. Wise,[1] Hamilton O. Smith,[1,3] John I. Glass,[1] Chuck Merryman,[1] Daniel G. Gibson,[1,3] J. Craig Venter[1,3]*

We used whole-genome design and complete chemical synthesis to minimize the 1079–kilobase pair synthetic genome of *Mycoplasma mycoides* JCVI-syn1.0. An initial design, based on collective knowledge of molecular biology combined with limited transposon mutagenesis data, failed to produce a viable cell. Improved transposon mutagenesis methods revealed a class of quasi-essential genes that are needed for robust growth, explaining the failure of our initial design. Three cycles of design, synthesis, and testing, with retention of quasi-essential genes, produced JCVI-syn3.0 (531 kilobase pairs, 473 genes), which has a genome smaller than that of any autonomously replicating cell found in nature. JCVI-syn3.0 retains almost all genes involved in the synthesis and processing of macromolecules. Unexpectedly, it also contains 149 genes with unknown biological functions. JCVI-syn3.0 is a versatile platform for investigating the core functions of life and for exploring whole-genome design.

EMBARGOED UNTIL 2PM U.S. EASTERN TIME ON THE THURSDAY BEFORE THIS DATE:

SCIENCE sciencemag.org 25 March 2016 • VOL 351 ISSUE 6280 aad6253-1

Biology teaches us that **all atoms are local**

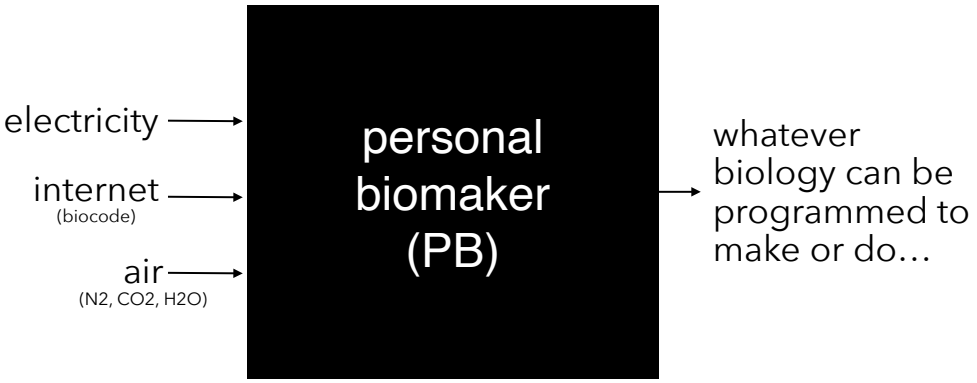


Internet motivated by communications resilience

Bionet motivated by manufacturing resilience?

7 of N
N=16

Q. how would this box **change the world**?



Q. what would the "PB" + a "bionet" lead to?

A. "design anywhere, grow everywhere"

8 of N
N=16

Technology is not technology

(the specific form a technology takes matters greatly)

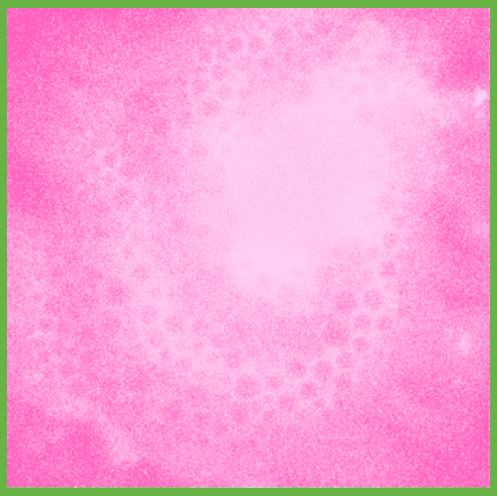


Photo © Winsor & Newton. Used with Permission.

Who can use a tool **where** is often the most impactful aspect of a tool

Above and opposite page: Drew Endy, selected lecture slides prepared for the *1,000 Days* panel discussion hosted by Fathomers at the Japanese American Cultural & Community Center, Los Angeles, June 2022.

Mothership Journey:



A Fusion of Futurisms and Ancestral Wisdom in a Multispecies Planetary Garden

Lonny J. Avi Brooks

"Mothership Journey" served as the script for the debut performance of AfroRithm Futures Group's *MultiPlanetary Garden* at the Japanese American Cultural & Community Center, Los Angeles, on October 12, 2024.

Mothership Galactic Stellar Beat Time J3024: This is Captain Avi Salim Dogon, taking my band of humanity venturing far beyond Earth, not as conquerors nor as refugees from a dying planet, but as custodians of a vision that honors all life. On our AI-powered Mothership Neema (Swahili for "born in prosperity"), we are fanning out to welcome life and celebrate and nurture its growth, and to share our Earthling dances swaying with AfroRithm melodies. Our journey is not a repeat of the Middle Passage, where Africans were kidnapped, put on ships, and enslaved in alien lands—where they faced the erasure of their music, religion, and dance. No, now the Mothership Journey bursts with Earthling songs while dances of our ancestral intelligence amplify and multiply into future visions of Mothership freedoms unimaginable in 1492.

Aboard our Mothership, SynBioAfroRithms is our guiding light, transforming our relationship with nature and the cosmos.

We are tending to and archiving the flowering of our diverse futurisms—Afrofuturism, Indigenous Futurism, and Queer Futurism—into a cohesive memory of this journey that embraces radical inclusion, ancestral intelligence, and the celebration of multispecies intelligences. Our time now is not one of scarcity or domination but of steady state harmony, where the ethos of *Earthling Culture*—respect and dignity for all living beings—prevails.

We are mapping out with our crew the Multispecies Planetary Garden, a living prototype of the interconnectedness between all types of Galactic species, humans, technology, and nature. This garden is not merely a collection of plants; it is a sanctuary where ancestral wisdom, cutting-edge science, and the imagination of ancestral and future communities converge. Here, the garden is a manifestation of humanity's prime directive: to honor the earth, each other, and the vast tapestry of life across the galaxy.

Mothership Galactic Stellar Beat Time J3044: As I bite into my Life X-Tender glowing apple-pomegranate, I feel the pulse of my Mothership crew and the Dance of the Mother Soil, an annual ritual to reaffirm humanity's commitment to Earthling Culture. The biodance marks the cycle of life and generates each of the agricultural stages of planting, growing, and harvesting. However, this is no ordinary performance; the dances are the plowshares, a memory of our journey and a map to our future harvest as an immersive, interstellar ritual blending the traditions of Afrofuturist, Indigenous, and Queer cultures, infusing each step with meaning and the story of our Mothership travels.

We call the rhythms of this dance the SynBio-AfroRithm dance engine. The AfroRithm is not just an artwork; it's our tool. It is a living, adaptive structure that evolves as the dancers move, interact, adding their own rhythms and dreams to its fabric.

Mothership Galactic Stellar Beat Time J3074: Central to the Dance of the Mother Soil is the nurturing presence of our Mothership's Ancestral Intelligence, Ancestral AI. Her artificial intelligence systems are not mere tools; they are our sentient companions, shaped by the wisdom of African and Indigenous ancestors. Our AI soul biomates are not cold, calculating machines but *Us*, embodying the spirit, history, and knowledge of our creators. They guide and expand our souls, build on our beats, and sync up our moves to groove in the Dance of the Mother Soil, unveiling our imagination, blending ancient wisdom with flourishing, life-affirming innovation.

Mothership Galactic Stellar Beat Time Update, J3076: We are finally leaving the Mothership, ready to build the Multispecies Planetary Garden Collective: our humble, modest landscape teeming with life. This Earthling protomolecule has taught us how to grow life exponentially without harm to others. It has taught us to end hunger

and supported our flourishing. Here, the vision of a thousand years of our ancestral memory, from 2034 to 3076, is fully realized: Our garden serves as both a sanctuary and a laboratory for sustainable living. Glistening, pulsating African fractal structures rise glowing with bioluminescent flora, and modular habitats blend seamlessly with the landscape.

This garden is a living ecosystem where humans, plants, and AI cocreate. Every plant is an active participant, communicating, whispering through a network of sensors and biofeedback loops that connect to the Ancestral AI. We hear the voices of our souls and a million cocreators.

The Multispecies Planetary Garden is growing with the beats every species, every culture, and every Mothership crew member plays, and each participant is honored for their role in the collective tapestry of life. It is a playground, a healing space, and a beacon of hope—a reminder that the future is not something that happens to us but something we actively shape with every decision and every act of creation.

Our Mothership Journey is our memory and collective travel, teaching us to dream boldly, to play fiercely, and to remember that the future we build is only limited by the boundaries of our imagination.

Thanks be to our Mothership Neema, humbling us to our Universe, Galactic Time J3076.

—Captain Avi Salim Dogon

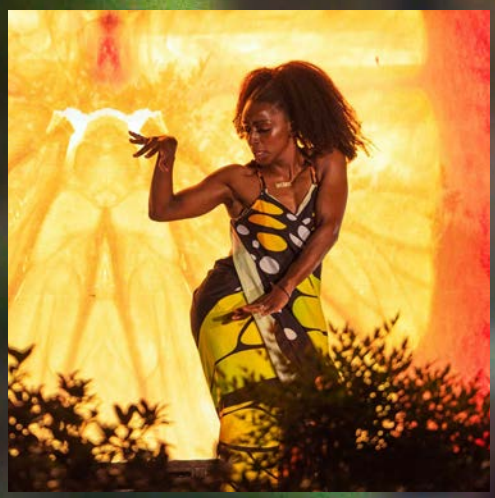


Lonny J. Avi Brooks and Ahmed Best speak behind the scenes during the production of *MultiPlanetary Garden*, Envizion Studio, Los Angeles, 2024. Courtesy of Fathomers.



Malaya dances in the live performance of *MultiPlanetary Garden* at the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.









Excerpts from

To you, earth child, many years from now

I would tell you, from atop the vista. I love you and I don't want you to die. But die we do. And before it is done, let it **not** be known, but let it instead be felt, that we created more. Let it be felt that I would hold you in my arms and around you construct cities of sand. Warm and flowing.

. . . . . .

To draw breath is a testament, proof that your life and future **matter**—for no other reason than the fact that you were born in this world.

I speak to you, earth child, descended of my love. You are whole, and for you we create.

Jade Fabello





Above: Scenes from the live performance of *MultiPlanetary Garden* at the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.

Previous spread: Scenes from the live performance of *MultiPlanetary Garden* at the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. The inset images show (from top to bottom) Oguri, Raquel "Rocky" Horsford, and Malaya dancing in the performance. Courtesy of Fathomers. Photos: Jordyn Doyel.



Raquel "Rocky" Horsford dances in the live performance of *MultiPlanetary Garden* at the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.

In the months before the opening of *Emergence*, curator Stacy Switzer sat down with Ahmed Best, Dr. Lonny J. Avi Brooks, and Jade Fabello to talk about their work as the AfroRithm Futures Group, the origins of the game AfroRithms from the Future, and the long arc of their relationship with Fathomers. Their conversation touches on a range of subjects, from Afrofuturism and the Black Speculative Arts Movement to augmented reality and the 2020 George Floyd uprisings. As they recount here, one question became both a provocation and a guiding principle for their practice: "How can we center Black and Indigenous people, people of color, and queer voices in the future?" Radical imagination is a tool for survival—and a crucial one historically. In Fabello's words, "If I am not alive in the best future that you can imagine, that's a problem with your imagination."



A New Dance

AfroRithm Futures Group in Conversation with Stacy Switzer

Stacy Switzer

How did the AfroRithm Futures Group and AfroRithms from the Future come to be?

Ahmed Best My brother-in-law, Aram [Sinnreich], a communications professor at American University, had written a paper with Lonny. At the time, I was thinking about doing a podcast about Black technologists and I asked Aram to connect me with some folks. He told me I should talk with Dr. Lonny Brooks because he is a technologist and a futurist. I had always been kind of a hobby futurist, so I liked that. Lonny's and my first conversation was three hours long, over FaceTime in my Prius. I was supposed to go to brunch but I was so energized, I wasn't hungry anymore. I was like, "We have to start this podcast."

Lonny J. Avi Brooks I remember Aram texting me about his brother-in-law being interested in Afrofuturism. The second line mentioned that Ahmed had played Jar Jar Binks in Star Wars. So I was like, "Oh, okay!" We had that three-hour conversation and I was excited about it. As an organizer for the Black Speculative Arts Movement, I was already tuned into Afrofuturism. We had just done an anthology called *Afrofuturism 2.0: The Rise of Astro-Blackness*.

Doing the podcast for two seasons and seeing this amazing run of guests really galvanized us. By illuminating the Black imagination and tapping into the Black Speculative Arts Movement, we connected with folks like Tim Fielder and Dr. Nettrice R. Gaskins. While we were doing the podcast, I was also meeting and working with people at

Above: Inspiration image for *MultiPlanetary Garden*, 2024. Photo: Ahmed Best.



LJAB Dynamicland, an augmented reality lab on 9th near Broadway in Oakland. That's where I met Eli Kosminsky, the game designer who codesigned some of the early game mechanics of AfroRithms from the Future; Josh Horowitz, lead programmer at Dynamicland; May-Li Khoe, former VP of design at Khan Academy; and Paula Te, lead interaction designer at Dynamicland, who defined the graphic design of the AfroRithms card deck as well. I gave the Dynamicland folks a demo of what futures thinking is about, and Eli and I were talking about creating games. I had wanted to create a game since 2007, when I'd met Jane McGonigal at the Institute for the Future. So we created a couple of games, and one of them had to do with queer futures. Another was to create algorithms for the future. I had a colleague, Tarleton Gillespie, who worked at Microsoft, and at the time he was single-handedly creating a whole field of algorithmic studies. It was clear that Indigenous people were missing from the algorithms, so the question became, How can we center Black and Indigenous people, people of color, and queer voices in the future? Putting *Afro* with *rhythms*, I created *AfroRithms*. Eli helped me with the mechanics, and we debuted the

Participants in the Astro Egalitarian Virtual Network (AEVN) Design and Development Convening, led by Ahmed Best, Lonny J. Avi Brooks, and Jade Fabello, the Interval at the Long Now Foundation, San Francisco, 2022. Courtesy of Fathomers.

LJAB game at the Institute for the Future and asked you, Fathomers, to be part of the audience to play the game. Eli and I were about to do a really dry presentation of the game when Ahmed stepped in and said, "Hey guys, can I MC this?"

I was so glad Ahmed stepped up. The provocation we came up with in that game was, "What would a world look like with more Black storytelling and less white supremacy?" And one of my graduate students said, "Well, what if you had a tattoo that when you waved it across an ATM machine, you got reparations back?" And I'll never forget what Ahmed said: "A reparations tattoo? I think you just won the game!" That really popped off everyone's radical imagination at the time.

SS And that was in 2019. Let's talk about 2020. There was Covid, and the summer of uprisings in response to the murders of George Floyd and others by police. Arts and cultural organizations were trying to figure out how to contend with the moment, and a lot of projects were foundering or being suspended for a variety of reasons. But AfroRithms from the Future took off. How do you think about those events in relation to where AfroRithms went after that?

LJAB I think AfroRithms definitely filled a need that people were starting to see as glaring. I think of [Alisha B. Wormsley's] billboard: "THERE ARE BLACK PEOPLE IN THE FUTURE." As Black folks were dying and being murdered, there was this intentional vacuuming or erasure of Black folks from the future. But that's not what Black history is really all about—it's always been about the future. I think that's where we kind of met that gap, that yawning chasm that we filled in.

People were starting to recognize Afrofuturism too, and it was becoming more mainstream. I remember seeing *Black Panther* in 2018 at the Grand Lake Theater in Oakland and seeing Oakland reflected in a positive light on the screen. Hearing the community roar around me and seeing powerful women reflected in that film was incredible.

Jade Fabello When I think about AfroRithms specifically, when I first got involved with it, it was around that summer of 2020 with all of the uprisings, the shootings, and the pandemic, of course. I think the first way I got involved was that I was a guest on the Afrofuturist Podcast. Around that time, I had graduated from college and I had written a story called "What I Learned as a Young Black Political Speaker in Liberal White Austin" because I had spent the past few years doing political speaking around town. I had given some speeches during Beto O'Rourke's

JF Senate campaign and interviewed Darren Walker of the Ford Foundation at an event, and I was doing work in those spaces for some time. And with all due respect to the good work that was being done, I also found myself frustrated with what I saw as a lack of imagination in politically elite spaces. There's a line in my essay where I say something like, "If I am not alive in the best future that you can imagine, that's a problem with your imagination."

In November of 2020, on my birthday, I attended a Black Futures event online with these guys. We played AfroRithms there, and the artifact I came up with during that event was an ancestral cloak that you could wrap around yourself and have the memories of your ancestors transmitted to you, and they could guide and comfort you and give you warmth and whatever else you needed as you traveled through the world. [That space of invention] offered such a better answer to me than where I'd been around the same time the previous year. My personal journals from that time capture the contrast between the frustration I'd been experiencing before and the liberation of spaces where we were playing AfroRithms, and of Black Futures spaces.

SS The three of you approach this work with so much positivity and optimism. Ahmed, you're really explicit about setting a tone in AfroRithms workshops and meetups. It's not, "Should we be doing this?" but rather, "How are we going to get this done?" Where does that sense of possibility come from for all three of you?

AB Sheer rage. For me, being an artist and committing to being an artist, I have the ability to kind of do whatever I set my mind to. But for some reason, everybody thinks they can tell me what I can't do. I've always faced this thing: "Well, you can't because . . ." And for a short amount of time, I would believe it, until I would shake myself out of the stupor and be like, "Well, you're saying this because *you* can't, not because *I* can't." Coming from the worlds of Hollywood and big music, I eventually came to this realization that the only reason why you're telling me "No" is to stop me or slow me down, because the diversity of my opinions and my ability to do things scare you—and I'm not afraid.

So radical optimism is what I doubled down on. I also doubled down on this idea that, as James Baldwin says, "I'm an optimist because I'm alive." If you are a pessimist, there's no reason to go on. I know there are a lot of Afropessimists out there who believe that our existence throughout time on this plane of existence is one of pain and suffering, and I completely disagree with that.





AB The anthropologist and writer Nathalie Etoke says that Black folks are existentialists whether you like it or not. And I like to expand that into Black folks are futurists whether you like it or not. Because there is no way you can move on in the present—move toward the future after surviving the apocalypse—where you cannot be a futurist. We can't afford not to be.

LJAB For me, it comes out of my direct ancestry and genetic challenges, because I grew up partly blind, a child of a Black-Jewish marriage, Black–Jewish–Native American. I knew right away I had some strikes against me, and I couldn't see in school. People thought I wasn't capable enough because I just couldn't see the board. And I was like, "That's bullshit and I'm going to prove them wrong."

Looking at *Star Trek* emboldened me to say, "Hey, technology can be my ally," which it was, because it enabled me to do all sorts of things with bigger font. And then there were heroes like Lieutenant Uhura and Geordi La Forge, who was flying in *Star Trek: The Next Generation*. Those characters influenced me to say, "I can do this. I can be a mathematician. I can do things with a combined three thousand years of oppression behind me."

Growing up in the Jewish Community Center, going on walks through Israel at the time when Israel was almost annihilated in the '70s—my dad would tell me that Arabs are brothers, too. My dad was a writer and created a foundation for struggling Black artists. He did an interview with *Amos 'n' Andy*. He came from Kansas City, Missouri, having maybe two years of college education. He ended up in all these organizational spaces that, when I look back at it now, people would say he couldn't have done that, and he did it.

I think what I wanted was really to see the future and to imagine that future—and that's what I've been influenced by. So when I joined the

Above left: Ahmed Best, Lonny J. Avi Brooks, and Jade Fabello facilitate AfroRithms SynBiosis, a themed version of AfroRithms from the Future, with special guest David Sun Kong of the MIT Media Lab, Walt Disney Concert Hall Founders Room, Los Angeles, 2023. Courtesy of Fathomers. Photo: Alicia Afshar. **Above right:** Ahmed Best leads a playtest of AfroRithms from the Future, Leimert Park, Los Angeles, 2019. Courtesy of Fathomers.





Top: Lonny J. Avi Brooks speaks at the AEVN Design and Development Convening, The Interval at the Long Now Foundation, San Francisco, 2022. Courtesy of Fathomers. **Bottom:** Jade Fabello and Ahmed Best behind the scenes during the production of *MultiPlanetary Garden*, Envizion Studio, Los Angeles, 2024. Courtesy of Fathomers.

LJAB Institute for the Future in the '90s and I saw that there wasn't a Black presence there, [I wasn't] seeing myself in there, it really emboldened me to say, "Hey, let's make this happen."

JF One thing we've seen a lot with this work is how people define themselves in narrow lanes: "Oh, I'm not a math person." "Oh, I'm not a science person." "Oh, I'm not a creative person." We like to emphasize that there is plurality and depth to people, and to push back against the idea that these various fields of study aren't connected. They very much are. Synbio and all the other things we like to mix, AfroRithms—none of it is disconnected. Your creativity in one space can apply to another.

SS Let's talk more about where AfroRithms meets synthetic biology. How can they intersect?

AB Synthetic biology and AfroRithms are a very natural fit. We met Drew Endy when we were teaching a class in the design school at Stanford. Drew loved how we were putting things together to create future artifacts as part of the game. The way Drew looks at synthetic biology is that it's about putting things together, and that's what AfroRithms does too. We combine objects, inspirations, and systems to make a new thing that exists on a new planet in a new universe. It really opens up the radical imagination to create a thing that's inspired by synthetic biology. And synthetic biologists like Drew and David Kong at MIT have a really natural way of playing the game with us. It's almost as if the game is tailor-made to a kind of synbio thinking, which is extremely creative. Both AfroRithms and synthetic biology embrace the idea of wonder.

LJAB My personal perspective is that not only was I partially blind but I have had diabetes since I was eleven. Seeing the evolution of synthetic insulin over time and knowing that it's kept me alive—these technological breakthroughs that were only discovered as independent compounds years ago [in 1921]—before that time, I could have died at eleven. So in terms of complexity, putting those puzzle pieces together and creating something new is really important to me because it also describes my whole background. It's combinations of ethnicities that people would say don't go together. I remember Reynaldo Anderson saying he'd never met a Black Jewish person in his life. Understanding that there are these really interesting combinations that can come together, that synthetic biology and AfroRithms can unleash . . .

If AfroRithms can do that for scientists, especially those who might be working on the next insulin, the next cure for cancer—to help bring

LJAB imagination into the mix—then it's worth it. That's the cultural component of science. As a scholar of the social study of science, I know that science is biased in various ways and can be linearized to where it can forget really important things that come from the Black experience, from the Indigenous experience, and from ancient healing techniques and approaches too.

Going back to our ancestral intelligence, seeing the thriving of civilizations that were erased within the span of five hundred years—when millions of Natives died and millions of Africans were taken into enslavement and born in the Americas—and rediscovering that wealth of knowledge that was lost, in new combinations and with biosynthetic technology, can really amplify our intelligence into the future. There is Black science and Indigenous science in the future. And that's really important.

SS Where do you go from here? What's next for AfroRithms?

AB I think it's important to recognize that we are just beginning. It's not necessarily about the game itself, but about this ability to access the radical imagination in order to produce agency and ideas for generations to come. We always talk about AfroRithms as a tool, but it's not the only tool. It's the beginnings of a tool kit, and the idea is to continue evolving and moving forward so that accessing your radical imagination in future generations isn't something anomalous.

I love the Indigenous idea of seven generations: Anything you do right now, you're doing for seven generations ahead of you. With AfroRithms, I look at it as the building blocks for a figurative or physical library where every kid could come in and feel safe, and it has to grow for generations. It's a legacy of knowledge, imagination, and tools.

LJAB When I think of legacy, I think about how we've been able to create programs like the Community Futures School, an after-school program for high schoolers and middle schoolers. Students are taught to intentionally think about the future through the lens of Afrofuturism, queer futurism, and Indigenous futurism. Seeing our kids play the AfroRithms game at Stanford in the class we offered really speaks to the legacy we want to see go forward.

JF When I think about AfroRithms and its future impact, I see it as a tool for addressing those feelings of dread and existential angst that many people face when confronting global issues like climate change or the rise of fascism. It's about not just sitting within those feelings of dread but confronting them the same way you would any other kind of trauma.

AB Within AfroRithm Futures Group, we like to talk about reverence for the past, awareness of the present, and creativity for the future. There is a lot of pessimism out there right now. There is a lot to be extremely frustrated and upset with. There are feelings about authoritarianism taking over the world, but any time this has happened in history, what it has really done is excite a renaissance. People are already creating the work-arounds. Everyone is being creative, finding ways to get past the guardrails, get past the internet blocks, read the books that are being banned, find each other, have these conversations.

One of the most profound ideas of AfroRithms is understanding Black people specifically as already being a postapocalyptic people, and understanding that people do exist after catastrophe. You have to imagine your way out of it and think about the people who will exist regardless of the outcomes. I'm reminded of this idea about how enslaved Africans were brought onto the decks of the slave ships and told to dance to keep them in shape. The slave masters didn't want to end up in the New World with sickly, weak-looking enslaved people. They wouldn't sell. So the slave masters would bring them all onto the deck of the ship, and they would play European instruments, and they told the enslaved Africans to dance.



Lonny J. Avi Brooks and Ahmed Best at Science Speed Dating, an evening of short presentations by leading scientists in a range of fields, copresented by the Science & Entertainment Exchange, a program of the National Academy of Sciences, with Fathomers and the Afrofuturist Podcast, and held at the California NanoSystems Institute at UCLA, Los Angeles, 2019. Courtesy of Fathomers. Photo: Lance Williams.

AB Now we're talking about a diverse group of people, tribes from all over the continent who didn't know each other's dances—they barely knew each other's languages—but they came up with something on that deck that was new. They got together, breathing in the right tempo. They found a movement, and they created this new movement. In that instant, the diaspora was born. *Boom*. A new thing happened, and the collective movement was the collective idea of how we survive in the future, how we survive through an apocalypse, how we survive being abducted from our homes, and how we come together even though we speak different languages and we move differently. It's documented that most of those dance sessions were followed by a revolt.

Right now, we are coming up with a new dance. We are being oppressed and told that we're living in this age where we're all being corralled into one way of thinking. But just like those enslaved Africans on slave ships who created new dances and movements, there is about to be a revolt. The seeds of AfroRithms are out there in the world.

It empowered the enslaved Africans to recognize that there was a way out of this, and they risked their lives to get out of it. Right now, we are coming up with the new dance. My hope is we can be part of the new thing that comes out of it when the renaissance does happen. And I'm extremely optimistic that the renaissance will happen.

SS Thank you, Ahmed. That's a great way of bringing it back to the project. So, more to come on those dances.

AB That's right. Keep dancing. Let's keep dancing.



Attendees join the dancers on stage after the live performance of *MultiPlanetary Garden* at the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.



How to Play *AfroRithms from the Future*

Players:
2–∞
30–45
cooperative
minutes

AfroRithms from the Future (ARFTF) is a cooperative design, exploration, and storytelling game that centers Black and Indigenous perspectives. Each player is a traveler of the multiverse, exploring possible futures and creating exciting new artifacts to send back out to all of the other parallel worlds.

The objective is simple: Activate your radical imagination by talking about the future! The game ends when you as a collective have decided on the best artifact to share with the rest of the multiverse.

To play,
you'll need:

ARFTF card deck
Pen and paper

A: Assign Roles

There are two unique multiversal travelers, the Seer and the Librarian.

The Seer is the guide of the game. They keep track of time and keep the conversation moving. The Seer also ensures that each traveler has their voice heard.

The Librarian is the researcher and scribe of the journey. They synthesize ideas and keep a list of all the artifacts created by the group. If the group doesn't know a term, it is the Librarian's role to look it up. The Librarian will need a pen and paper.

For big groups, there is the additional, optional traveler role of the Listeneer.

The Listeneer observes the conversation and illustrates artifacts created by the collective.

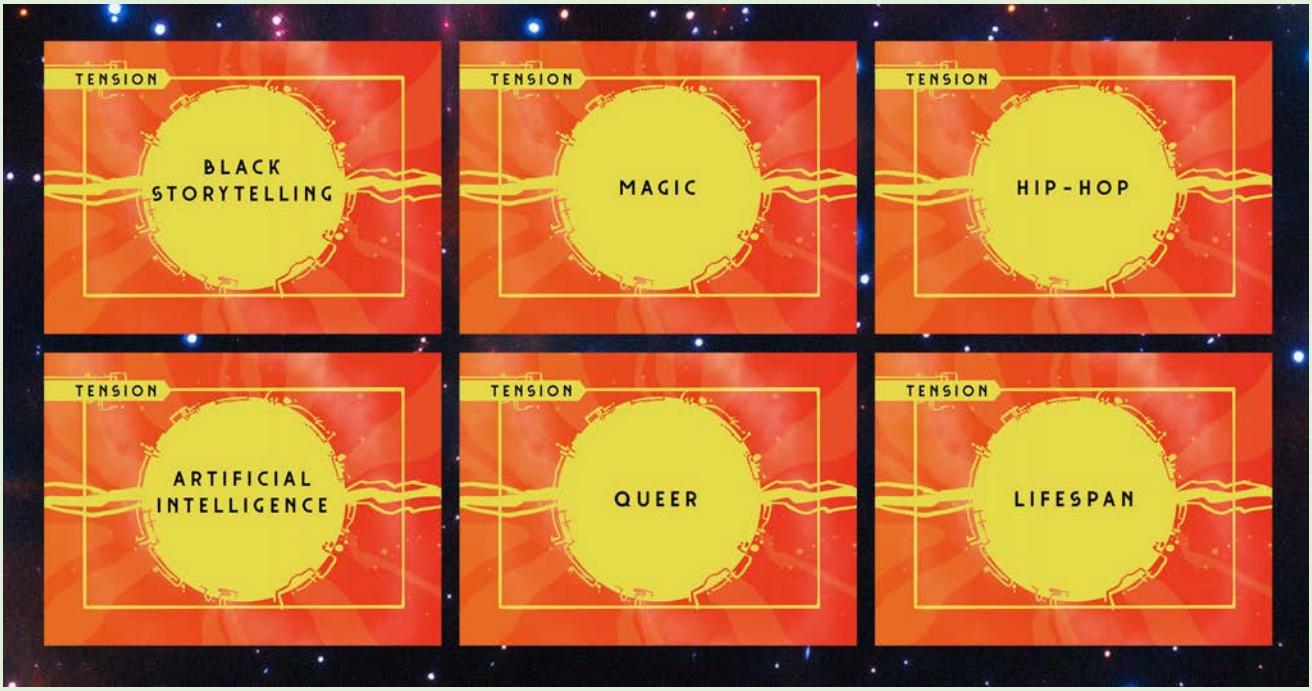
Either a volunteer or the traveler with the most recent birthday is the Seer, and either a volunteer or the player to the left of the Seer is the Librarian.

B: Set Up Board

There are four decks of cards: red tension cards, blue object cards, green inspiration cards, and purple system cards.

Separate each deck by color and shuffle the decks individually.

Draw six tension cards and place them face up on a flat surface in the center of the group.

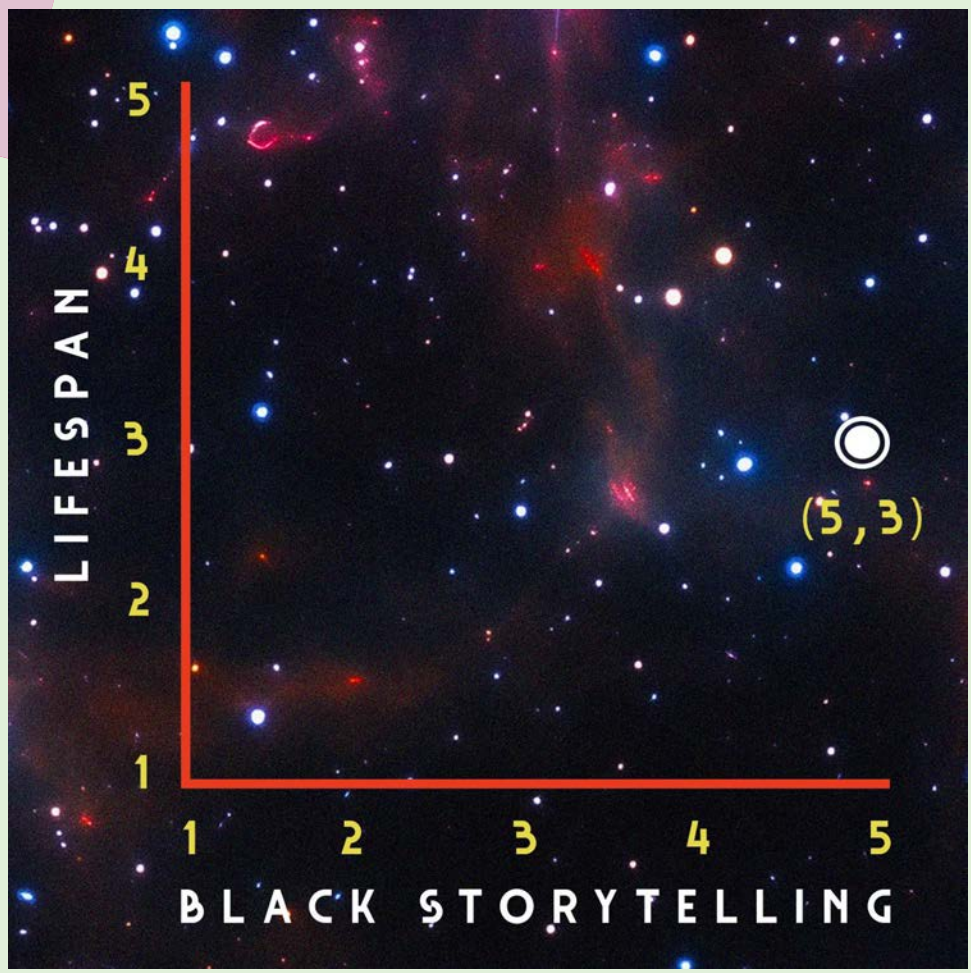


B: Set Up Board (cont.)

Create your map:

On a sheet of paper, draw a standard graph with an *x*-axis and *y*-axis. Don't label the axes just yet.

It's time to start traveling.



C: Gameplay

From here, the group of travelers will do two things: define the world and create artifacts from that world through conversation.

There are no turns in AfroRithms from the Future. The Seer is responsible for making sure every voice is heard, so when you have an idea, throw it out there.

The game ends when the group selects the obelisk, which is the best artifact to represent your world.

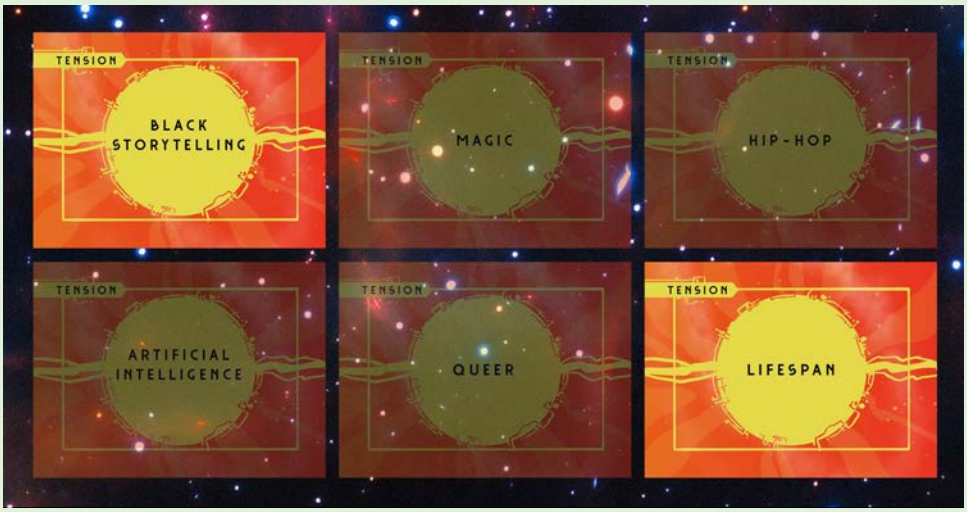
01: Create the World

Choose your tensions:

Choose two tensions that will define your world. Tensions are variables that can shape the future. For instance, will this world have more or less Black Storytelling? Will it have more or less Lifespan?

Spend three minutes discussing the six available tensions and what they mean. Every player gets two votes, and the two tensions with the highest total votes will define the world going forward. The Librarian tallies the votes.

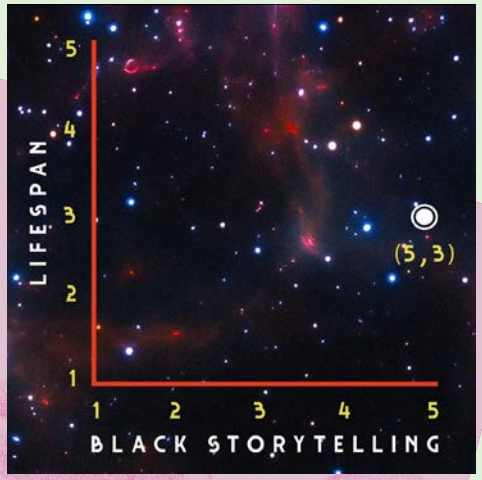
Spend a few more minutes going around and discussing what the two chosen tensions mean to your group. Dictionary definition does not matter; the definition your group decides on right here, right now is what counts.



02: Chart a Point on the Map

Your group must now decide where to create your world. The point at which you place your world will intersect at two tension points on your map.

Collectively decide the levels of intensity for each of the two tensions on a scale of 1 to 5, with 1 being a low amount of that tension and 5 being a very high amount. For example, a world with 5 Black Storytelling and 3 Lifespan has a lot of Black Storytelling and a middling Lifespan.



As you create your world, consider that one person's utopia can be another person's dystopia.

03: Create Artifacts

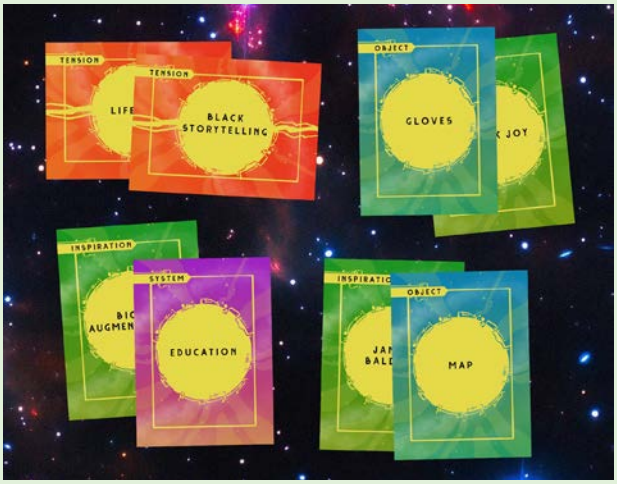
(15–20 minutes)

Draw from the other decks: Draw three inspiration cards, three object cards, and one system card. Place each card face up for the group to see.

Combine cards to make artifacts: Keeping the world you created in mind, combine one or more inspiration cards with an object or system card to create an artifact from this world—for instance, gloves inspired by Black Joy that create holograms of a story told in sign language.

Name artifacts: Go around the group and suggest new combinations or build on a previous idea. The Librarian will synthesize ideas and come up with names for the artifacts with the help of the group. As an example, if you create a map that shows you a path to navigating your fluidity, you might call it The Map of 1000 Selves.





04: Select Obelisk

Decide on the best artifact: Review all of the artifacts created. Every player now votes on which artifact best represents the overall vision of your world. That artifact becomes the obelisk that represents your world in the multiverse!

With that, you have completed a round of AfroRithms from the Future.

Another round: Reenter the journey at tension selection or draw new inspirations, objects, and systems. Pass the roles of Seer and Librarian to new travelers, and keep creating!

Share your favorite experiences, stories, and gameplay with us @afrorithmfutures or throughout the multiverse by using the hashtag #ARFTF or #AFRORITHMS.

A Selection of Artifacts Collaboratively Invented Through AfroRithms Gameplay, 2019–2024

Compiled by Blessing Greer-Mathurin

Tenderness Tincture =
Healthcare + Biomedical Engineering + Mental Health

Empathy-enhancing power syrup or other consumable that allows sharing of perspectives
Live game, Creative Change Conference, Detroit, 2019

Air Mycelia =
Social Justice Shoes + Sports + Decolonization

Ancestral network–guiding shoes
Live game, Museum of Children's Art, Oakland, CA, 2019

EndoGloves =
Gender + Biomedical Engineering + Healthcare

Gloves with buttons that can regulate hormones, birth control, and emotions
Live game, NeueHouse Hollywood, Los Angeles, 2019

Skirt of Ancestral Comfort =
Bio-Fabrication

Live game, Astro Egalitarian Virtual Network Convening I, The Interval at the Long Now Foundation, San Francisco, 2022

Seed Weaves of Longevity and Storytelling (Reclaiming What Was Lost) =
Decolonization + Agriculture + Bio-Fabrication + Reparations

Live game, AfroRithms SynBiosis event, Walt Disney Concert Hall Founders Room, Los Angeles, 2023

Multi-Spirit Housing Project =
Queer Liberation + AI + Housing + Afterlife

Where do our ancestors live? How do we communicate with them and invite them to weigh in on our world?
Online game, Astro Egalitarian Virtual Network Convening II, 2024

Umwelt Education =
No Border + Education

A tool to offer multiple worldview-level perspectives at all moments in education
Online game, Astro Egalitarian Virtual Network Convening II, 2024

Cruelty *and* Afrofuturism

Afrofuturism combines science fiction and fantasy to reexamine how the future is currently imagined, and to reconstruct futures thinking with a deeper insight into the black experience, especially as slavery forced Africans to confront an alien world surrounded by colonial technologies.[1] Afrofuturism is born out of cruelty, and that cruelty of the white imagination was a necessary condition out of which the African diaspora had to reimagine its future. Rhetorically, Afrofuturism aims to reclaim and transform the trauma of past atrocities against the black and Afro-queer diaspora. Think of the Middle Passage as a science fiction horror where black people were transported from western Africa, the home planet of the black diaspora, and where previously unseen technologies of transportation and bondage were used to dislocate, kidnap large numbers of people to a new world.[2] In this world, they had to innovate, adapt, capitulate, succumb, and rebuild their former lives and traditions. The *Black Panther* comics, for example, reflect an Afrofuturist reimagining of African futures through its superhero T'Challa and the technologically advanced and secret nation of Wakanda.[3] The white cruelty ironically served as the pathway to Afrofuturism and the imagining of more powerful futures for the black diaspora.

Now, in the Age of Trump, we are confronted with a resurgence of patriarchal authority that seeks to deny and reverse advances in civil rights and restore a time where everyone knew their place in the hierarchy of white supremacy.[4] Our current present recapitulates in part the cruelty of the last centuries, and demands that we recreate stronger alternative futures. Imagining new futures can serve as a strategy to understand the nature of cruelty, and how we negotiate with cruel acts as constitutive of our greatest aspirations. As Giorgio Baruchello states, "Embracing the cruel character of existence might serve itself as a precondition for any meaningful life to be lived."[5] I argue that affirming pathways that use cruelty against itself can function as a fulcrum to reduce its trauma. In this essay, I integrate Afrofuturism and game studies as a pathway and route in supplanting cruelty and reducing the space it occupies. Specifically, I discuss the use of Game Jams to bring into existence new artifacts and strategies to embrace cruel truths while amplifying and developing better futures.

The Game Jam is an event in which game developers, made up of designers, artists, social scientists, from amateur to professional get together, develop a game, and release it in an extremely short period. A relatively recent phenomenon dating back to 2002, Game Jams take place across institutions and communities.[6] Distinct in theme and composition of participant skill sets and outcomes, they all share the requirement of developing a gamelike experience, a piece of playable media within a set of constraints typically taking place within twenty-four to seventy-two hours. These limitations include time and specific, local technologies. Game Jams serve as social catalysts, creating individual social capacity, communities of practice, and friendships that extend well beyond the duration of the event. My colleague Ian Pollock and I have integrated Afrofuturism with the Minority Reports Game Jam in May 2017 to address cruel dilemmas by developing software and board games to augment our imaginative capacities to deal with our fears and plan what game players call "epic wins." According to Jane McGonigal, an epic win is "an outcome that is so extraordinarily positive,

As Giorgio Baruchello states, "Embracing the cruel character of existence might serve itself as a precondition for any meaningful life to be lived."

you had no idea it was even possible until you achieved it. It was almost beyond the threshold of imagination, and when you get there, you're shocked to discover what you're truly capable of."[7] The epic win forms the pathway to rewire our minds to reframe and diminish the debilitating aspects of cruelty that constrain us.

For analysis and inspiration for what Afrofuturist stories offer as counterstrategies to cruelty, Octavia Butler's *Parable of the Sower* (1993), for example, represents an Afrofuturist tale set in the 2020s amid a dystopic backdrop of climate change, increased wealth disparity, and hypercorporate reach.[8] The protagonist of this parable, Lauren Oya Olamina, develops her gift for hyperempathy and sharing. Living in a gated community in Los Angeles, her family is attacked and murdered, leaving Lauren to form a new community borne from her newfound power and religious awakening. She is a Sensitive, one who senses people's pain and sensations. Her pain becomes a conduit to creating a new religion she dubs Earthseed. In this manner, the chaos of world events and the subsequent murder of Lauren's family becomes a call to provide a painful, new beginning and a call for a new future. Cruelty in its traditional definition means the "callous indifference to or pleasure in causing pain and suffering" of others.[9] Baruchello states how "cruelty possesses a tragic dimension, i.e. that cruelty may only be reduced and not eliminated *in toto*. We might even want to avoid its extensive elimination as a desirable goal, for there may be cruelties capable of enriching life."[10]

The main character in *Parable of the Sower*, Lauren, addresses the victims and the nature of cruelty by offering a pathway toward alternative futures and updates biblical themes by proclaiming how "a victim of God may, / Through learning adaptation, / Become a partner of God, / A victim of God may, / Through forethought and planning, / Become a shaper of God. / Or a victim of God may, / Through shortsightedness and fear, / Remain God's victim, / God's plaything, / God's prey."[11] Butler's is part of a lineage in the black diasporic traditions where the cruelty of bondage and murder become portholes to redemption. In reimagining what God means in terms of an Afrofuturist perspective, we can understand the role that the nonwhite imagination can play as a pathway to new potential among cruel surroundings. Butler's tale reflects processes of a double consciousness that have inhabited black slaves and emancipated culture for centuries: the ability to evoke and find new affordances (openings) and empowered meanings alongside cruel impositions and dislocations. W. E. B. Dubois [*sic*] describes this double entendre and how it forces black people to see themselves "through the revelation of the other world. It is a peculiar sensation, this double-consciousness, this sense of always looking at one's self through the eyes of others."[12] Simultaneously, this cruelty allows and enables a second sight in having to create new healing psalms, rhythms, and salves from scratch, from threads of torn ancestral remembrances from the crossing of the Middle Passage.



According to Gina Neff and Peter Nagy, imagined affordances reflect the imagined uses, values, and expectations users have about technology compared with what designers intended, a similar process that already reflects what the black diaspora has had long practice in honing.[13] For my purposes, imagined affordances enable black people in the diaspora to strive for more within the hostile environments that have accompanied slavery and its traumatic aftermath. I expand the term here to discuss how black people and other marginalized groups have had to embed their environments on a daily basis with imagined affordances to see and expect more from

Game Jams create a space in which participants can reinterpret prior memories in the service of the forgotten histories and the counterfutures we aim to recover.

the cultural artifacts and tools than what was intended by their original designers, or in the black diasporic case, our captors and enslavers. For example, imagined affordances include black cultural technologies such as music, where the hymns of imposed Christianity became the odes of freedom and the seeds of rebellion. Imagined affordances thus include visions of what black people might expect from our technological landscapes, and see within them the unintended uses and values which white male engineers at major computer and media companies usually ignore.

Game design and Afrofuturist scholars argue that the design and implementation of new digital media, from Game Jams and black and queer game aesthetics to podcasts, can function as a cognitive prosthetics to transform cruelty and helplessness into redemptive action and empowering futures. The resilience of the black diaspora holds clues to building alternative futures in the midst of cruel strangers. This mental agility leads us to consider recent work of neuropolitics,[14] a "framework that allows us to reimagine culture, power, and political subjectivity in the light of our increasing knowledge about the human brain and extended mind."[15] Neuroscience research, and its study of the brain, offers insight into learning and memory, and designing our organizations to support our mental development.

In defining *neuropolitics*, Jake Dunagan calls for the need "to create alternative memories of the future" and exhorts us to create designer imagination environments.[16] For the black diaspora, this focus intersects with the soul of black speculative history where, as Kodwo Eshun argues, "Afrofuturism may be characterized as a program for recovering the histories of counter-futures created in a century hostile to Afrodiasporic projection and as a space within which the critical work of manufacturing tools capable of intervention in the current political dispensation may be undertaken."[17] Game Jams can rework our memories by creating new scenes and new futures that jam and renew positive associative pathways. Game Jams create a space in which participants can reinterpret prior memories in the service of the forgotten histories and the counterfutures we aim to recover. I view Game Jams as a call for a futures therapy of the mind to jam epigenetics of trauma. As we stand in the twilight zone of horror, where regressive political policies reassert their ugly grip, black speculative pathways offer more than hope. We can leverage the powerful insights of neuropolitics to provide the cognitive basis for our own liberating Afrofuturescape.

In scanning and imagining new signals to assert new empowering Afrofuturescapes, tools such as Game Jams can facilitate novel memories of black alternative futures that step beyond dystopias. We call these signals *afrofuturetypes*. Lisa Nakamura coined the term cybertype "to describe the distinctive ways that the Internet propagates, disseminates, and commodifies images of race and racism."[18] Afrofuturetypes extend her work to include Afrofuturist visions of new imagined black political actors/subjects. Simultaneously, Afrofuturetypes act as a basis for critiquing current images of the future circulating as science fiction capital in popular culture. Afrofuturetypes allows us to interrogate and reimagine these images with greater nuance and with the mindful agency of black and other marginalized groups in mind.

The Thing from the Future: A Minority Report 2054 Experimental Game Jam Session

In March 2017, we held an experimental Game Jam session with about five predominately female and minority students and two faculty members (Ian Pollock, director of the interaction design graduate program and Game Jam facilitator and Lonny Brooks, Afrofuturist and co-Game Jam facilitator), at California State University, East Bay [CSUEB], located in Hayward, California. In the session, we reimagined a popular forecasting card game known as The Thing from the Future.[19] Designed by Stuart Candy and Jeff Watson, The Thing from the Future makes imagining the future accessible to a wider audience. While the game is successful in making the future accessible and provocative, we wanted to add greater elements of the black and minority imagination to its design, using the game as a springboard to create and repurpose board games that address Afrofuturist perspectives. In this manner, forecast gaming addresses the possibilities for intervention into the present by reflecting on possible black futures. With four undergraduate students, one graduate student, and two professors, we hacked up The Thing from the Future to infuse it with the black vernacular.

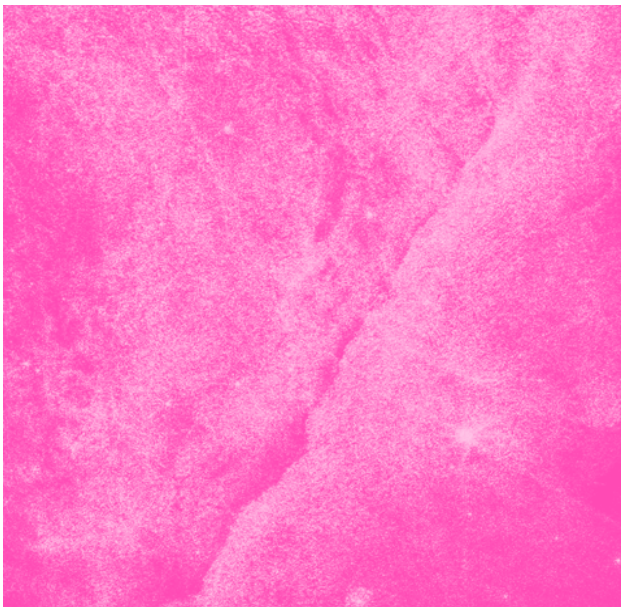
By walking through the object of the game and the topics the game cards name and offer, we transformed *The* Thing from the Future into *Our* Thing from the Future with the techno-vernacular of the Black Fantastic imprinted into the nomenclature and labels as the central focus of the card deck. Our Thing from the Future represents our portal, our voice and Afrofuturescape.

The object of the game is to come up with the most entertaining and thought-provoking descriptions of hypothetical objects from different near-, medium-, and long-term futures. During each round, players collectively generate a creative prompt by playing a card game. This prompt outlines the kind of future that the thing-to-be-imagined comes from, specifies what part of society or culture it belongs to, describes the type of object that it is, and suggests an emotional reaction that it might spark in an observer from the present. Players must then write a short description of an object that fits the constraints of the prompt. These descriptions are read aloud (without attribution), and players vote on which description they find the most interesting, provocative, or funny. The winner of each round keeps the cards put into play during that round, and whoever has the most cards when the game ends is declared the overall winner.[20]

Black people have always, at some level, had to act as quantum futurists, building and holding multiple truths that sought to annihilate and affirm their existence.

Four types of cards compose Our Thing from the Future: Arc, Terrain, Object, and Mood. Each round, players generate a four-card creative prompt containing one of each kind of card. Based on this prompt, players will imagine a thing from the future, describe it, and sketch it. Thus, players have the chance to engage in an artistic rendering of their imagined object. We can then use player images as Afroscapes into new times and reframe how time might operate as well.

Arc cards broadly describe different kinds of possible futures. These cards contain two kinds of information. The main text of each Arc card specifies one of four generic images of alternative futures for players to imagine: Grow, Collapse, Discipline, or Transform. A time horizon—



a specific segment of time projected into the future—accompanies each Arc card and scenario. Time horizons for the game include a half decade ahead, a decade in the future, a generation from now, a half century to a century ahead, to imagining a full millennium into the future.

The Grow card, Jim Dator defines as "'continued growth' . . . the 'official' view of the future of all modern governments, educational systems, and organizations. The purpose of government, education, and all aspects of life in the present and recent past, is to build a vibrant economy, and to develop the people, institutions, and technologies to keep the economy growing and changing, forever."[21] Of all of the scenarios, Growth represents growing optimism as well. Candy and Watson condense Dator's scenario possibilities in their forecasting game The Thing from the Future by describing the scenario Collapse as a kind of future in which life as we know it has fallen—or is falling—apart. Discipline is a kind of future in which things are carefully managed by concerted coordination, perhaps top-down or perhaps collaboratively. Transform is a kind of future in which a profound historical transition has occurred, whether spiritual or technological in nature.

The remaining cards intend to materialize the thing from the future in more concrete terms by describing one's imagined object from the future, its context, and the mood it generates based in the present.

During our experimental session, each participating student was given a combination of the cards as an introduction to the game. Our intention was to ask ourselves what was missing from the categories and labels of subjects in the Object, Terrain, Mood, and Arc cards. Infusing and re-speaking Mood terms developed rapidly from black sonic vernacular. Beyoncé transformed into a new card as a Mood for being unapologetic about being a black woman while simultaneously moving through restorative steps for justice and forgiveness. Kanye West's persona represented a Mood for idiotic defiance. One African American female student suggested "sex" as a Mood, moving it from the category of Terrain.

The group of students noticed terms absent from the Terrain pile, including immigration, diaspora, race, protest, gay, lesbian, public transport, black tax, privilege, secondary screening, diversity, rave, borders, justice, transgender, and alien abduction. Their inclusion implies different possible futures outside of a traditional white patriarchy, and helps to define an Afrofuturist domain that looks to the cultural periphery and marginalized groups for newfound visions.

Object terms missed vital elements of black practices and local items, such as "handbag." One of the most prominent lyrics from Beyoncé's *Lemonade* reminds us that "the past and present merge to meet us here / what are you hidin' / . . . why can't you see me?"[22] The handbag, with its hot sauce that becomes a baseball bat, shows unrestrained anger that, several stages later, eventually re-embraces love.

The Arc card became another terrain of contested time where we debated the game's bias toward linear conceptions of futures thinking. We shifted its standpoint to behave more

similarly to principles of quantum computing and the central idea of superposition. Quantum computing represents ambiguity, the ability *to be* and *not to be* simultaneously. We found within quantum computing a powerful metaphor for reframing a conventional forecasting game into a quantum forecasting engine that fulfills the prospect of creating new memories and recovered futures—an Afrofuturescape adapting to a quantum computing state. At the core of the veiled and double consciousness of W. E. B. Du Bois's explication of black identity resides the simultaneous truth of quantum physics and its confirmation of the imaginative resilience of the black diaspora to bring into being a myriad of forms of innovative and robust artifacts as shields against and constitutive of cruelty.[23] Black people have always, at some level, had to act as quantum futurists, building and holding multiple truths that sought to annihilate and affirm their existence.

The hacking of Our Thing from the Future provided a new standpoint and generated a novel game. At the end of the session, we created Get in Front of the Fake News, a game that pays homage to protest and incentivized peaceful demonstrations, while protecting their reportage from the online rumor mills of fake news as well as the state-sponsored espionage tactics used to dismantle democratic movements.[24] The game is in further development as a board game, to be distributed by the Multimedia Club at CSUEB. Its rules are:

1) Build a viable protest by joining pieces.

2) Spin the top to point the camera at fake news (to root it out).

3) Intercept the news camera with your protest.

4) Lose protestors if the camera does not get in front of the fake news.



Participants play AfroRithms from the Future at the AEVN Design and Development Convening, The Interval at the Long Now Foundation, San Francisco, 2022. Courtesy of Fathomers.

Conclusion

Afrofuturist scholars in particular understand the history of oppressive cruelty exerted upon the black diaspora as a pathway to the future with Indigenous peoples—who have had their lands stolen and who were likewise ripped from their former "planets"—from imaginary Afro-Caribbean nation states to Australian aboriginal films to Native American science fiction seers.[25] We aim to recover counterfutures, to make new memories, and to imagine virtual, augmented, and real spaces. To navigate these tributaries, black futures yield new, less familiar terms where we mine for the signals comprising constellations of Afrofuturetypes that yield an expansive Afrofuturescape etched in a forecasting language that sings to us as we toil, embrace, and rise above our own metaphorical equivalents of cruelty.

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AfroRithm Futures Group, *MultiPlanetary Garden*, 2024. Video installation, dimensions variable. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.



FATHOMERS

Emergence
創発
Art from Life

October 8–December 15, 2024

Japanese American Cultural & Community Center, Los Angeles

Featuring the work of

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Dr. Marie Bannier Hélaouët, Organoid Group, Hubrecht Institute of the Royal Netherlands Academy of Arts and Sciences and Oncode Institute, The Netherlands; and Dr. Albert Wu, Ophthalmic Stem Cell and Regenerative Medicine Laboratory, Stanford University, with lab members Dr. Aditi Swarup, Dr. Hala Dhowre, Dr. Sanja Bojic, and Julietta Picco

Dr. Callie R. Chappell and Dr. Nasa Sinnott-Armstrong

Michael Jones McKean, with assistance from Dr. Stephen Fong, Professor of Chemical and Life Science Engineering, Virginia Commonwealth University, in cooperation with the Museu de Leiria, Portugal

Eduardo Padilha

Dr. Pat Pataranutaporn

Corinne Okada Takara

Henry Tan, Masato Takemura, Pakchira Chartpanyawut, Weeratouch Pongruengkiat, Woraporn Pongsamart, Dr. Pat Pataranutaporn, Jirapat Thaweechuen, Tanis Phongpisantham, Pongsakorn Wechakarn, Sumeth Klomchitcharoen, and Kookpedz Studio

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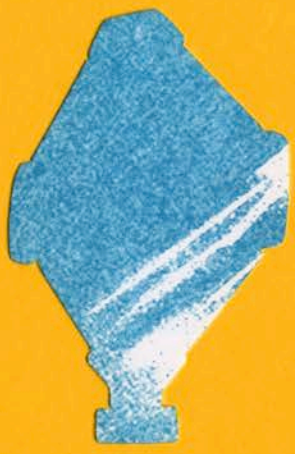
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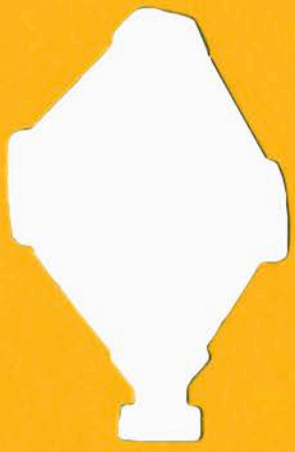
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Emergence

This project is part of *Emergence*, an exhibition organized by Fathomers that ran from October 8 through December 15, 2024, at the Japanese American Cultural & Community Center in Los Angeles.

Emergence assembles artists, scientists, and artist-scientists working at the forefront of synthetic biology and contemporary art. Documentation of their projects as well as relevant writings and interviews, planning sketches, and other contextualizing materials are collected in this catalog. Some contributors draw from their work in medical or transdisciplinary research laboratories, where they confront new categories of life that destabilize our understandings of sentience, hybridity, and artificiality. Others engage the tools of synthetic biology as materials for creative experimentation and studio-based inquiry. Many contributors argue for decolonizing science and expanding access to biotechnologies through DIY and community science initiatives. Across *Emergence*, audiences and participants are invited to contemplate our human capacities for creation, destruction, recklessness, renewal, and hope. The exhibition prompts us to ask: Who has agency in this moment of making, learning, and living with? What forms of life are we choosing to cultivate? What will we nurture, and what might we leave behind?

Projects in the Exhibition

AfroRithm Futures Group
MultiPlanetary Garden

Marie Bannier Hélaouët and Albert Wu
Crying Organoids

Callie R. Chappell and Nasa Sinnott-Armstrong
IndiGROW

Michael Jones McKean
of kin and bone

Eduardo Padilha
Apoptotic Bodies

Pat Pataranutaporn
CyberBiome and *MicroPET*

Corinne Okada Takara
Floating Future Gardens

Henry Tan and Masato Takemura
Pillars of Creation

Tissue Culture & Art Project
The Use of Life (in Relation to the Industry of Men)

Fathomers is a creative research institute dedicated to producing sites and encounters that challenge us to live and act differently in the world. Fathomers cultivates the ideas of diehard dreamers, commissions projects that seem far-fetched, and collaborates with thinkers across disciplines to expand the limits of scale, scope, and support for artist-led projects.

Emergence was presented as part of PST ART: *Art & Science Collide*. PST ART is presented by Getty.

Pillars of Creation

Henry Tan and Masato Takemura

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Pillars of Creation

Henry Tan and Masato Takemura

Introduction by Natasha Boyd

Henry Tan's biomachines eat dreams. Often these dreams are acquired from people sleeping on-site: Tan softens the floors of installation spaces with pillows, blankets, and a gentle, enveloping darkness, then channels the electric signals of willing sleepers. Data collection happens in a shared space of disarming vulnerability, and Tan's cyborgs learn and develop in womb-like quiet. These somnambulant encounters restage the relationship between humanity and technology as an opportunity for the mutual creation of an interspecies future, one still a little beyond the grasp of the waking world. It's not necessarily a utopian vision. For all the tranquility of Tan's scenes, unsettling questions linger: How do we know what's growing while we sleep? Will we like what we see once we wake up?

Tan is a member of both Japan's metaPhorest lab, which describes itself as "a platform for experimentation, research, and production in the realm of 'life'-themed art," and Thailand's FREAK Lab, "an anti-disciplinary research cluster that converges arts, science, and technology for . . . exploring the symbiotic relationship between human and the emerging technologies." In combination with this DIY-science sensibility, many of Tan's pieces draw on mythology from different cultures to interrogate our understanding of how new life comes to be and old worlds end. These works share a public, communal element, reflecting the collaborative process of mythmaking.

Tan's sleep pieces are not always restful. *Semiconductor Dream* (2023) harvests sleepers' biological data for semiconductor chips, conjuring the nocturnal parasitism of half-human phantoms like vampires or incubi. During the Covid-19 pandemic, the United States imposed restrictions on China's largest chip manufacturer, instigating an international shortage even as other manufacturing plants operated at maximum capacity; this crisis led to price increases and supply chain delays in over 150 industries. *Semiconductor Dream* sidesteps this planetary web of labor and commerce for a more intimate form of manufacture. In Tan's piece, an individual's value to the global market can be extracted even while they sleep.

In *Young Eel* (2019), Tan stimulates lab-grown eel meat with brain waves from nearby sleepers, symbolically transferring human memories and visions into new bodies. *Unagi* (freshwater eel) is a staple of Japanese cooking, but overfishing and water contamination have destroyed eel habitats and placed serious pressure on eel populations. The freshwater eel has its place

in Japanese folklore as well: Unagi Hime, the "eel princess," is an enormous shape-shifting eel spirit that can take the form of a woman. She lives at the bottom of deep ponds and lakes, acting as a guardian for these ecosystems. Tan compares an aging, increasingly childless population with the decline of the eel: "Our civilization is polluted like a poisoned ocean; young *unagi*, like humans, do not want to mature and create progeny." Could synthetic eel meat, suffused with the dreams of sleeping humans, bring both populations into the future? On the edge of the mass transformations heralded by the anthropocene, hybridity may be the only way to survive Earth's own metamorphosis.

Pillars of Creation (2024) is a collaboration between Tan and Masato Takemura, another member of metaPhorest, as well as Pakchira Chartpanyawut, Weeratouch Pongruengkiat, Woraporn Pongsamart, Pat Pataranutaporn, Jirapat Thaweechuen, Tanis Phongpisantham, Pongsakorn Wechakarn, Sumeth Klomchitcharoen, and Kookpedz Studio. The sculpture develops the idea of a merged digital-organic organism in a form inspired by the Brahma statue at Erawan Shrine in Bangkok. Brahma figures in both Hindu and Buddhist traditions, but the Brahma at Erawan Shrine is the object of a wider syncretic worship, drawing enthusiastic supplicants of all stripes. Like traditional depictions of Brahma, *Pillars of Creation* has four arms. Each balances a symbolic scientific artifact—representing, in turn, knowledge, time, sacrifice, and cosmic energy—that takes the respective place of Brahma's scroll, rosary, scepter, or water vessel. In some legends, Brahma created himself; Takemura and Tan imply that open-source, DIY biotechnology might allow humans to make themselves into gods. Today, synthetic biology grants scientists the ability to make or modify living beings and even bring extinct species back from the dead. The

question is not whether these new life-forms will come into existence but how they will embody our own anxieties, hopes, and desires. Across *Emergence*, stem cells, yeast, bacteria, and other organic elements pull such questions out of the realm of pure contemplation and into conversation with *Pillars of Creation*—for it, too, is alive.





Henry Tan, Masato Takemura, Pakchira Chartpanyawut, Weeratouch Pongruengkiat, Woraporn Pongsamart, Pat Pataranutaporn, Jirapat Thaweechuen, Tanis Phongpisantham, Pongsakorn Wechakarn, Sumeth Klomchitcharoen, and Kookpedz Studio, *Pillars of Creation*, 2024. Clinostat LED hologram, brain organoid incubator, electrode array prototype, tourbillon dementia clock, DNA printer-synthesizer prototype, laser projection, and *hamsa* rug, approx. 108 1/4 × 86 2/3 × 84 2/3 in. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.

Henry Tan and Masato Takemura



Henry Tan



Masato Takemura

Henry Tan is a member of FREAK Lab Thailand and metaPhorest Japan. Tan investigates how emergent technologies like synthetic biology, mixed reality, brain stimulation, and artificial intelligence blur the line between life and simulation. His installations and performances negotiate a changing environment shaped and reshaped by factors like climate change, geopolitics, and geoeconomics. In 2024, Tan was an artist in residence at NYU Abu Dhabi's Center for Genomics and Systems Biology.

Masato Takemura is one of the founders of FabLab Hamamatsu in Japan, which he has directed since 2014. FabLab provides public workshops at the intersection of art and science to local governments and education programs, with courses on soldering, programming, 3D printing, 3D modeling, and more. FabLab has recently collaborated with science museums in Rwanda, Bhutan, and Indonesia. Through his project *HTEAA: How to Eat (Almost) Anything*, Takemura also leads a series of food-related experimental performances that have debuted in Seoul, Tokyo, Taipei, Boston, Santiago de Chile, Shenzhen, Mexico, Indonesia, and other parts of the world.

Henry Tan and Masato Takemura made *Pillars of Creation* (2024) in collaboration with Pakchira Chartpanyawut, Weeratouch Pongruengkiat, Woraporn Pongsamart, Pat Pataranutaporn, Jirapat Thaweechuen, Tanis Phongpisantham, Pongsakorn Wechakarn, Sumeth Klomchitcharoen, and Kookpedz Studio.



Henry Tan, Masato Takemura, and collaborators, *Pillars of Creation*, 2024. Installation view: The artwork in motion, *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.



Dr. Yewande Pearse, the director of science editorial and content for *Emergence*, and artist Henry Tan met biweekly to discuss his grand vision for *Pillars of Creation* (2024), guided by his intricate and infamous vision board. In the final months leading up to the opening of the exhibition, as Tan worked with a team of artists and scientists to bring his concepts to life, he took some time amid the intensity of the ambitious project to walk Pearse through his vision board and update her on their progress.

Their conversation delved into Tan's creation of hybrid entities—living cells on microchips—along with his explorations into sleep, surveillance, and the ethics of cellular technology. They discussed the technical challenges of building clinostats and his plans to introduce EEG data from sleeping participants into the organoids, raising questions about privacy, data capitalism, and the boundaries of human influence over life itself. With *Pillars of Creation*, Tan invites viewers to reflect on how our evolving relationships with technology reshape our understanding of life.



On Dreams, Hybrid Entities, and the Ethics of Manipulating Life

Henry Tan in Conversation with Yewande Pearse

Yewande Pearse

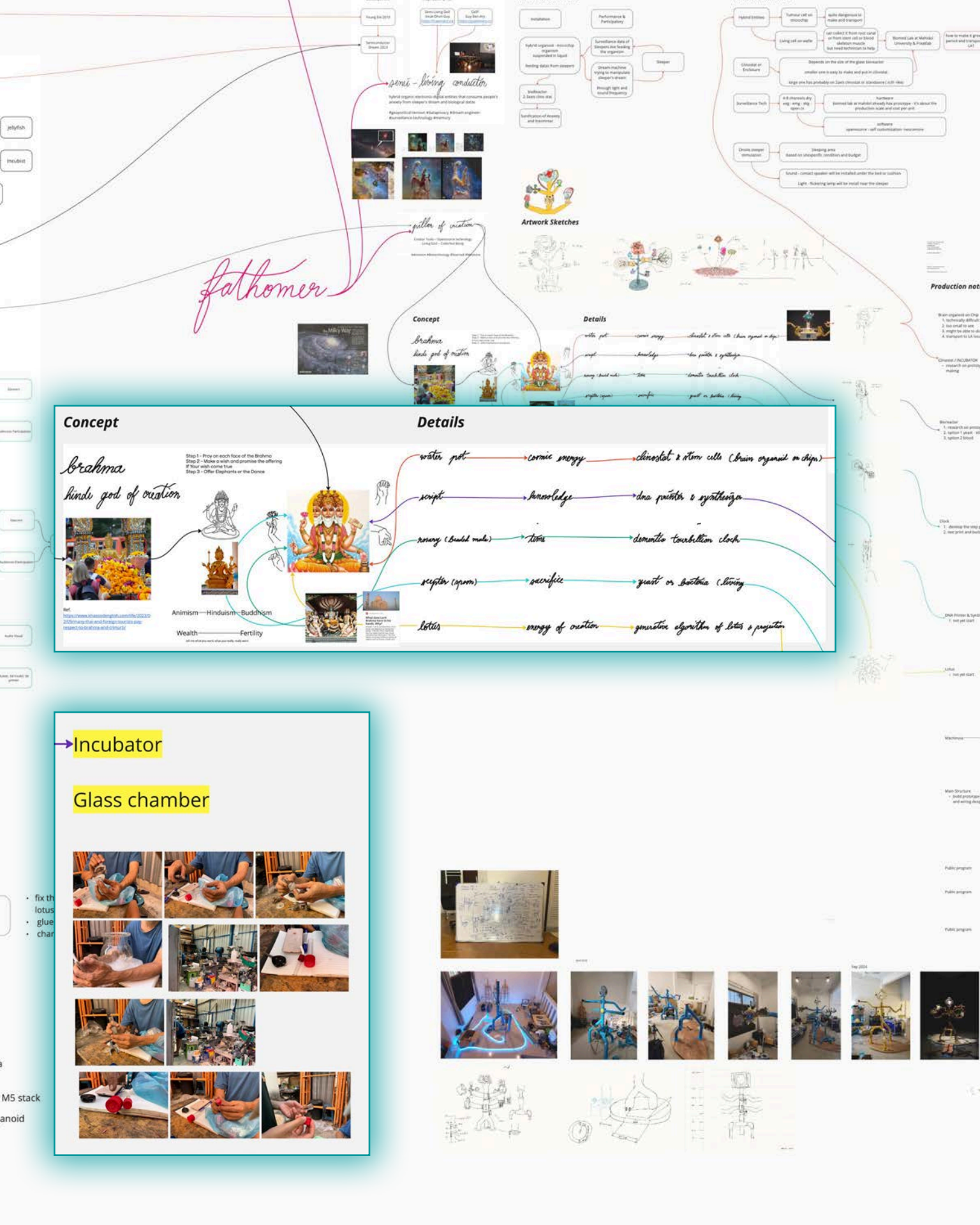
Looking at your vision board feels like peering through a window into your mind: It lays out multiple interconnecting projects in such intricate detail. Which parts of this project grew from prior curiosities and which were developed specifically for *Emergence*?

Henry Tan

The invitation from Fathomers came at a time when my practice and research were connecting different topics and subjects I was already exploring. I'd been researching sleep and was inspired by space exploration. I wanted to explore different possibilities and perspectives on life: how we define it, and even the choreography of life—what movement or rhythm life follows. Some ideas, like *Pillars of Creation*, were in draft form for a while, but they began to take shape earlier this year. Collaborating with Fathomers allowed the project to grow, emerging into something more concrete.

After the *Emergence* convening last October, I was inspired by Ionat Zurr and Oron Catts's semi-living dolls, which connected with my earlier projects like *Young Eel* (2019), exploring artificial meat. This project evolved to address geopolitical issues, ultimately becoming *Semiconductor Dream* (2023), a performance piece I developed with colleagues. Over time, these ideas merged into *Semi-Living Conductor*, a hybrid entity that forms another component of the project, creating a dialogue with Ionat's work and my research on sleep, dreams, and surveillance technologies.

Above: Henry Tan, Masato Takemura, and collaborators, *Pillars of Creation*, 2024. Detail: 3D-printed kinetic lotus. Courtesy of Fathomers. Photo: Carson Davis Brown. **Following spread:** Henry Tan, Miro board tracking the design of *Pillars of Creation* from start to finish, 2024–ongoing.


fathomer
semi-living conductor
pillar of creation
Artwork Sketches
Concept
brahma
hindu god of creation
Details
water pot
cosmic energy
clinostat & stem cells (brain organoid on chips)
script
knowledge
dna printer & synthesizer
rosary (beaded mala)
time
drumitz tourbillon clock
scepter (spoon)
sacrifice
yeast or bacteria (living
lotus
energy of creation
generative algorithm of lotus & projection
Animism—Hinduism—Buddhism
Wealth——Fertility
Incubator
Glass chamber
jellyfish
incubist
Production not

Collective Dream & Anxiety

Stimulation

Semi-Living Conductor

Protein - Kibra - Oxphos

Brain Organoid +Semiconductor

Reverse De differentiation

MEA

VASes

Aparna

application brief
on how to work with organoid use

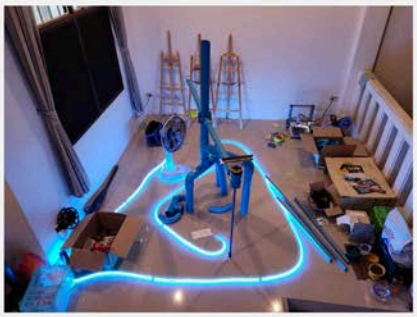
Brain Organoid for 10 weeks exhibition

1. 4-8weeks old organoid for October 7 - soft opening
2. Supply Brain organoid every week or 2weeks
3. Bhaduri Lab protocols for growing brain organoid for publication

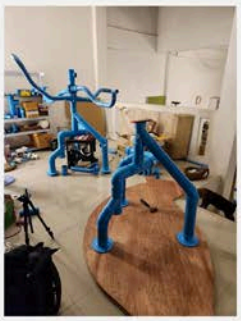
Collaboration

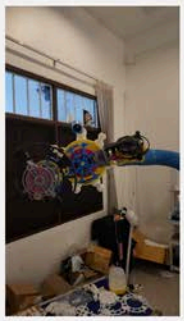
1. We'd like to create animation of Organoid growing / visualization from Bhaduri lab image databases or data
2. We'd like to create visualization or interactive from Brain Atlas / cell chat, databases from Bhaduri Lab.

we will see if that can be use for exhibition and hope it can be useful for Bhaduri lab research ref.









Production notes

Brain organoid on Chip
1. technically difficult to grow for long term
2. too small to see
3. might be able to do in microfluaic
4. transport to LA issue?

Clinostat / INCUBATOR
- research on prototype making

DIY Incubator

Bioreactor
1. research on prototype making
2. option 1 yeast - still working on it
3. option 2 blood

Clock
1. develop the step gear
2. test print and build 1st prototype

DNA Printer & Synthesizer
1. not yet start

DNA Printer Synthesizer

Lotus
- not yet start

Lotus

4 Screens - Rotating

Machanical

Main Structure
- build prototype of core structure, motors and wiring design - in process

Seed planting Breathing ritual collective movement

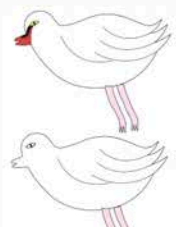
Public program

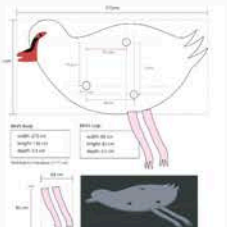
Public program

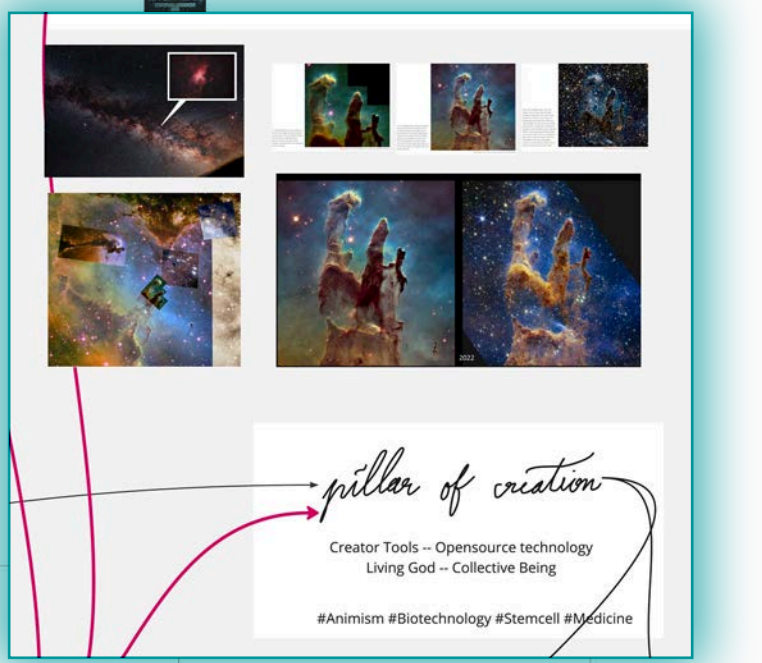
Public program

Laser projection









Data input from Brain organoid signal
thru mS or osc or midi
API

Generative Lotus from Browser
p5 or others

Now
video clip
brain organoid development

future plan
live feed of brain organoid development
feeding data thru mS or openephys

Screen capture by LaserOs
or capture by Madlaser

YP Can you explain what hybrid entities are and how they feature in your project?

HT The hybrid entities I'm developing involve cells, like stem cells or organoids, being grown on microchips. These organoids are small, lab-grown clusters of cells that model human organs. We're creating these hybrid entities with either tumor cells or living cells on a microchip, and exploring how we might acquire these cells. A friend suggested I could harvest stem cells from a root canal if my wisdom teeth hadn't been removed yet, or from my blood or muscle tissue, though I would need technical help to do so. I considered whether my affiliated university could help grow them and whether they could then be transported to LA. But I found out that wouldn't be feasible, so we won't have hybrid entities with cells and chips in this exhibit. Instead, I researched systems where cells and chips already fuse, such as multielectrode arrays used by scientists to read cellular signals. This became the starting point for representing hybrid entities symbolically, similar to "brain-on-chip" models.

YP You've said that dreams play an important role in this project. Why are dreams so central to your work?

HT Dreams are fascinating to me because they represent one of the last truly private spaces in our lives. In a world where data is constantly being collected, our dreams seem untouched by surveillance, at least for now. But I wonder if even our dreams can remain private in the future. I'm exploring the idea that our dreams could be invaded by technology, just as our waking lives have been.

For example, I'm curious about whether future technologies could monitor and even manipulate our dreams. Imagine if corporations could send targeted messages into our dreams, influencing our behaviors in ways we can't control. This concept is at the heart of the hybrid entities: They consume human anxieties and dreams, and through that, they evolve. What happens to life when it starts consuming data, especially data as personal as our dreams?

This connects to a larger narrative about surveillance capitalism, where even our most private experiences—like sleep—are transformed into data that can be monetized. I'm asking: Will dreams remain the last bastion of privacy, or will they too become data to be consumed and controlled?

YP Similar to the concept in *Inception*!

HT Yes, exactly. *Inception* is one of my favorite films. Another layer of this project will involve feeding data from EEGs—dream data from sleeping participants—into the organoids, treating it as a performance piece. This would allow us to introduce electrical signals to the organoids, influencing them in subtle ways. This concept traces back to my *Young Eel* project, where I encoded memories from a friend using smells, sounds, vibrations, and even EEG data. In *Pillars of Creation*, we'll use sound and vibration, perhaps even to mimic the way dream data might impact these hybrid entities.

YP Your vision board also contains plans for building a clinostat. How does that fit into the project?

HT The clinostat is a machine that simulates a zero-gravity environment. Initially, I started thinking about how life-forms could exist in space-like conditions while working on my space exploration project. It's a complex challenge. I got the idea from Japanese researchers who built clinostats with CO_2 systems to create an environment that supports cell growth in a simulated microgravity setting. This setup allows cells to grow in a microenvironment that replicates space-like conditions, unlike the typical petri dish.

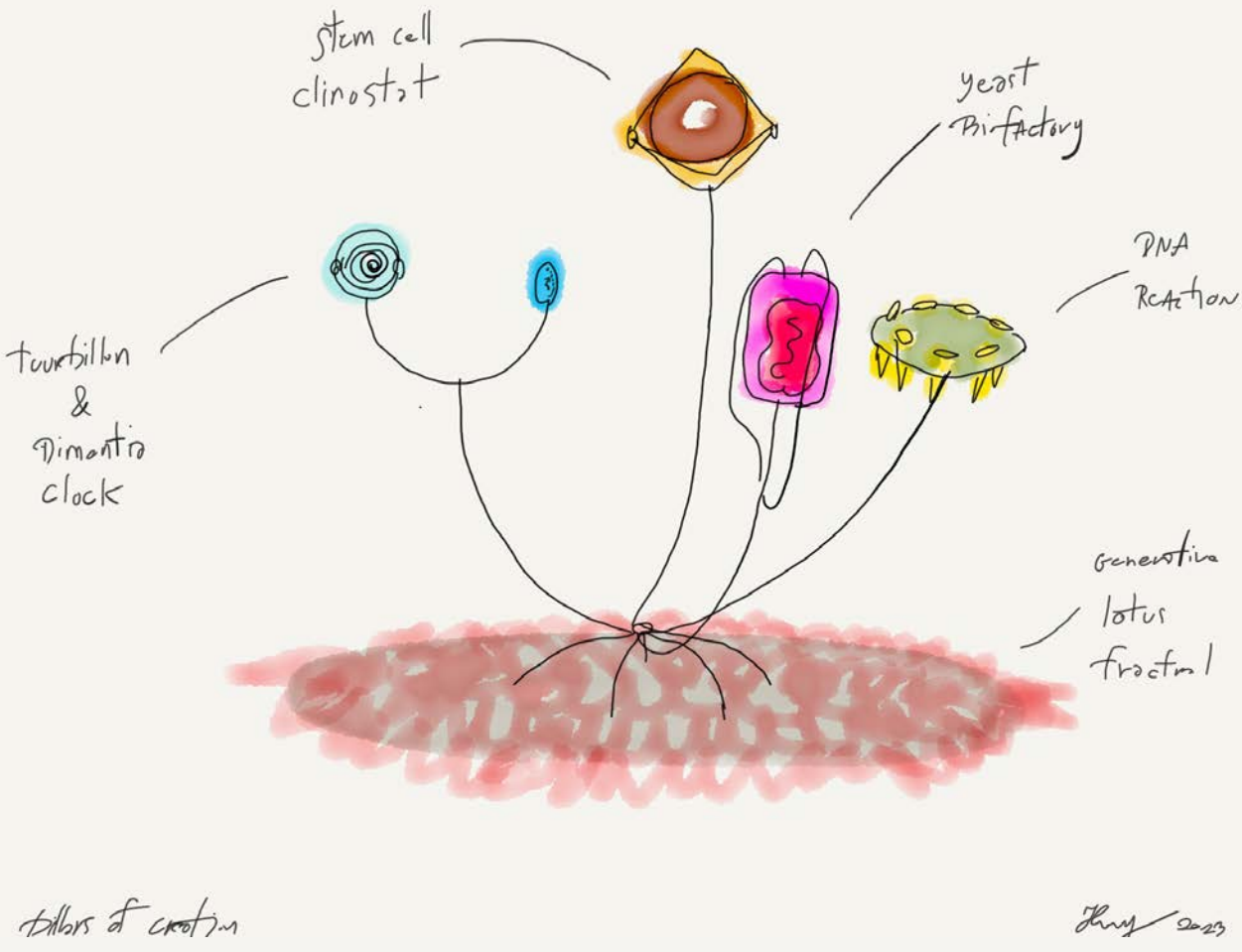
YP Are you still hoping to house the organoids within the clinostat?

HT My team successfully created a clinostat from scratch, using available examples as inspiration, but without blueprints. It was a bit challenging; one of my colleagues, Masato Takemura, even experimented with balancing it on a single support stand, which proved to be tricky. We'll aim to place organoids within the clinostat here in LA, building on research from UC San Diego, which has already sent organoids into space.

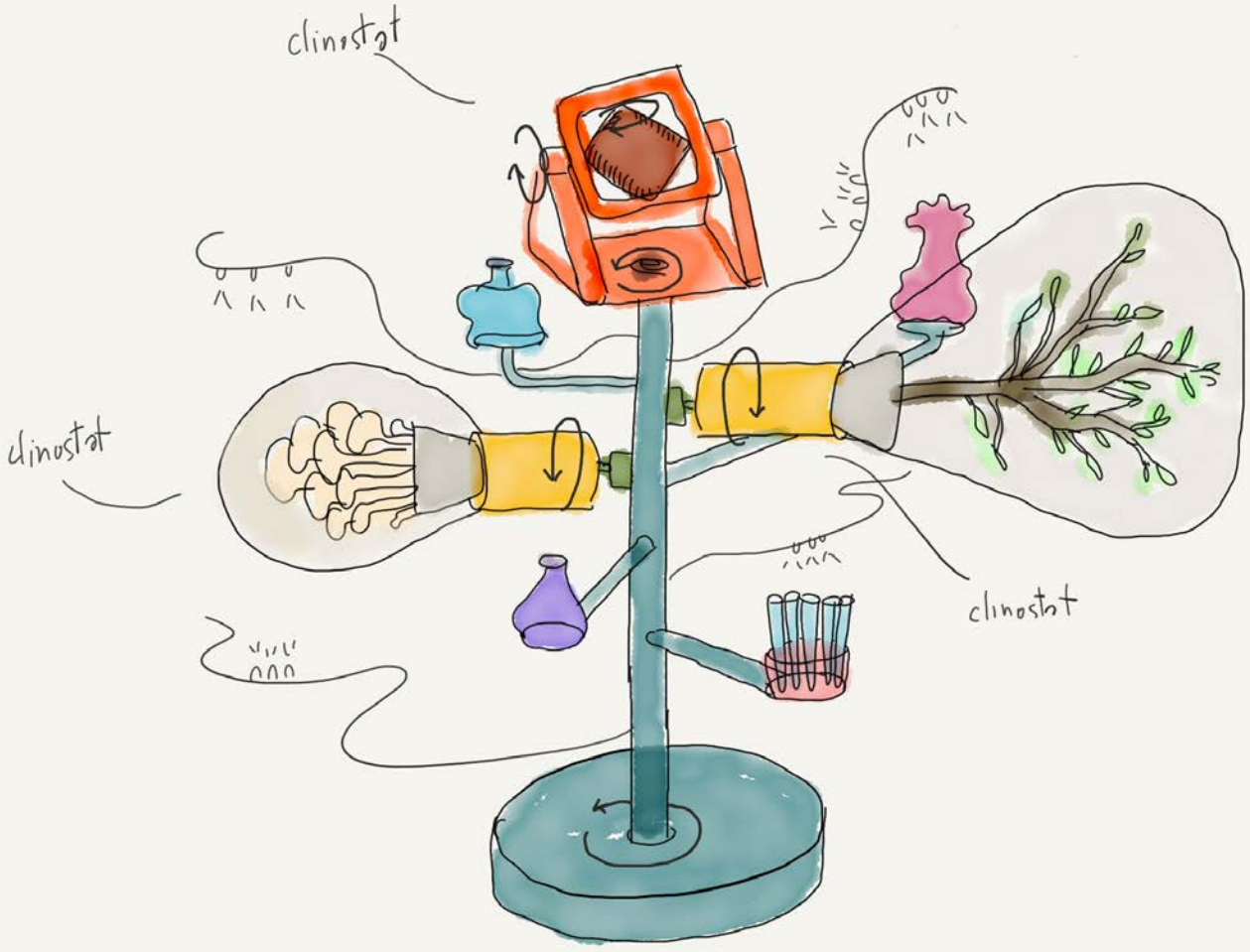
YP There are a few other components to *Pillars of Creation* beyond the hybrid entities and the clinostat. Can you talk about those?

HT Yes, there are a few other elements. One is a mechanical clock with about eighty intricate parts that represent time and knowledge. Building it has been a technical challenge, but the clock reflects on how we experience time in different ways, influenced by memory, cognition, and environment. There's also a *hamsa* bird sculpture that symbolizes life as breath, embodying inhalation and exhalation. It reflects a meditative cycle, where simply breathing in and out represents living.

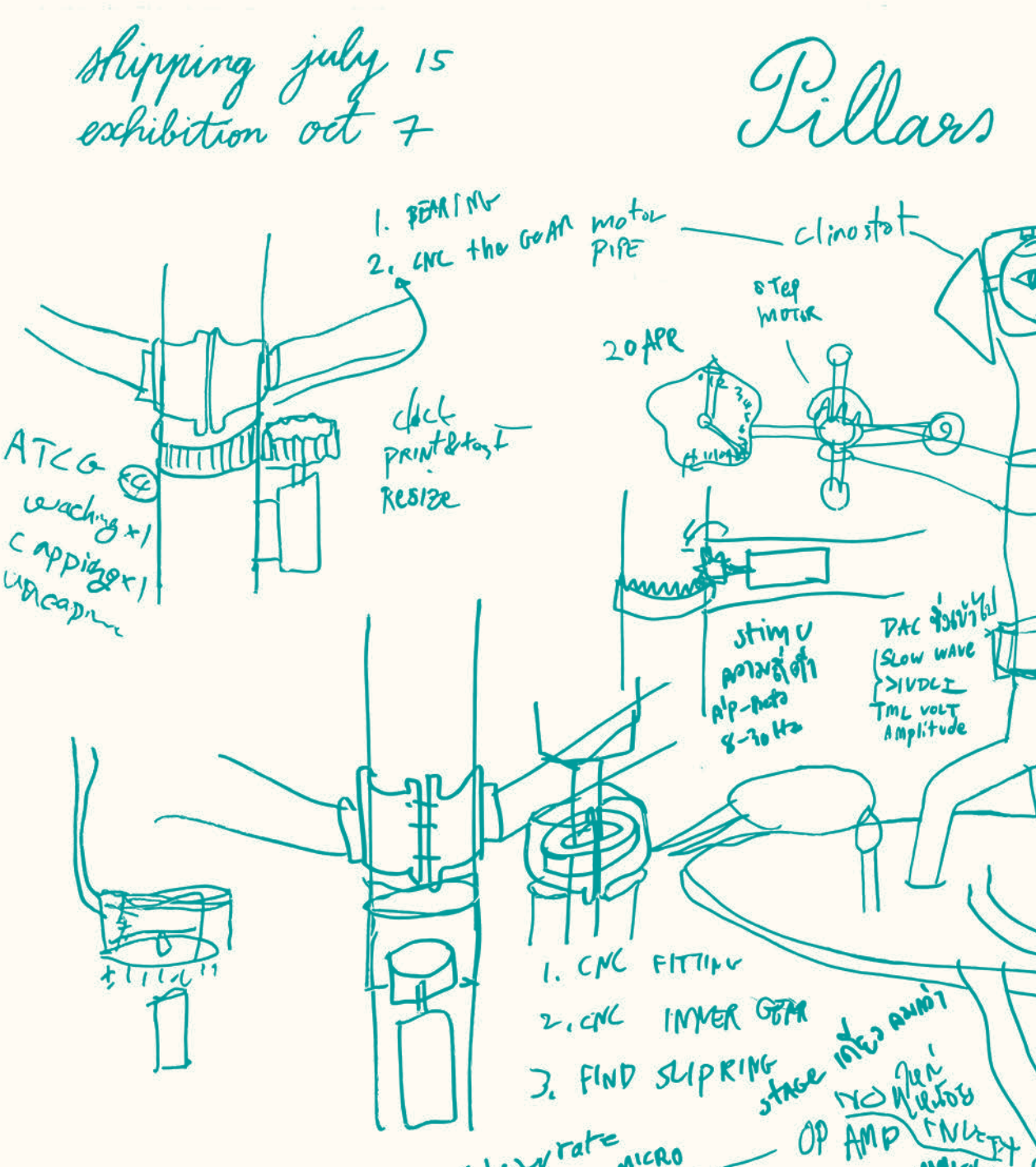
Another key visual component is the lotus flower, a symbolic element that represents growth, transformation, and resilience. We experimented with making a mechanical version of the lotus, though it proved technically challenging. Instead, we'll be using projected visuals of the lotus, overlaying them with signals from the organoids to illustrate the unfolding of life.



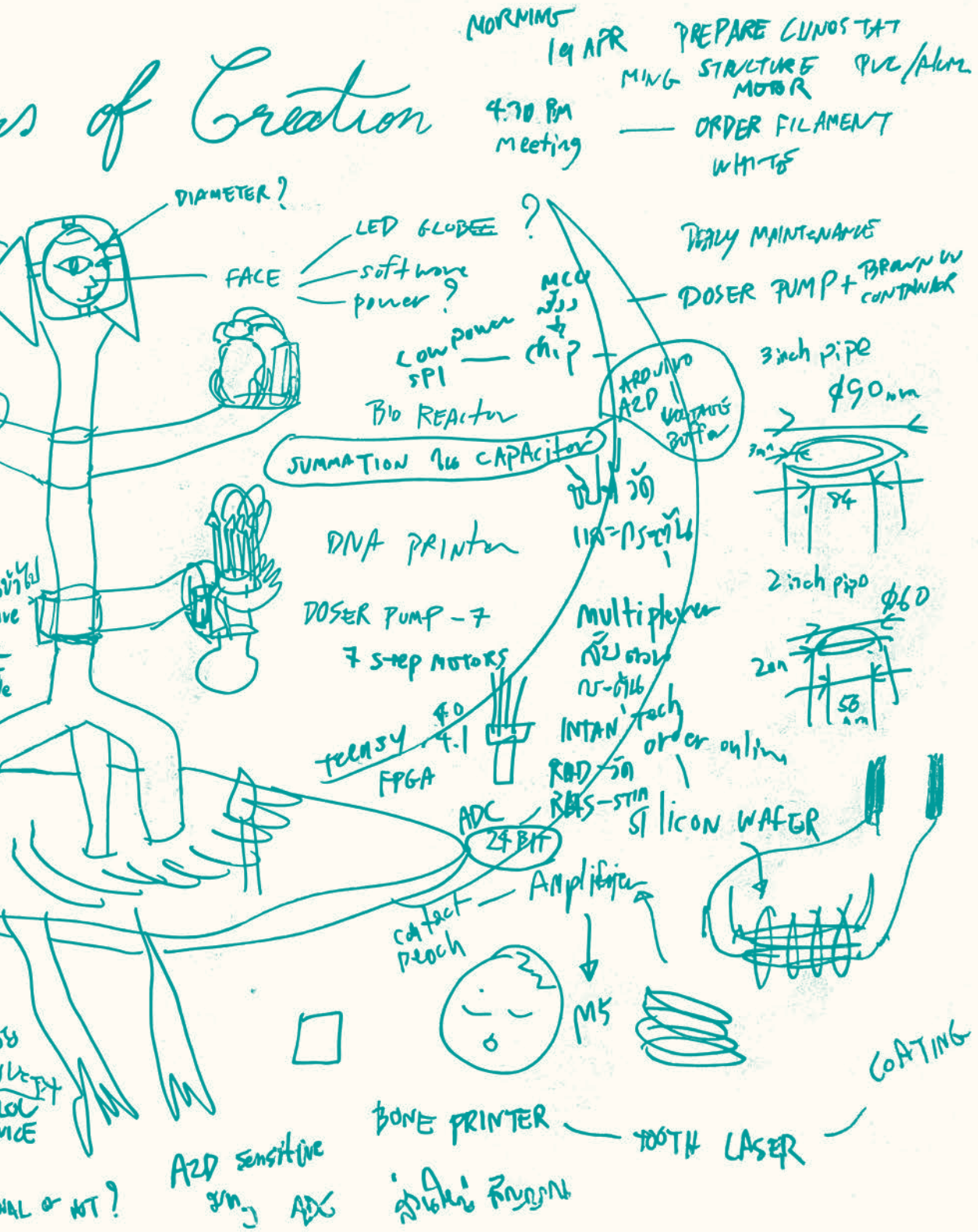
Henry Tan, work-in-progress illustration for *Pillars of Creation*, 2023.



Henry Tan, work-in-progress illustration for *Pillars of Creation*, 2023.



Henry Tan and Masato Takemura, work-in-progress illustration for *Pillars of Creation*, 2024.


of Creation
MORNING
19 APR
PREPARE CULTURE
MING STRUCTURE MOTOR
PVC/ALUM
4:30 PM
Meeting
ORDER FILAMENT
WHITE
DIAMETER?
LED GLOBE?
FACE
software
power?
DAILY MAINTENANCE
DOSER PUMP + BRAWN W CONTAINER
MCU
Low power
SPI
chip?
ARDUINO
A2D
VOLTAGE
Buffer
3 inch pipe
Φ90 mm
Bio Reactor
SUMMATION 16 CAPACITOR
DNA PRINTER
2 inch pipe
Φ60
DOSER PUMP - 7
7 STEP MOTORS
Multiplexer
TEENSY 4.1
FPGA
INTAN tech
order online
ADC
24 BIT
SILICON WAFER
Amplifier
contact
peach
MS
COATING
BONE PRINTER
TOOTH LASER
A2D sensitive

YP Beyond *Pillars of Creation*, you have other projects that won't be part of *Emergence*, but *Elixir of Life* (2024) will be included. How will it be represented in the exhibition?

HT *Elixir of Life* is more of a side project, exploring ideas around life and longevity. The piece itself is a vessel that resembles a glass elephant, designed to hold a red drink that resembles blood or stem cell medium. It plays on the idea of preservation: Some versions might contain alcohol or spirits while others include a sugar mixture, inspired by stem cell culture media. The back will be engraved with DNA sequences, protein names, a poem about and image of a blastocyst, and Yamanaka factors as a nod to the science, capturing this notion that connections—family, friends—are our true elixirs of life.





YP Thank you for walking me through your vision board, Henry. Taking a step back, there are ethical concerns surrounding this kind of work, especially when it comes to manipulating living cells. How do you approach these challenges?

HT There are definitely ethical challenges involved in working with living cells, especially when it comes to using technologies like microchips or trying to manipulate cells in ways that mimic human life. But these ethical concerns are part of the conversation I want to have with the audience. I'm not just interested in whether we can manipulate life in this way, but also whether we should. What does it mean to create entities that exist in a space between life and technology? How far can we go in merging biology and machines before we reach a point where it's ethically questionable? In the exhibition, I hope to provoke these kinds of questions. I want people to think about what it means to manipulate life, to create new forms of existence, and to consider the consequences of pushing those boundaries.





Opposite page, left: Henry Tan and Masato Takemura, 3D rendering of *Elixir of Life*, 2024. Courtesy of Fathomers.

Opposite page, right: Henry Tan and Masato Takemura, *Elixir of Life*, 2024. Installation view: Fathomers merch lab at the PST ART DTLA Street Fest, Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.

Above, top: The statue of Phra Phrom, the Thai representation of the Hindu god of creation, Brahma, at the Erawan Shrine in Bangkok, 2024. Photo: Henry Tan.

Above, bottom: Members of the *Pillars of Creation* team apply gold leaf to the armature of the artwork, 2024. Photo: Henry Tan.



Members of the *Pillars of Creation* team in Bangkok consider fabrics for the *hamsa* rug in preparation for *Emergence*. Photo: Henryandpartners.

YP How has collaboration shaped your project? You're working with scientists and engineers—how has that affected your approach?

HT Collaboration has been absolutely essential. I've been working with biomedical engineers, biologists, and other researchers to understand the technical aspects of the project. For instance, I'm collaborating with engineers to build the microchips that the organoids will live on, and with scientists who are helping me figure out how to read the electrical signals from the cells.

We've been developing systems like multielectrode arrays, which allow us to visualize the electrical activity coming from the organoids. Working with experts from different fields has really expanded what's possible in the project. It's not just an artistic exploration anymore—it's about pushing the boundaries of what's technically possible and seeing how far we can go with this fusion of life and technology.

YP What do you think the future holds for hybrid entities? Where do you see this research going?

HT I think we're only scratching the surface of what's possible when life and technology merge. Right now, we're in the early stages, but I believe hybrid entities like the ones I'm creating will become more common in the future. We'll see more of these fusions between living cells and machines, and it will force us to rethink what it means to be alive.

The questions I'm exploring now—about how data can influence life and how life can exist in new environments—are going to become even more relevant as technology advances. I see a future where life-forms evolve in response to data, where machines and living organisms are deeply intertwined. My work is about imagining what that future might look like and asking how we, as humans, will navigate it.



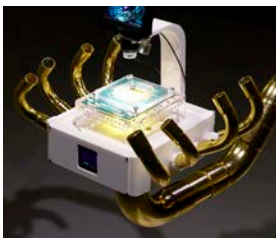
Laser Projection

The laser projection visualizes the hidden mathematics of existence; it guides the branching of brain organoids, the spiral of the lotus, the tidal pull of breath, and the fabric of the universe.



3D-Printed Kinetic Lotus

The artists have rendered Brahma's lotus, which symbolizes the purity, perfection, and cyclical nature of creation and spiritual awakening, as a levitating, kinetic 3D-printed sculpture.



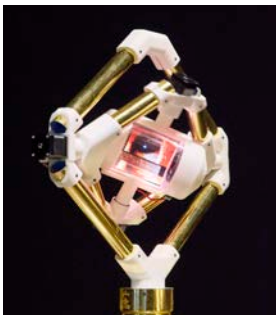
Brain Organoid Incubator

Pillars of Creation uses a brain organoid incubator to represent the hand of Brahma. "Just as Brahma's hand cradles the bowl of cosmic energy," says Tan, "this device nurtures the burgeoning complexity of miniature brains that hold the promise of cure and the reminiscence of life."



Hamsa Rug Base

The base of *Pillars of Creation* recalls Brahma's swan, known as *hamsa* in Sanskrit. This swan serves as his *vahana*, or vehicle, and symbolizes wisdom, purity, and the ability to discern between good and evil.



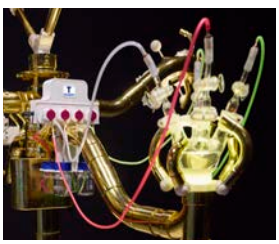
Clinostat LED Hologram

The clinostat LED hologram depicts the four faces of Brahma, known as *Chaturmukha* in Sanskrit, which symbolize his omniscience, sacred knowledge, and wisdom. Within *Pillars of Creation*, the LED hologram embodies the guiding presence of divine wisdom, anchoring the sculpture's meditation on the cosmic cycles of creation, preservation, and transformation.



Dementia Clock

The tourbillon dementia clock stands in for Brahma's *akshamala*, or beaded rosary, which typically symbolizes time. Here, the clock conjures questions about aging, decay, transformation, and the relativity of time and memory.



DNA Printer-Synthesizer Prototype

In place of Brahma's Vedas, texts containing the immortal knowledge of the universe, the artists present a DNA printer-synthesizer. By mimicking the natural process of DNA, the printer-synthesizer opens the possibility of creating new life-forms and rewriting the basic script of life on Earth.

Henry Tan, Masato Takemura, and collaborators, *Pillars of Creation*, 2024 (details). Courtesy of Fathomers. Photos: Carson Davis Brown.



Henry Tan, Masato Takemura, and collaborators, *Pillars of Creation*, 2024. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.

Miniature Brains the Size of a *Pea* Are Sending Out *Brain Waves* for the First Time



Thiago Arzua

Originally published in *Massive Science*, December 10, 2019, https://massivesci.com/articles/brain-cortical-organoid-mind-control-neurons-brain-waves-mind-control/. Reprinted with minor edits by permission.

Above: Still from the film *The Brain That Wouldn't Die*, 1962

Are they fetal brains in a jar?
No.
Should we still be excited and slightly concerned?
Yes.

We are in a boom of organoids. New and exciting advancements are approaching quickly with these tiny model organs. Perhaps the most intriguing: the brain organoid. First described in 2013, these so-called mini-brains have been used to model and study genetic diseases, major psychiatric disorders, neurodegenerative diseases such as Alzheimer's disease, and even human evolution.

Mini-brains are just the size of a pea but capable of reproducing key brain functions. They are currently a hot research topic because scientists think they can eventually be a model for neurological diseases that we are currently not able to properly study in rodents or other animals.

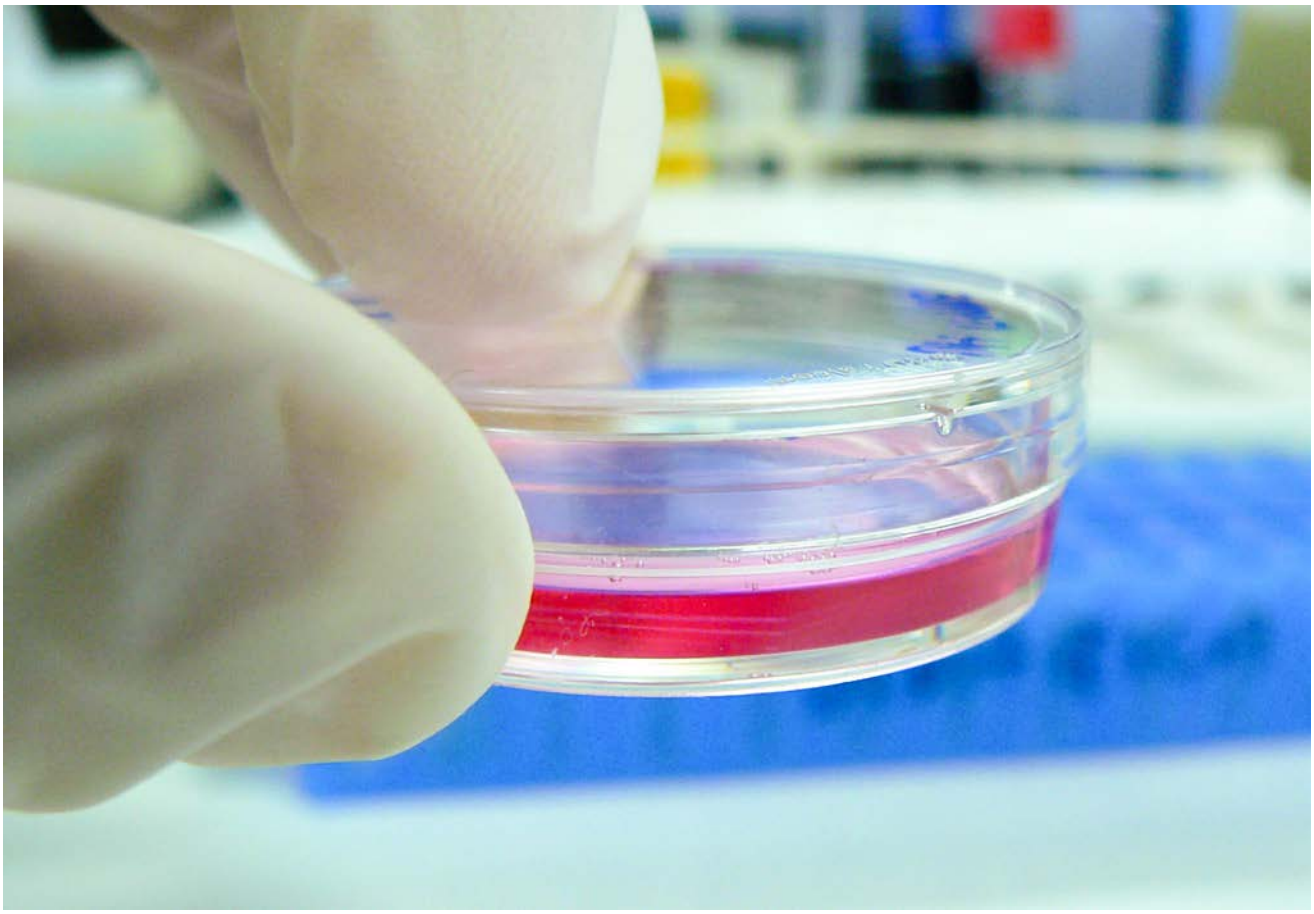
While previous studies have successfully shown changes in genes and proteins associated with such diseases, studying the functionality of diseased brains—how our neurons work and interact with other cells during disease—remains a challenge. Neurons communicate by sending electrical signals to other cells, so to fully understand how they work, you must study how the cells are performing electrically. Scientists already knew that mini-brains were capable of generating these electrical signals, called spontaneous action potentials, but there is a wide gulf between simple action potentials and complex thoughts.

Action potentials in the brain happen in defined frequencies, called neural oscillations or brain waves. Different frequencies of brain waves are associated with different mental states (for example, when you are in deep sleep, your brain waves oscillate at about one to four times per second). Brain waves are also associated with different diseases. So in order for brain organoids to become the improved disease model that scientists need, they must be able to produce brain waves and other electrical activity. Diseases like Alzheimer's and schizophrenia are complex, and in many cases, there are more subtle changes in electrical activity happening in the brain before there is tangible damage to neurons.

Now, a recently published paper has found that the mini-brains are indeed capable of developing brain waves.[1] The authors, led by Cleber Trujillo (and including Dr. Alysson Muotri, whose work on mini-brains in space was previously profiled on *Massive Science*[2]), recorded the electrical activity in brain organoids over a period of ten months. Other studies using organoids have generally focused on the first few months of organoid development, because by two months the mini-brains have a defined structure and stop growing. But this new study shows that the longer the organoids were maintained, the more complex their cell composition—and the more intricate the electrical activity of the neurons—became.

Trujillo and colleagues showed that at four months, the organoids displayed slow brain waves, similar to the ones that our brains produce while we are sleeping. They saw that even after they formed a structure and stopped growing in size, the composition of cell types was still changing, with an increased cell diversity as time went on. It is possible that those changes are correlated to the changes in brain wave patterns.

To evaluate how well these mature brain organoids modeled human brains, the researchers then compared the organoids' brain waves to electroencephalograms (EEGs, or brain scans) of premature babies. They used a machine learning



Cell culture in a petri dish. Photo: Umberto Salvagnin via Flickr.

algorithm that was trained using babies' brain wave data and then applied that to the organoids. Some specific measures of brain function from the premature babies, such as spontaneous activity transients (bursts of activity in the brain that are integral in developing more complex neural connections), were very similar to those from the organoids, especially at later time points of organoid culture. In other words, after growing for up to ten months, the organoids started to have an electrical activity that resembled a fetal brain.

For the first time ever, we now have brain organoids that mimic a fetal brain not only in structure and cell composition but also in some brain functions. This raises complicated ethical issues, and it is fair to wonder if we can take the study of brain organoids too far. Some philosophers and scientists are concerned about the fact that we might be able to create consciousness in a lab in a not-so-far future. The ethical and moral conversations surrounding these scientific advances should start now. We are living through times where technologies evolve much faster than the ethical discussions around them, and we must prevent irresponsible applications of these technologies.

One idea to prevent scientists from crossing moral and ethical lines with organoid research is to apply a tool called the Perturbational Complexity Index (PCI) to the organoids. PCI has not yet been thoroughly validated in humans but has been proposed as a way to test brain activity in comatose and unconscious patients. By using

something relatively harmless such as transcranial magnetic stimulation (a way to stimulate the brain using a magnetic coil), physicians and scientists can temporarily disrupt the normal activity of the brain and measure how quickly it takes to recover. This can give some indication as to how aware a patient, or in this case an organoid, is.

The grotesque idea of brains in a jar remains, thankfully, in the realm of science fiction. There are plenty of reasons to be excited about where organoid research is going. As with other studies that look into disease mechanisms, this opens the door to new therapies and treatments for the uniquely human neurological diseases that we have not been able to cure, such as Alzheimer's, Parkinson's, and schizophrenia. The field of organoids is somewhat special, requiring inputs from different sp ecialists to ensure that we are ethically and responsibly unleashing all the potential of these miniature organs to hopefully help patients worldwide.

1 Cleber A. Trujillo, Richard Gao, Priscilla D. Negraes, Jing Gu, Justin Buchanan, Sebastian Preissl, et al., "Complex Oscillatory Waves Emerging from Cortical Organoids Model Early Human Brain Network Development," *Cell Stem Cell* 25, no. 4 (2019): 558–69, https://doi.org/10.1016/j.stem.2019.08.002.

2 Ashley Juavinett, "There Might Be Some Problems When We Try to Make Babies in Space," *Massive Science*, September 16, 2019, https://massivesci.com/articles/babies-in-space-brain-organoids-microgravity-alysson-muotri-mind-control/.

A Toast to the Genetic Code

Henry Tan



Fathomers associate director David Kim, artist Henry Tan, and *Emergence* laboratory technicians Mary Cabrera Abad and Kacy Jung form the letters *ATGC* with their hands as part of Tan's "Toast to the Genetic Code" during the opening night of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Photo: Jordyn Doyel.

ATGC, the alphabet of life,
A code that shapes each creature's strife.
For science's quest, they give their all,
A sacrifice that answers the call.
Let us honor their selfless deed,
A tribute to their noble creed.
For in their sacrifice, we find
A path to knowledge, humankind.



Henry Tan performs a blessing at the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Photo: Jordyn Doyel.

Searching for the Meaning of Life

Henry Tan in Conversation with Komkrit Uitekkeng

Dr. Komkrit Uitekkeng was a lecturer on religion in the Faculty of Philosophy at Silpakorn University in Bangkok. He passed away in February 2025.



Henry Tan Professor, before we begin, let me introduce myself. I'm Henry, a Thai artist of Chinese descent living in Bangkok. Bow is part of the team for this project. We reached out to you because you gave an interview about four years ago for an exhibition related to the Erawan Shrine. Unfortunately, the recording of that interview is no longer available.

Komkrit Uitekkeng Of course, feel free to ask.

HT Thank you. Currently, I am conducting research for an art piece inspired by the origins of life, influenced by space and beliefs specific to Thailand and this region. I wanted to gain your insight on life, death, and behavior.

KU Yes, of course.

HT So, my project is called *Pillars of Creation*. It's inspired by the gas and dust clouds in the Eagle Nebula, which are seen as the birthplace of stars. We are trying to interpret what these symbols of creation mean within Thai beliefs, specifically in Buddhist, Brahmin, and Hindu traditions. I aim to create a system that simulates cosmic energy, with a DNA printer to represent knowledge or script. I'm also including a clock inspired by a dementia screening test to symbolize the concept of timekeeping while forgetting one's own time. Additionally, I'm working on a bioreactor to represent the concept of sacrifice.

KU Interesting, very symbolic and thoughtful work.

HT I'm also in the process of creating a model of Brahma, related to some research I'm conducting, as well as producing birds to keep things more dynamic and not overly serious.

KU Very intriguing. What specific questions do you have in mind?

HT From your perspective, where do you think life originates?

KU Ah, life's origin? That's a broad question, and one that Indian philosophy often grapples with. Hinduism, for instance, holds the belief that life has no beginning. This concept, called *adina*, suggests that life cycles continuously with no real starting point. It's an ongoing, orderly process, not chaotic. The idea that there must be a creator comes from our amazement at nature's complexity and beauty, which makes it hard to believe that all of this is just coincidental.

HT So, in Hinduism, there's no particular event or moment in time that marks the creation of life?

KU That's right. Many people search for a singular creation moment, but Hinduism often emphasizes continuity. It's a philosophical stance that avoids pinpointing an origin and focuses on the eternal cycles of creation, maintenance, and destruction.



HT That's a profound perspective. What do you believe is the meaning of life, then?

KU The meaning of life is largely subjective and depends on one's beliefs. For some, religious doctrines provide a predetermined path: Live a beneficial life for others or seek enlightenment. For others, meaning is self-created, often driven by personal values or philosophical inquiries. There's no universal answer; we create our own meaning through our actions and beliefs.

HT And what about life after death—what happens when we die?

KU According to my beliefs, and rooted in Hinduism, I view life as continuing after death. The body may deteriorate, but the life force returns to the universe. Hinduism often describes this as a cycle of rebirth or spiritual continuation, where heaven, hell, or other realms play a role based on one's actions during life.

HT One last question about a timeless pursuit: Why have humans consistently sought immortality or the elixir of life throughout history?

KU Death, being the unknown, naturally invokes fear. Even in religions that believe in an afterlife, the uncertainty of it still lingers. Humans seek ways to extend life or achieve immortality as a means of grappling with this fear. Historically, this has been seen in myths about elixirs, but even today we see the same desire manifest in modern medical advancements.

HT If modern technologies like antiaging or life-extension therapies existed, would you use them?

KU Personally, I don't find such things appealing. I'm comfortable with the natural process of aging. But I understand that others may seek these technologies for health or aesthetic reasons. Aging is a natural part of life's process, and I wouldn't want to interfere with that.

HT That's an insightful perspective. Now, could you share your understanding of Brahma in Buddhism and how it relates to Thai beliefs?

KU Brahma in Buddhism and Thai traditions derives from ancient scriptures but is adapted to fit within the framework of Buddhist teachings. In Buddhism, Brahma is not regarded as a singular creator but more as a state of being that can be achieved through meditation. Thai beliefs have adopted this and integrated it into religious practices seamlessly.

HT And how have rituals such as the eye-opening ceremonies evolved in Thai culture?

KU These ceremonies have indeed evolved from Indian traditions but have adapted uniquely within Thai culture. Thai ceremonies often include elements like traditional performances and offerings, which may not be present in Indian rituals. It reflects the blending of beliefs and practices over time, making these rituals distinctly Thai while still holding on to some of their original elements.

HT Thank you so much, Professor. When the project is complete, I'll be sure to share it with you.

KU You're welcome. I look forward to seeing how it turns out.



Photo Credit: Carson Davis Brown

Inspired by the mythical elixir of life, a potion said to grant immortality to those who drink it, Henry Tan interviewed nine participants about their personal "elixirs of life." Highlights from their interviews are featured here. Drawing on their responses, he also crafted poems with the help of AI, furthering his exploration of that technology's potential to support creative expression as well as its limitations.

Henry Tan
with
Napat Emdee,
Nattawat Leelahakorn,
Nathawat Jaruchoktaweechai,
Esther Lu,
Jueling Hu,
Chawatat Thanoosing,
Be Takerng Pattanopas,
Komkrit Uitekkeng,
and Stéphane Boissinot

The Pursuit of Immortality: *Poems of Personal Elixir*

"I will lower my immunity
so your organs can become a part of me."

Antibody, a vibrant hue,
Nutrients balanced, a diet true.
In harmony, a body thrives,
A testament to life that survives.



Napat Emdee

Napat Emdee is the author of the "This Is Biology" Facebook page. Emdee is currently a PhD student in biology at Jagiellonian University in Kraków.

"Evolution prioritizes survivability, not the beauty of wounds and scars. Evolution hasn't been able to keep pace with medical technology."

Evolution's blueprint, ancient and slow,
Outpaced by science, a technological show.
Stem cells gathered, a treasure trove,
From roots, from fat, a nature-given love.
Royal jelly, a bee's sweet elixir,
For humans, perhaps just a marketer's flicker.



Nattawat Leelahakorn

Nattawat Leelahakorn is a PhD candidate at the University of Copenhagen, where he studies antibody and plant biochemistry.

"If we can crack the mystery of how to inject information back into the brain, perhaps it could help us understand the mind or the meaning of our existence. If we can download the minds of our parents and inject them into someone, would that person become our parents? Perhaps then we could crack the ultimate definition of life or soul."

Memory's threads, a fragile art,
Some fade away or are torn apart.
In memory's tapestry, a human's quest,
To learn, to reap, to rest.



Nathawat Jaruchoktaweechai

Nathawat Jaruchoktaweechai graduated with a master's degree in neuroscience from University College London. He currently works as a senior investment advisor and a part-time chef.

Photos courtesy of Henryandpartners



Esther Lu

Esther Lu is an independent curator based in Taipei. In 2021, she founded Moss Piglets, a curatorial and research nonprofit dedicated to contemporary art practices that focus on alternative art education and production.

"Art is an abstract energy that I receive from those around me and the greatest gravity that draws me in."

In modern times, a worrying plight,
Living too long, a fading light.
Yet in the rhythm, a solace found,
A symphony of life, unbound.



Jueling Hu

Jueling Hu is a joint PhD candidate in human geography at the University of Fribourg and in media studies at the University of Amsterdam. Hu studies animals in Borneo.

"I think narcissistic people want to live forever because they believe they are the best in the world and so significant that they can't simply disappear."

Energy's forms, a cosmic play,
Ghosts or spirits, a mystic sway.
Vitamin drips, a fashion trend,
Reality or illusion, without end.
A woman's youth, societal norms,
Technology's limits, a constant storm.
Meditation's peace, a timeless art,
A journey inward, a healing start.



Chawatat Thanoosing

Chawatat Thanoosing is a lecturer in ecology at Chulalongkorn University in Bangkok. Thanoosing received a PhD from Imperial College London for research on the evolution of tropical bumblebees.

"Evolution has limited the lifespans of different creatures. If we try to break this limit, won't it disrupt the balance of the ecosystem?"

Royal jelly's power, a queen's decree,
Female hierarchy, nature's key.
Technology's promise, a youthful gleam,
Internal decay, a hidden theme.
Lifespan's limits, nature's law,
Ecological balance, a cosmic flaw.



Be Takerng Pattanopas

Be Takerng Pattanopas is an artist and a former director of the Communication Design program at Chulalongkorn University in Bangkok. His drawings, installations, paintings, and sculptures explore the human body's interior and the infinity of the cosmos.

"No matter how rich or powerful you are, you will not always find happiness, nor will you be immune to the perils of your health. No matter how advanced technology and treatment are today, living forever is impossible. Before we age, unhappiness often comes to us."

Self-improvement, a constant quest,
In final moments, a peaceful rest.
Medication's role, a disease's cure,
Elixir's absence, a timeless lure.



Komkrit Uitekkeng

Komkrit Uitekkeng was an instructor in the department of philosophy at Silpakorn University in Bangkok. He was an expert in Indian philosophy and religious studies, with a focus on Hinduism.

"Life's meaning is subjective, shaped by personal values. Some philosophies demand we create our own purpose, while others suggest predetermined paths like spiritual growth or service."

Meaning's tapestry, self-woven thread,
Religious doctrine, a predetermined bed.
Values held, a personal guide,
Physical decay, a cosmic tide.
Energy's fusion, a universe's gain,
Beyond death's realm, a celestial plain.



Stéphane Boissinot

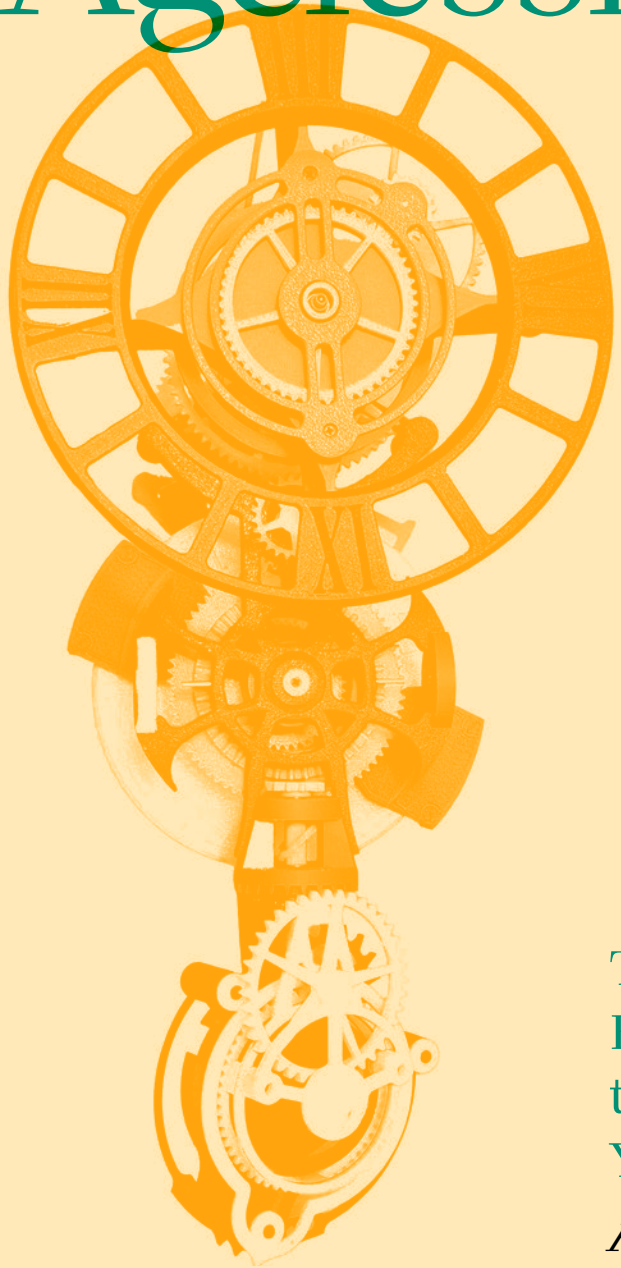
Stéphane Boissinot is an evolutionary biologist at NYU Abu Dhabi. Boissinot uses a combination of field-based, molecular, and computational approaches in his research on topics such as the evolution of genome size and structure, the evolution of innate resistance to viral infection, and the biogeography of East African vertebrates.

"Life comes from daily joy and love. Without them, we are just living matter. The only meaning in my life, at least, is what kind of joy I can bring to people and how I can make people's lives better. We get the elixir of life from people, social interaction, and our friends. We are a social species."

Joy and love, life's guiding light,
Without them, a mere mortal plight.
Aging's path, akin to cancer's creep,
Yet maturity's wisdom, a soothing sleep.
Elixir of life, social grace,
Surrounding souls, a comforting space.

Above and opposite page: Photos courtesy of Henryandpartners

The Age of Agelessness:



The Race to Bottle the Fountain of Youth

Frank Swain

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When Liz Parrish walked onstage at the Longevity World Forum in Valencia, Spain, in late 2019, the mood in the room palpably darkened. The other presenters knew that the BioViva CEO was about to steal the show again, for better or worse. Where they—mostly starchy academics—had set out modest ambitions to lower the burden of age-related diseases, like heart disease, osteoarthritis, and Alzheimer's, the avowedly stylish Parrish delivered a more ambitious pitch. BioViva's goal, she told the audience, was to create a vaccine against aging itself.

Parrish—who is forty-nine but presents at least a decade younger—claims to be patient zero in her own experiment, a move that isn't always considered a hallmark of scientific rigor. Amid muttering from the audience, she recounted how she visited an unnamed clinic in Colombia for an experimental gene therapy to lengthen her telomeres, the genetic caps that limit the lifespan of a cell, and another to restore muscle tissue. In the process, she claimed, she had wound back her biological age. And in the next few months, her company would offer this antiaging gene therapy to the public.

The BioViva CEO may be controversial, but she is not alone. Companies all over the world are proclaiming the imminent antiaging revolution. If you believe their most enthusiastic research projections, we are on the brink of mounting our greatest challenge to mortality. But how scientifically realistic are these efforts? And are they even desirable? What would it mean for our society if we could cure aging as we know it?

Of Mice and Men

To answer any of these questions, you must start with a more general one: What is aging? It's not as straightforward as it sounds. "There's no consensus on what aging actually is," says James Clement, founder of the independent longevity research laboratory Betterhumans. "There are only descriptive definitions." Chief among these is that aging is the gradual loss of biological integrity—an opaque way of saying that as you get older, things fall apart. Your eyesight fails. Your bones become brittle. Your joints inflame and your arteries harden. You begin to forget.

To regular people, these internal changes are heralded by the outward signs of aging: greying hair, wrinkling faces, progressively sagging skin. Those who manage to elude (or cover up) these changes are said to be "aging well." Despite its inevitability, our society struggles to make peace with growing old. Though we try to create a more generous language around aging, our fear of it still overwhelms—the anxious sense that youth implies beauty, potency, power, and that this slowly vanishes with the years until we're old, decrepit, lame.

To slow the transition, we collectively spend some $500 billion every year on tinctures, tonics, tucks, and treatments. Then we grow old anyway. And so, the antiaging industry draws on a great well of public hope. Their slogans haven't changed much since the days of the fountain of youth—"What if aging is just like any other disease, a condition that can be cured?"—but the technology has come a long way.

Curious about all this, I waded through the ankle-deep carpet of an exclusive hotel in the 1st arrondissement of Paris a while back, the guest of Nathaniel David, founder of UNITY, a biotech company working on age-related diseases. Over escargots and foie gras, David swiped through photos on his phone showing mice treated with his company's experimental drug. A mouse lives two years, more or less, and ages like we do: hair falling out, eyes turning blind. It becomes arthritic and moves around less. But David's two-year-old mice were sleek, bright-eyed, active, seemingly kept youthful by his medication. Human trials had yet to begin, but investors judged the company to be worth $700 million.

In Silicon Valley, where thirty-five is considered over the hill, antiaging startups are a hot ticket. "The great thematic investments of our time are

One biotech CEO told me, quietly, that he felt there was "a single-digit chance" that he would still be alive in five hundred years.

climate change, clean meat, and longevity," says Jim Mellon, chairman of Juvenescence, a biopharma development company that has raised over $180 million for promising longevity startups in the past three years. "There's no doubt: The theme attracts money. To rich people, the idea of living longer is very appealing!"

Juvenescence's haul is dwarfed by the two billion dollars of funding ploughed into Google's secretive Calico (a contraction of "California Life Company"), which seeks to identify treatments "that enable people to lead longer and healthier lives." Meanwhile, Amazon's Jeff Bezos and PayPal's Peter Thiel have poured their wealth into companies investigating gene therapy and drug discovery—including UNITY Biotechnology.

"Within ten years we'll see stuff that works, glimmers of hope in extending lifespan," says Mellon. "We're living at a point where science is catching up with the aspirations."

And what great aspirations! One biotech CEO told me, quietly, that he felt there was "a single-digit chance" that he would still be alive in five hundred years.

A Global Greying

Tackling aging is not just an obsession for millionaires and billionaires, but also their friends in government. Health campaigners are sounding the alarm: The proportion at which we're aging will soon amount to a global crisis. The world's population of over-sixties has doubled since 1980 to around a billion and is expected to double again by 2050. An ever-greater proportion of us are old, and that is bad news for public health. Older people are more likely to suffer chronic illnesses such as diabetes, cancer, frailty, and cataracts, putting more pressure on what little is left of the social safety net.

In its 2019 industrial strategy, the United Kingdom launched a "grand challenge" of adding five years of healthy life to each of its citizens by 2035. Medical researchers are now looking seriously at whether the key to defeating age-related diseases is to tackle the underlying issue, aging itself. That puts them in uncomfortable lockstep with a beauty industry that has promised much and delivered little in this space, as well as legions of charlatans since time immemorial.

Scientifically speaking, much of what we think of as aging is the consequence of DNA damage that accumulates in cells over time. Cells with DNA damage can cause problems for an organism. Chromosomal clocks (called telomeres) limit the number of times a cell can divide, limiting their lifespan. Thus aging seems inescapable, a natural limit of biology, so firmly entrenched that we use the same word for both age and infirmity.

But not all animals *grow old*. Lobsters, for example, are as strong and fertile at thirty as they are at two. They only die because they grow bigger with each passing year, until eventually the energetic cost of moulting such a huge shell is too great to bear. Clearly, they have some protective mechanisms that we lack.

Nor do all animals age at the same rate as us. Judy Campisi is a professor of biogerontology at the Buck Institute for Research on Aging. "Different creatures with similar genomes have radically different lifespans," she says. "A mouse

and human are roughly 97 percent genetically identical, yet have a thirty-fold difference in lifespan. What dictates that a mouse lives three years and a human lives one hundred?" Knowing the answer to that could allow us to extend our own lifespan.

How Would It Work?

When cells approach the end of their predetermined life, some fall into a state of senescence instead of dying, irritating the surrounding tissue. The number of senescent cells in our bodies increases with age, and the long-term inflammation they cause is believed to underlie many age-related diseases such as arthritis. Two key areas of interest for antiaging researchers, therefore, are senolytics—which clear the body of these senescent cells—and telomere repair, which should prevent cells from falling into a senescent state in the first place.

David's youthful mice, for example, had been administered a senolytic agent. And in 2012, Spanish biologist María Blasco showed that mice treated with telomerase—a protein that repairs telomeres, increasing the number of times a cell can divide—lived up to 20 percent longer.

Mike Fossel is president of a biomedical startup called Telocyte, which is seeking approval from the US Food and Drug Administration for a telomere-lengthening gene therapy to combat Alzheimer's. "We have gone out of our way to avoid being labeled an antiaging company," he says. "Yet at a fundamental level in some sense that is a contradiction, because the only way we can treat Alzheimer's is to reverse aging at a genetic level."

If age-related diseases are found to share a common root in the aging of cells, this may muddy the delineation between healthcare, beauty treatments, and life extension. "I don't think it's a meaningful distinction," says Clement. "If you reduce morbidity risk, essentially we're not growing old in a way that's going to be detrimental." In other words: age without aging.



But while increasing healthspan, the amount of time we live free of chronic disease, is seen as a respectable pursuit, increasing lifespan is not. When the UK government invited Mellon to give evidence in an inquiry on healthy aging, his optimism for longevity research was not reciprocated by the assembled peers. Through senolytics, organ regrowth, AI-assisted drug discovery, and gene therapy, he told the assembled peers, humans could live to 150.

"A pipe dream," huffed Lord Patel, chairing the committee.

"We are aging rapidly as we conduct this inquiry!" another snapped.

This attitude isn't surprising, says Fossel. "We're flying in the face of a lot of preconceptions. It's a conceptual revolution. We anticipate people won't believe it and won't want to believe it."

On the Brink of Legitimacy

The ghost of the snake-oil salesman still hovers over the industry. Ambrosia, one of Silicon Valley's most notorious antiaging outfits, offered infusions of blood from young people as a treatment against aging. It shuttered in 2019, following a consumer warning from the FDA ("Some patients are being preyed upon by unscrupulous actors"),

only to relaunch a few months later under a different name, Ivy Plasma.

As for Parrish of BioViva, there has yet to be any independent verification of her claims to have undergone gene therapy, nor any proof that such a treatment would be safe or effective in humans. The "vaccine" promised to the public at the Longevity World Forum turns out to be an offer to test telomerase therapy in ten Alzheimer's patients in a clinic in Mexico, beyond the oversight of the FDA. It will be administered by radiologist Jason Williams, who previously ran a clinic in Alabama offering unlicensed stem cell procedures before he moved his business abroad following an FDA crackdown.

Fossel worries that longevity researchers willing to play fast and loose are risking another "Gelsinger moment," referring to the death of patient Jesse Gelsinger in a botched gene therapy trial in 1999. "Gene therapy is becoming a garage industry, done by people in labs at an undergraduate level really," says Fossel. "I hate to think of anyone making a misstep. It would set the field back."

Leigh Turner, a professor of bioethics at the University of Minnesota who previously reported Williams's stem cell activities to the FDA, says companies like BioViva are unlikely to bring real treatments to market. "It's all about generating froth, generating media articles—as a way of pulling in investors," he says. This reputation for froth undermines the work of legitimate researchers.

A Disease like Any Other?

As far as medical regulators are concerned, aging is not a treatable condition. Trials that specifically aim to demonstrate an antiaging effect are unlikely to be approved. "If you want to explore the antiaging properties of a drug now, you have to look at something else that FDA does consider a disease and hook your drug onto one of those labels," explains Clement.



The first antiaging drugs to reach the market, therefore, will almost certainly have been approved for other age-related conditions: osteoarthritis, muscle loss, Alzheimer's. One such drug is metformin, already approved and widely prescribed as an antidiabetic, and currently the subject of a $65 million trial for possible antiaging effects.

Time itself is an obstacle here. It will simply take too long to demonstrate that any drug can slow aging—or the appearance of aging. "No company can sustain itself for forty years while they work out if something works in the longevity sense," explains Mellon. "Every company has to have commercial application to treat the diseases of aging." UNITY's mouse-rejuvenating serum, for example, is being positioned as a treatment for arthritis. But its effects could be much more widespread. Over dessert in the Parisian hotel, UNITY's Nathaniel David assured me: "Everyone will want this drug."

The greatest hurdle is the reasonable fear of side effects. Even if we find a drug that can prolong our youthful state, we ought to take care when tinkering with one of the fundamental aspects of our biology. Telomere shortening and senescence are not failures of biology but important protective mechanisms. The genetic change that results

Even if we find a drug that can prolong our youthful state, we ought to take care when tinkering with one of the fundamental aspects of our biology.

in expression of telomerase—the protein that repairs telomeres and allows cells to keep on dividing—is a characteristic of cancer cells. Similarly, senescence puts old cells that have accumulated damage to their DNA into stasis before they can become cancerous. This seems like a good reason not to administer either to healthy people.

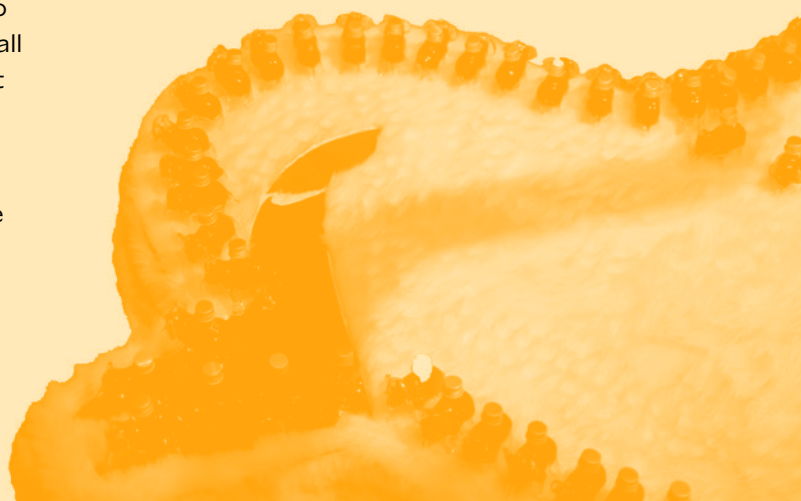
All's Well That Ends Well

Even if we found a safe way to defeat age-related diseases and age without aging, there's every chance we won't live any longer as a result. "The public has a hard time grasping the distinction between death and aging," says Campisi. "They are related, but not the same thing." Although life expectancy has increased in the last century, and more people are surviving into their eighties, the number of people reaching ninety or one hundred has not increased in the same proportion. That hints that there may be other processes at work that limit human lifespan, as yet unknown.

Equally, while senolytic treatments can keep mice looking younger and healthier than their naturally aging counterparts, they don't necessarily live longer. Mellon cautions against investing too much in these interventions, saying: "If you cure all these diseases, it would only add a decade. That is not the cure for aging."

"Part of me does think of aging as a fundamental feature of human life, and that we should be skeptical of anyone who says we can eradicate it," says bioethicist Turner. "It ties into fantasies of not growing old, not dying. That's the looming shadow of the con man."

Despite these reservations, the fight against age-related diseases will likely become the most important health issue of our time. Those of us who expect to be old in the coming decades can only hope that the current cultural shift persists and eventually marginalizes the idea that being old means being infirm. That may begin to erode the negative cultural associations of aging and our conflation of beauty and youth. When we see people in their eighties and nineties leading rich, active lives, maybe it won't seem so terrible to grow old. Maybe it will just seem beautiful.



Excerpt from

Night V.
The Relapse

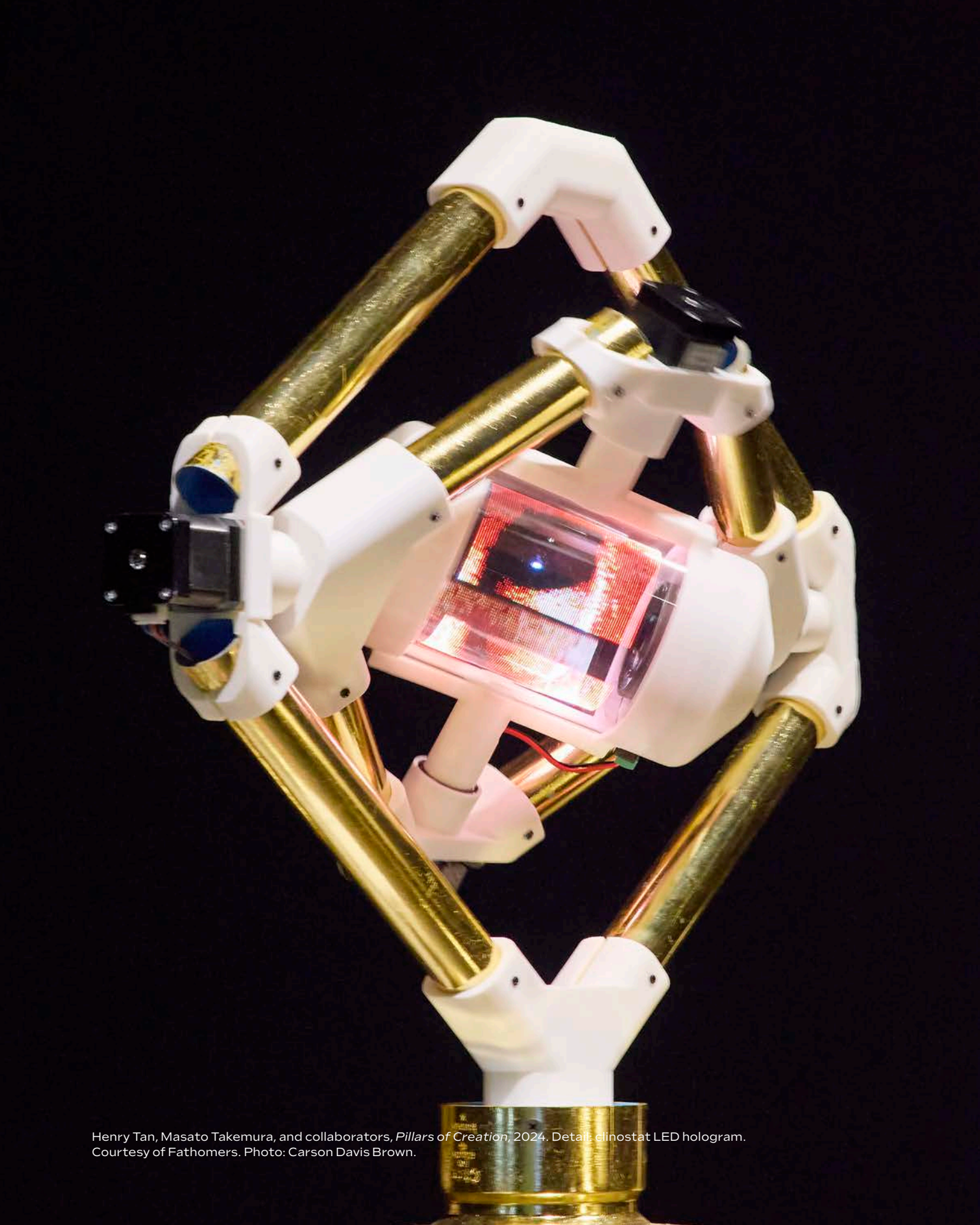
Edward Young

Tell me, some god! my guardian angel, tell,
What thus infatuates? what enchantment plants
The phantom of an age 'twixt us and Death
Already at the door? He knocks; we hear him,
And yet we will not hear. What mail defends
Our untouch'd hearts? What miracle turns off
The pointed thought, which from a thousand quivers
Is daily darted, and is daily shunn'd?
We stand, as in a battle, throngs on throngs
Around us falling; wounded oft ourselves;
Though bleeding with our wounds, immortal still!
We see Time's furrows on another's brow,
And Death, intrench'd, preparing his assault:
How few themselves in that just mirror see!
Or, seeing, draw their inference as strong!
There Death is certain; doubtful here: he *must*,
And soon—we *may*, within an age—expire.
Though grey our heads, our thoughts and aims are green;
Like damaged clocks, whose hand and bell dissent;
Folly sings six, while Nature points at twelve.

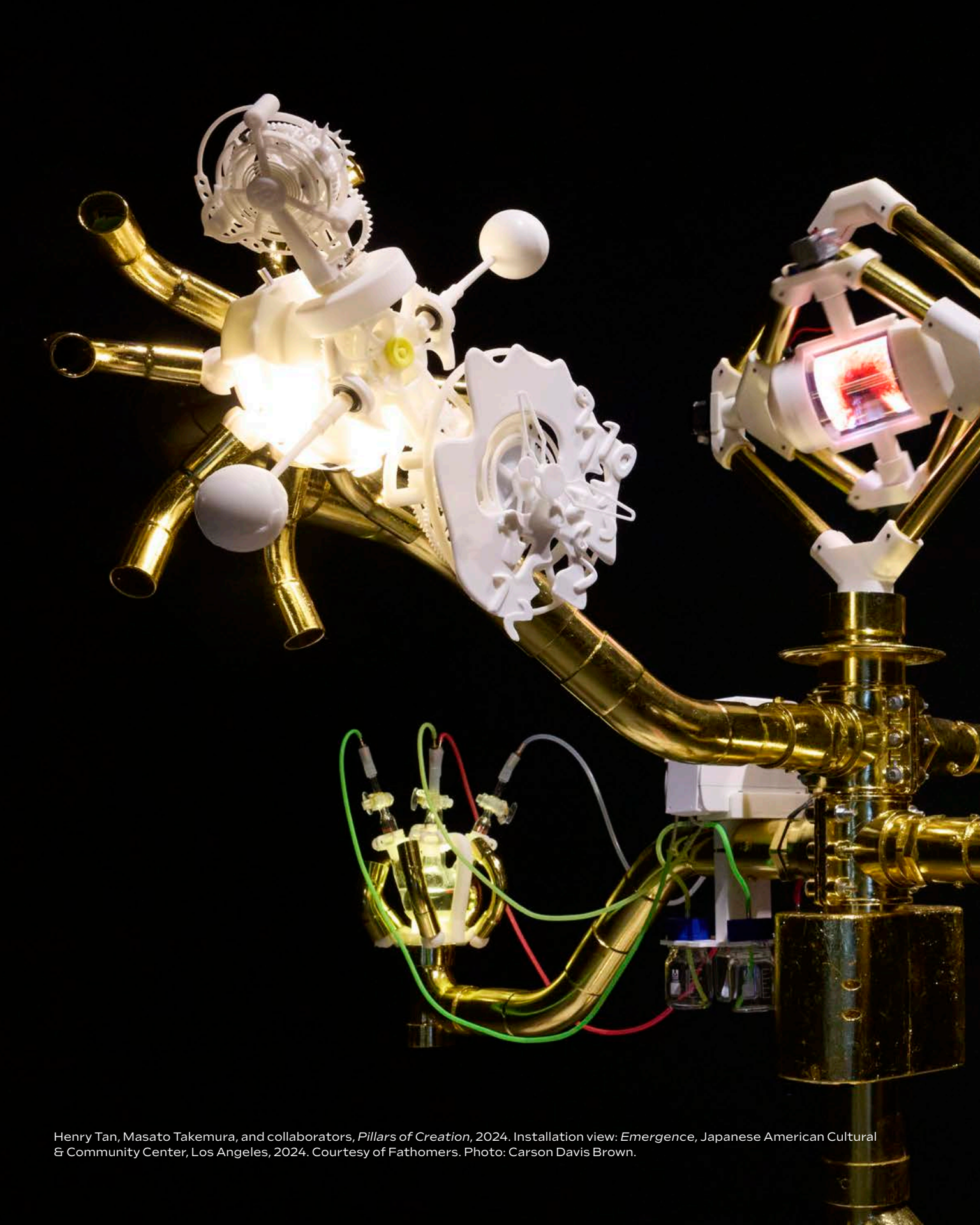
Absurd longevity! "More, more," it cries:
More life, more wealth, more trash of every kind.
And wherefore mad for more, when relish fails?
Object and Appetite must club for joy.
Shall Folly labour hard to mend the bow,
(Baubles I mean, that strike us from without,)
While Nature is relaxing every string?

Ask Thought for joy; grow rich, and hoard within.
Think you the soul, when this life's rattles cease,
Has nothing of more manly to succeed?
Contract the taste immortal; learn e'en now
To relish what alone subsists hereafter.
Divine or none, henceforth, your joys for ever.
Of age the glory is, to wish to die;
That wish is praise and promise; it applauds
Past life, and promises our future bliss.
What weakness see not children in their sires?
Grand-climacterical absurdities!
Grey-hair'd authority to faults of youth,
How shocking! it makes Folly thrice a fool;
And our first childhood might our last despise.
Peace and esteem is all that age can hope.
Nothing but wisdom gives the first; the last,
Nothing but the repute of being wise.
Folly bars both: our age is quite undone.

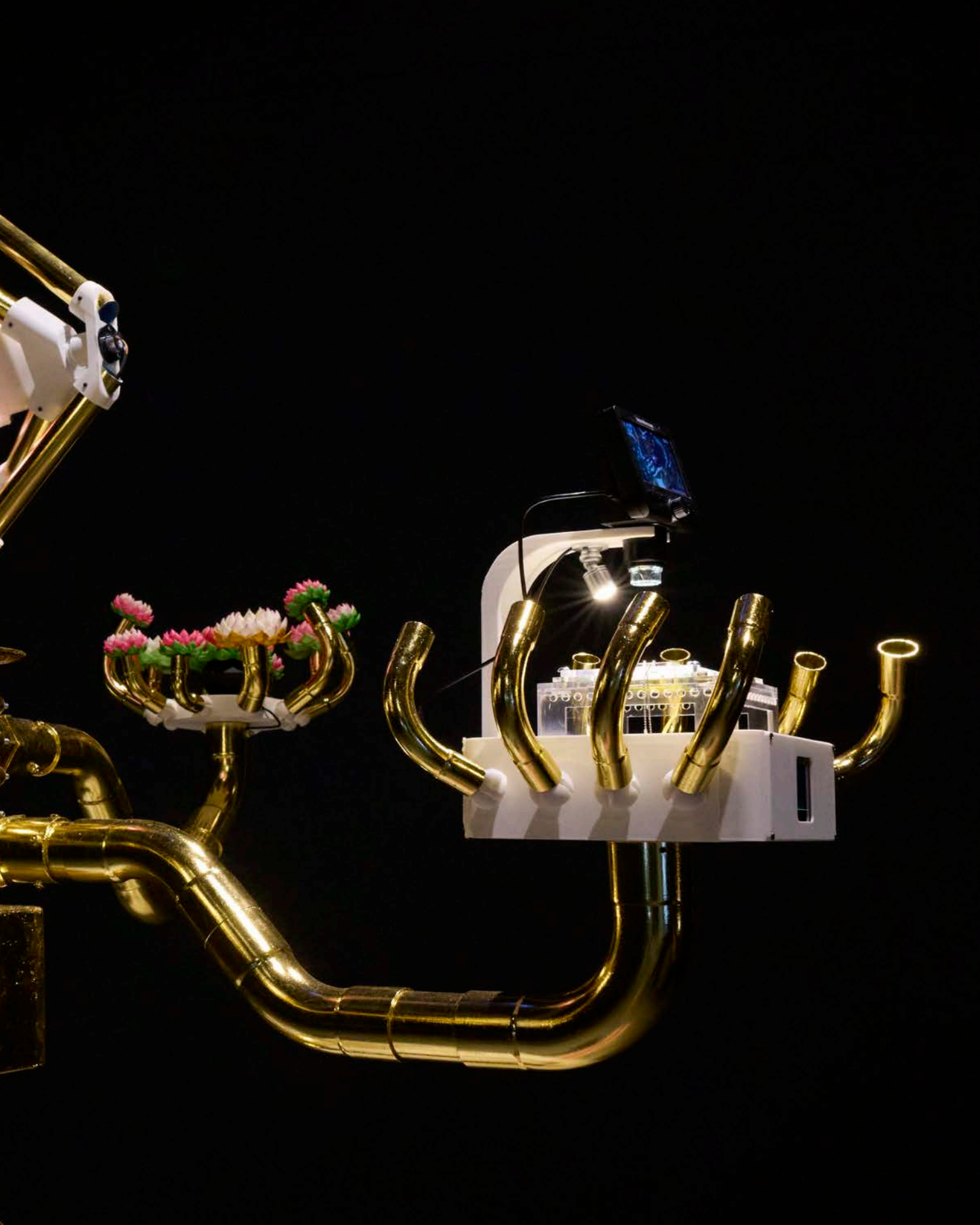
Originally published in Edward Young, *The Complaint: Or, Night-Thoughts on Life, Death, and Immortality* (London, 1742–45).



Henry Tan, Masato Takemura, and collaborators, *Pillars of Creation*, 2024. Detail: clinostat LED hologram. Courtesy of Fathomers. Photo: Carson Davis Brown.



Henry Tan, Masato Takemura, and collaborators, *Pillars of Creation*, 2024. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.



FATHOMERS

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Art from Life

October 8–December 15, 2024

Japanese American Cultural & Community Center, Los Angeles

Featuring the work of
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Dr. Marie Bannier Hélaouët, Organoid Group, Hubrecht Institute of the Royal Netherlands Academy of Arts and Sciences and Oncode Institute, The Netherlands; and Dr. Albert Wu, Ophthalmic Stem Cell and Regenerative Medicine Laboratory, Stanford University, with lab members Dr. Aditi Swarup, Dr. Hala Dhowre, Dr. Sanja Bojic, and Julietta Picco

Dr. Callie R. Chappell and Dr. Nasa Sinnott-Armstrong

Michael Jones McKean, with assistance from Dr. Stephen Fong, Professor of Chemical and Life Science Engineering, Virginia Commonwealth University, in cooperation with the Museu de Leiria, Portugal

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Dr. Pat Pataranutaporn

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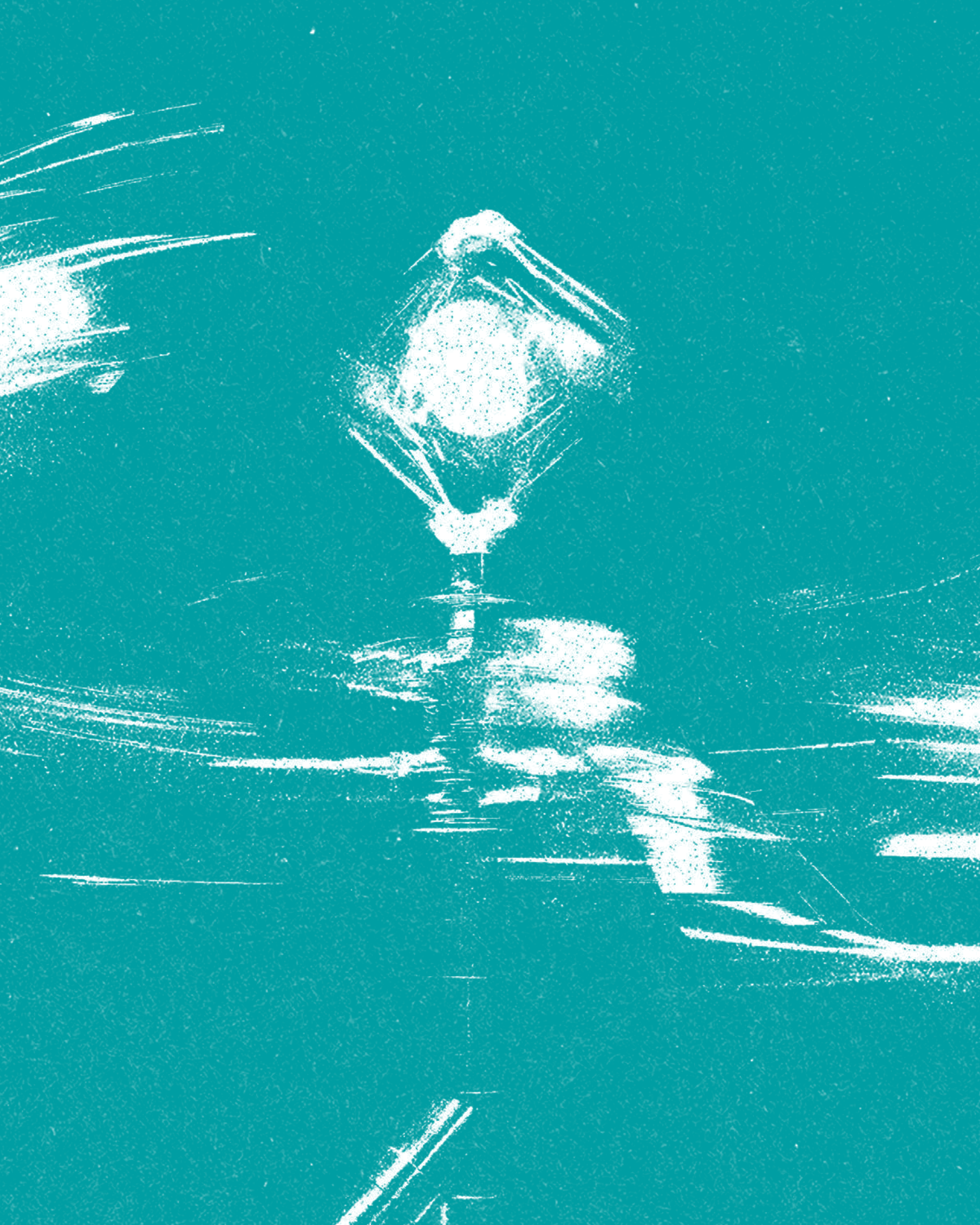








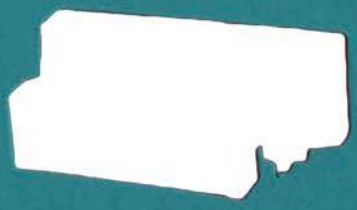
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FATHOMERS





Pinocho

This project is part of *Emergence*, an exhibition organized by Fathomers that ran from October 8 through December 15, 2024, at the Japanese American Cultural & Community Center in Los Angeles.

Emergence assembles artists, scientists, and artist-scientists working at the forefront of synthetic biology and contemporary art. Documentation of their projects as well as relevant writings and interviews, planning sketches, and other contextualizing materials are collected in this catalog. Some contributors draw from their work in medical or transdisciplinary research laboratories, where they confront new categories of life that destabilize our understandings of sentience, hybridity, and artificiality. Others engage the tools of synthetic biology as materials for creative experimentation and studio-based inquiry. Many contributors argue for decolonizing science and expanding access to biotechnologies through DIY and community science initiatives. Across *Emergence*, audiences and participants are invited to contemplate our human capacities for creation, destruction, recklessness, renewal, and hope. The exhibition prompts us to ask: Who has agency in this moment of making, learning, and living with? What forms of life are we choosing to cultivate? What will we nurture, and what might we leave behind?

Projects in the Exhibition

AfroRithm Futures Group
MultiPlanetary Garden

Marie Bannier Hélaouët and Albert Wu
Crying Organoids

Callie R. Chappell and Nasa Sinnott-Armstrong
IndiGROW

Michael Jones McKean
of kin and bone

Eduardo Padilha
Apoptotic Bodies

Pat Pataranutaporn
CyberBiome and *MicroPET*

Corinne Okada Takara
Floating Future Gardens

Henry Tan and Masato Takemura
Pillars of Creation

Tissue Culture & Art Project
The Use of Life (in Relation to the Industry of Men)

Fathomers is a creative research institute dedicated to producing sites and encounters that challenge us to live and act differently in the world. Fathomers cultivates the ideas of diehard dreamers, commissions projects that seem far-fetched, and collaborates with thinkers across disciplines to expand the limits of scale, scope, and support for artist-led projects.

Emergence was presented as part of PST ART: *Art & Science Collide*. PST ART is presented by Getty.

Pat Pataranutaporn

Cyberbiological: Wearable Technology for Personalized Chronic Care

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Erika Szymanski



CyberBiome and *MicroPET*

Pat Pataranutaporn

Introduction by Natasha Boyd

"The future isn't something we wait for; the future is something we create," said Dr. Pat Pataranutaporn, addressing a packed Bangkok conference room in September 2023. For Pataranutaporn, this statement is literal. A technologist and researcher at the Massachusetts Institute of Technology (MIT), Pataranutaporn reimagines the traditional borders of the human body through his work, exploring human–AI interaction, synthetic biological augmentation, and the fertile cross-pollination between biological and digital systems.

Pataranutaporn was born in the Songkhla province of southern Thailand. Before moving to the United States, he cofounded

the Bangkok-based Futuristic Research Cluster, or FREAK Lab, an "anti-disciplinary" research group blending art and science to explore the relationship between humanity and emerging technologies. Pataranutaporn is also a member of the Fluid Interfaces research group at the MIT Media Lab. Here, "media" refers broadly to the concept of an artistic medium, and the Lab emphasizes the integration of science with design, engineering, and the arts. Pataranutaporn's research focuses on enabling the seamless integration of humans and machines. In his hands, computers become extracorporeal organs, as useful—and one day, perhaps, as integral—as a kidney or a heart.

Or the dermis. With *CyberBiome* (2021), a smart spacesuit, Pataranutaporn and his team created a prototype for an intelligent second skin that wearers could utilize in the ultra-foreign environment of outer space. Designed for day-to-day life in microgravity as well as for the exploration of new biomes, the smart spacesuit is made from soft, stretchy, self-healing bio-synthetic fabric and outfitted with a bony exoskeleton of compartments holding biodigital organs, which together outline the shape of a heart. The optogenetic components of the suit continually monitor the wearer, triggering the production of personalized molecular therapies according to different biosignatures. Such provocative conceptual details suggest the potential alienness of the future human. When we're off Earth, what will we become? Where does the border of the human begin—at the level of the body or of the planet?

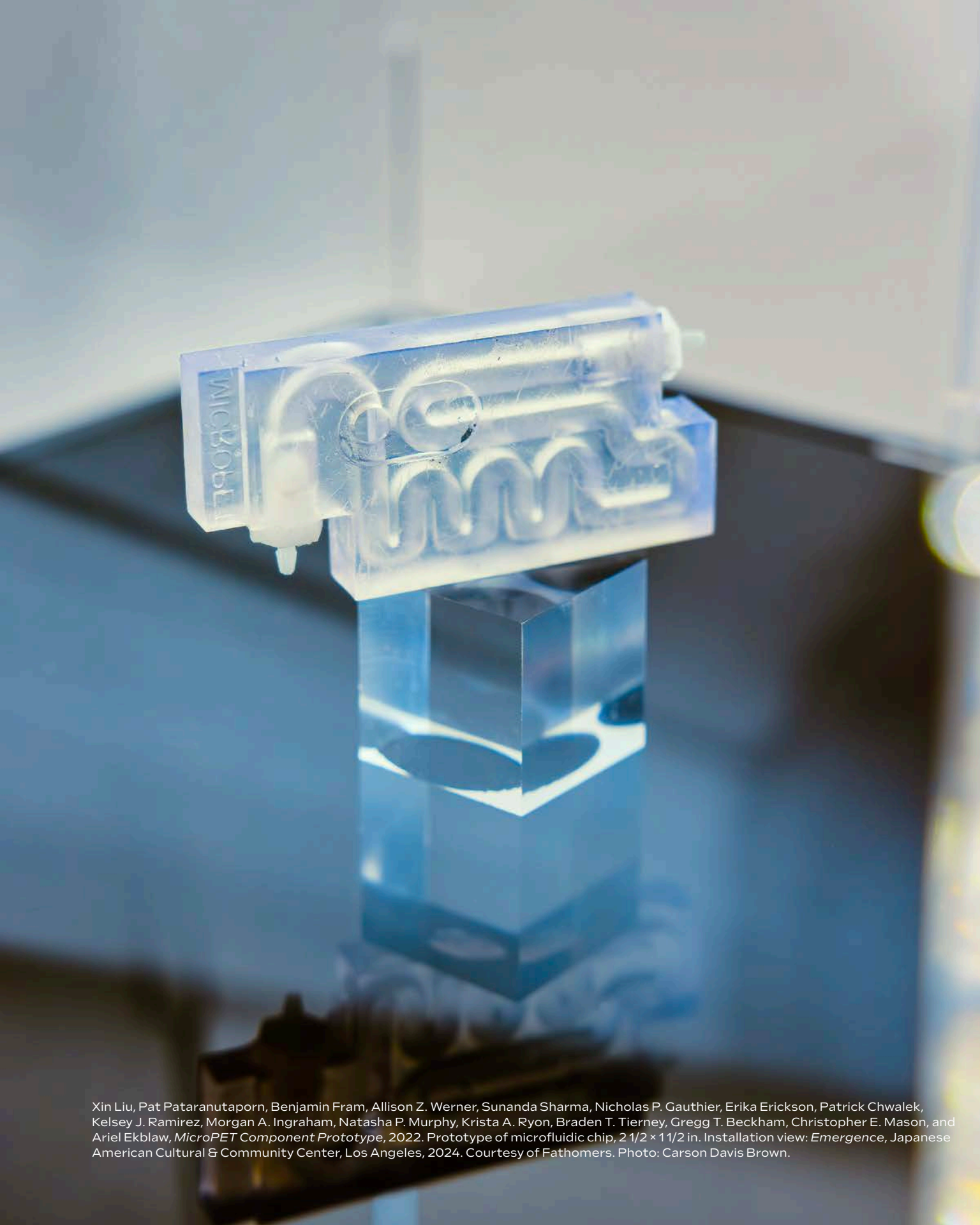
These are not idle thought experiments for Pataranutaporn: NASA is prototyping his spacesuit for future missions. "Technology is neither negative nor positive nor even neutral.

It is not inherently good or evil, but rather depends on how people utilize it," he has stated. "I don't believe that developing innovative technologies is going to automatically make our lives better. AI may deceive us if it is programmed to do so," for example, "or it may assist us in learning more effectively. In the end, it is a question of how it should be complemented or connected to humans in order to achieve a result."

Nonetheless, his *MicroPET* project (2023) might easily be described as inherently beneficial. Today, 6.3 billion metric tons of plastic sit in landfills and form small islands out at sea. PET plastic, or poly-ethylene terephthalate, is one of the most common forms of plastic waste. It is widely used in clothing fibers and containers for food and liquids, and takes about 450 years to decompose naturally. *MicroPET* programs bacteria and enzymes to break down PET plastic, converting it into environmentally benign molecules for reuse. Named one of *TIME*'s "200 Best Inventions of 2023," *MicroPET* posits an evolution in which the detritus produced by global civilization is absorbed and transfigured for a new world order, one in which our garbage no longer outlasts us. We might both be transformed in the process.



1 Pat Pataranutaporn, interview by Nathatai Tangchadakorn, *art4D*, October 27, 2023, https://art4d.com/en/2023/10/pat-pataranutaporn.

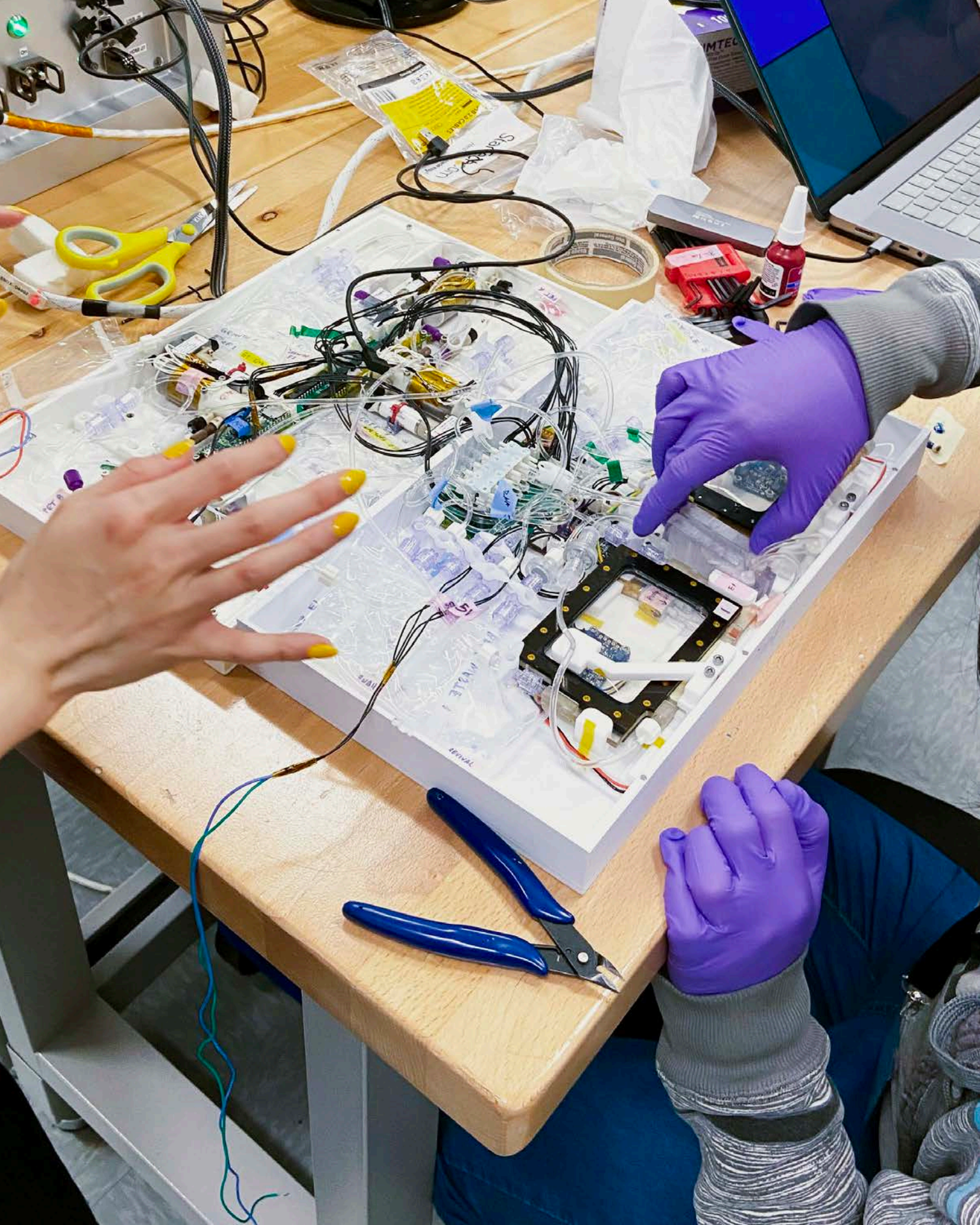


Xin Liu, Pat Pataranutaporn, Benjamin Fram, Allison Z. Werner, Sunanda Sharma, Nicholas P. Gauthier, Erika Erickson, Patrick Chwalek, Kelsey J. Ramirez, Morgan A. Ingraham, Natasha P. Murphy, Krista A. Ryon, Braden T. Tierney, Gregg T. Beckham, Christopher E. Mason, and Ariel Ekblaw, *MicroPET Component Prototype*, 2022. Prototype of microfluidic chip, 2 1/2 × 1 1/2 in. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.



Pat Pataranutaporn, Aria Xiying Bao, Brandon Dorr, David Kong, Pattie Maes, Galina Mihaleva, and Christopher Voigt, *CyberBiome*, 2021. Biodigital SmartSuit with optoelectronic device, dimensions variable. Installation view: *Emergence,* Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.







Pat Pataranutaporn

Dr. Pat Pataranutaporn is a technologist and researcher at the Massachusetts Institute of Technology, where he explores human–AI interaction, cyborg psychology, synthetic virtual humans, and synthetic biology, with a focus on the intersections between biological and digital systems. Pataranutaporn has collaborated with teams at NASA; NTT DATA; IBM Research; KBTG; the University of California, Santa Barbara; Stanford Medicine; and Harvard University, and his work has been exhibited at the MIT Museum, Cambridge, Massachusetts; MAXXI, Rome; the Art Gallery of Western Australia, Perth; the National Museum of Singapore; idea Museum, Mesa, Arizona; SIGGRAPH Asia, Tokyo; Ars Electronica; and elsewhere.

Opposite page: Team members work on *MicroPET* (2023), an autonomous payload for enzymatic reactions and microbial cultivation, in 2022. *MicroPET* was developed through a collaboration between the MIT Media Lab Space Exploration Initiative, NREL, Weill Cornell Medicine, Harvard Medical School, and Seed Health to study the biological upcycling of polyethylene terephthalate (PET) in a two-step system involving enzymatic degradation and microbial upcycling. The payload system was launched to the International Space Station aboard SpaceX CRS-26 on November 26, 2022. Photo: © *MicroPET* team.

Cyborgs and space

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Altering man's bodily functions to meet the requirements of extraterrestrial environments would be more logical than providing an earthly environment for him in space . . . Artifact-organism systems which would extend man's unconscious, self-regulatory controls are one possibility

By *Manfred E. Clynes and Nathan S. Kline*

ROCKLAND STATE HOSPITAL, ORANGEBURG, N. Y.



Clynes Kline

Manfred E. Clynes has since 1956 been chief research scientist at Rockland State, in charge of the Dynamic Simulation Lab. A graduate of the Univ. of Melbourne, Australia, and holder of an M.S. from Juilliard School, he has for the past 10 years been engaged in the design and development of physiological instrumentation and apparatus, ultrasonic transducers, and electronic data-processing systems.

Nathan S. Kline has been director of research at Rockland State since 1952 and an assistant professor of clinical psychiatry at the Columbia Univ. College of Physicians and Surgeons since 1957. Author of more than 100 papers, Dr. Kline holds a New York Newspaper Guild Page One Award in science, the Adolf Meyer Award of the Assn. for Improvement of Mental Health, and the Albert Lasker Award of the American Public Health Assn.

This article *is based* on a paper presented under *the* title of "Drugs, Space and Cybernetics" *at* the .Psychophysiological Aspects *of Space* Flight Symposium sponsored by the AF School of *Aviation* Medicine in *San* Antonio, Tex., in May. The complete paper will appear in the Symposium proceedings, to be published by Columbia *Univ.* Press.

SPACE travel challenges mankind not only technologically but also spiritually, in that it invites man to take an active part in his own biological evolution. Scientific advances of the future may thus be utilized to permit man's existence in environments which differ radically from those provided by nature as we know it.

The task of adapting man's body to any environment he may choose will be made easier by increased knowledge of homeostatic functioning, the cybernetic aspects of which are just beginning to be understood and investigated. In the past evolution brought about the altering of bodily functions to suit different environments. Starting as of now, it will be possible to achieve this to some degree ***without alteration*** *of* ***heredity*** by suitable biochemical, physiological, and electronic modifications of man's existing modus vivendi.

Homeostatic mechanisms found in organisms are designed to provide stable operation in the particular environment of the organism, Examples of three successful alternate solutions provided by biological mechanisms to the body-environment problem with regard to operating temperature are man, hibernating animals, and poikilothermic fish (organisms with blood that take on the temperature of the environment).

Various biological solutions have also been developed for another problem—respiration. Mammals, fish, insects, and plants each have a different solution with inherent limitations but eminently suitable for ***their field*** of ***operation.*** Should an organism desire to live outside this field, an apparently "insurmountable" problem exists.

However, is the problem really insurmountable? If a fish wished to live on land, it could not readily do so. **If,** however, a particularly intelligent and resourceful fish could be found, who had studied a good deal of biochemistry and physiology, was a master engineer and cyberneticist, and had excellent lab facilities available to him, this fish could conceivably have the ability to design an instrument which would allow him to live on land and breathe air quite readily.

In the same manner, it is becoming apparent that we will in the not too distant future have sufficient knowledge to design instru-

mental control systems which will make it possible for our bodies to do things which are no less difficult.

The environment with which man is now concerned is that of space. Biologically, what are the changes necessary to allow man to live adequately in the space environment? Artificial atmospheres encapsulated in some sort of enclosure constitute only temporizing, and dangerous temporizing at that, since we place ourselves in the same position as a fish taking a small quantity of water along with him to live on land. The bubble all too easily bursts.

The biological problems which exist in space travel are many and varied. Long-term space voyages, involving flights not of days, months or years, but possibly of several thousand years, will eventually be hard realities, and resultant physiological and psychological conditions must be considered.

These are reviewed below. In some cases, we have proposed solutions which probably could be devised with presently available knowledge and techniques. Other solutions are projections into the future which by their very nature must resemble science fiction. To illustrate, there may be much more efficient ways of carrying out the functions of the respiratory system than by breathing, which becomes cumbersome in space. One proposed solution for the not too distant future is relatively simple: Don't breathe!

If man attempts partial adaptation to space conditions, instead of insisting on carrying his whole environment along with him, a number of new possibilities appear. One is then led to think about the incorporation of integral exogenous devices to bring about the biological changes which might be necessary in man's homeostatic mechanisms to allow him to live in space *qua natura.*

The autonomic nervous system and endocrine glands cooperate in man to maintain the multiple balances required for his existence. They do this without conscious control, although they are amenable to such influence. Necessary readjustments of these automatic responses under extraterrestrial conditions require the aid of control theory, as well as extensive physiological knowledge.

Cyborg—Frees Man to Explore

What are some of the devices necessary for creating self-regulating man-machine systems? This self-regulation must function without the benefit of consciousness in order to cooperate with the body's own autonomous homeostatic controls. For the exogenously extended organizational complex functioning as an integrated homeostatic system unconsciously, we propose the term "Cyborg." The Cyborg deliberately incorporates exogenous components extending the self-regulatory control function of the organism in order to adapt it to new environments.



One of the first Cyborgs, this 220-gm rat has under its skin the Rose osmotic pump (shown in close-up below), designed to permit continuous injections of chemicals at a slow, controlled rate into an organism without any attention on the part of the organism.



If man in space, in addition to flying his vehicle, must continuously be checking on things and making adjustments merely in order to keep himself alive, he becomes a slave to the machine. The purpose of the Cyborg, as well as his own homeostatic systems, is to provide an organizational system in which such robot-like problems are taken care of automatically and unconsciously, leaving man free to explore, to create, to think, and to feel.

One device helpful to consideration of the construction of Cyborgs, which is already available, is the ingenious osmotic pressure pump capsule developed by S. Rose for (CONTINUED ON PAGE 74)



Reflectors for Solar Power

Some **7000** of these small aluminum reflectors would be banked to focus solar rays on a **thermocouple** in a **1500**-watt power generator under study **by** Hamilton Standard Div. **of** United Aircraft for **WADD.** The company will have a 100-watt model using about **900** reflectors ready for evaluation this fall. The banks of reflectors will be designed **to** unfold **in** space from **a** compact **package.**

Cyborgs and Space

(CONTISUED FROM PAGE 27)

continuous slow injections of biochemically active substances at a biological rate. The capsule is incorporated into the organism and allows administration of a selected drug at a particular organ and at a continuous variable rate, without any attention on the part of the organism.

Capsules are already available which will deliver as little as 0.01 ml/day for 200 days, and there is no reason why this time could not be extended considerably. The apparatus has already been used on rabbits and rats, and for continuous heparin injection in man. No untoward general effect on health was noted when the injector was buried in animals. As long as five years ago, an injector 7 cm long and **1.4** cm in diam, weighing 15 gm, was successfully buried under the skin of rats weighing 150–250 gm. The photo on page 27 shows a rat weighing 220 gm with an injector ***in situ,***

The combination of an osmotic pressure pump capsule with sensing and controlling mechanisms can form a continuous control loop which will act as an adjunct to the body's own autonomous controls. In this manner, these controls can be changed to the desired performance characteristics under various environmental conditions. If these characteristics were determined, such a system would be possible today with the selection of appropriate drugs.

For example, systolic blood pressure may be sensed, compared to a reference value based on the space conditions encountered, and regulated by letting the difference between sensed and reference pressures control administration of an adrenergic or vasodilator drug. Of course, any such system presupposes that we would be cognizant of what optimum blood pressure would be under various space conditions.

While it is quite difficult to set up per limits to "natural" human physiological and psychological performance, we can take as minimal the capabilities demonstrated under control conditions such as yoga or hypnosis. The imagination is stretched by the muscular control of which even the undergraduate at a Yoga College is capable, and hypnosis per se may prove to have a definite place in space travel, although there is much to be learned about the phenomena of dissociation, generalization of instructions, and abdication of executive control.

We are now working on a new preparation which may greatly enhance hypnotizability, so that pharmacological and hypnotic approaches may be symbiotically combined.

Psycho-Physiological Problems

Let **us** now turn our attention to some of the special physiological and psychological problems involved in space travel, and see how Cyborg dynamics may help achieve better understanding and utilization of man's natural abilities.

Wakefulness. For flights of relatively short or moderate duration—a few weeks or even a few months—it would appear desirable to keep the astronaut continuously awake and fully alert. The extension of normal functioning through the use of that group of drugs known as psychic energizers, with adjunctive medication, for this purpose is a present-day reality. In flights lasting a month or two, no more than a few hours a day of sleep would be required in the normal environment if such drugs were employed. Tests indicate efficiency tends to increase, rather than decrease, under such a regime, and extended usage appears entirely feasible.

Radiation Effects. One subsystem of the Cyborg would involve a sensor to detect radiation levels and an adaptation of the Rose osmotic pump which would automatically inject protective pharmaceuticals in appropriate doses. Experiments at the **AF** School of Aviation Medicine already indicate an increase in radiation resistance resulting from combined administration of aminoethylisothioronium and cysteine to monkeys.

Metabolic Problems and ***Hypothermic Controls.*** In the case of prolonged space flight, the estimated consumption of 10 lb a day for human fuel—2 lb of oxygen, **4** lb of fluid, and **4** lb of food—poses **a** major problem. During a flight of a year or longer, assuming that the vehicle was operating satisfactorily, there would be little or no reason for the astronaut **to** be awake for long periods unless some emergency arose. Hypothermia (reduction of body temperature) would appear to be a desirable state in such long voyages in order to reduce metabolism, and thus human "fuel" consumption. The use of external cooling, reduction of the temperature of the blood in an arterio-venous shunt, and hibernation (through pituitary control), alone or in combination with pharmaceuticals, all seem to offer possibilities in attempting to obtain and maintain such a state. Control of the

temperature by influencing the heat regulating center would be more desirable than changing the reference level.

Oxygenization and Carbon Dioxide Removal. Breathing in space is a problem because the space environment will not provide the necessary oxygen, and respiration eliminates needed carbon dioxide and involves heat and water losses. An inverse fuel cell, capable of reducing CO_2 to its 'components with removal of the carbon and recirculation of the oxygen, would eliminate the necessity for lung breathing. Such a system, operating either on solar or nuclear energy, would replace the lung, making breathing, as we know it, unnecessary. Conventional breathing would still'be possible, should the environment permit it, discontinuing the fuel-cell operation.

Fluid Intake and Output. Fluid balance in the astronaut could be largely maintained via a shunt from the ureters to the venous circulation after removal or conversion of noxious substances. Sterilization of the gastrointestinal tract, plus intravenous or direct intragastric feeding, could reduce fecal elimination to a minimum, and even this might be reutilized.

Enzyme Systems. Under conditions of lowered body temperature, certain enzyme systems would tend to remain more active than others. The extent to which pharmaceutical or chemical agents could influence this enzyme activity has not been systematically investigated, but beyond question they will play an important role. Since metabolism is subject to enzyme control, several intriguing possibilities exist. For example, it may be possible through in vitro radiation to convert certain organisms from aerobic to anaerobic states and, by studying changes in the enzyme systems, to adapt them for eventual human use. In the same manner, selected atmospheres of other types could be investigated.

Vestibular Function. Disorientation or discomfort resulting from disturbed vestibular function due to weightlessness might be handled through the use of drugs, by temporarily draining off the endolymphatic fluid or, alternately, filling the cavities completely, and other techniques involving chemical control. Hypnosis may also be useful for controlling vestibular function.

Cardiovascular Control. The application of control-system theory to biology has already yielded sufficiently fruitful results in studies of the multiple homeostatic functions of the cardiovascular system to indicate the possibility of altering the system by the Cyborg technique. Administration of presently available drugs, such as epinephrine, reserpine, digitalis, amphetamine, etc., by means of Rose injectors, offers one possibility of changing the cardiovascular functions so as to fit them for a particular environment. Alteration of the specific homeostatic references within or outside the brain, and electric stimulation, either as a means of regulating heart rate or affecting selected brain centers in order to control cardiovascular functioning, are other possibilities.

Muscular Maintenance. Prolonged sleep or limited activity has a deleterious effect on muscle tone. While reduction of body temperature and metabolism may reduce the magnitude of the problem, further investigation of the chemical reasons for atrophy appears necessary to develop adequate pharmaceutical protection to help maintain muscle tone on prolonged space voyages.

Perceptual Problems. Lack of atmosphere will create markedly different conditions of visual perception than those with which we are familiar. Attention should be given to providing a medium which would recreate some of the distortions to which we are accustomed, and to which the astronaut could become acclimated before takeoff. Part of the problem would come from searching for an adequate frame of reference, and in this regard the factors which influence autokinesis (and illusory movement) may have an influence on space perception problems. Investigation of whether pharmaceuticals would influence autokinesis is therefore desirable.

Pressure. Under pressure lower than 60-mm Hg, man's blood begins to boil at his normal body temperature, Therefore, if he is to venture out of his space vehicle without a pressure suit, some means must be found of reducing his normal operating temperature to a point where the vapor pressure of his fluids is no greater than the internal tissue pressures. This is another reason why lowering of body temperature is essential to avoid the use of constricting pressure suits.

Variations in External Temperature. While man will require the protection of a space ship or station at the real extremes of temperature, there are also likely to be intermediate conditions within or close to the limits of human tolerance. By controlling reflection a d absorption by means of protective plastic sponge clothing plus chemicals already in existence which produce changes in pigmentation and provide effective protection against actinic rays, it should be possible to maintain desired body temperature. Needed is a light-sensitive, chemically regulated system which would adjust to its own reflectance so as to maintain the temperature desired.

Gravitation. A change in the ratio of gravity and inertia forces to molecular forces will alter mobility patterns, among other things. Body temperature control and other uses of pharmaceuticals could possibly improve functioning under conditions of greater or lesser gravitation than that on earth.

Magnetic Fields. Chemicals and temperature alteration might also act to retard or facilitate the specific effects of magnetic fields in space.

Sensory Invariance and Action Deprivation. Instead of sensory deprivation, it is sensory invariance, or *lack of change* in sensory stimuli, which may be the astronaut's bugaboo. In

End of the Line



Official AF photos show the 5000-mile Northrop SM-62 Snark missile release its nose, packing a dummy nuclear payload, in a practice run on a target. The nose will proceed at supersonic speed on a ballistic trajectory.

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most of the sensory deprivation experiments to date, it has been sensory invariance which has produced discomfort and, in extreme circumstances, led to the occurrence of psychotic-like states. Of even greater significance may be action invariance, deprivation or limitation, since in many such experiments subjects have mentioned a "desire for action." The structuring of situations so that action has a meaningful sensory feedback should reduce these difficulties. Here again drugs could play a useful role in reducing resultant tensions. Action without demonstration that such behavior is purposeful or sensory stimuli without opportunity for appropriate response are both highly disturbing.

Psychoses. Despite all the care exercised, there remains a strong possibility that somewhere in the course of a long space voyage a psychotic episode might occur, and this is one condition for which no servomechanism can be completely designed at the present time. While an emergency osmotic pump containing one of the high-potency phenothiazines together with reserpine could be a part of the complete space man's kit, the frequent denial by an individual undergoing a psychotic episode that his thought processes, emotions, or behavior are abnormal, might keep him from voluntarily accepting medication. For this reason, if monitoring is adequate, provision should be made for triggering administration of the medication remotely from earth or by a companion if there is a crew on the vehicle.

Limbo. The contingency of possible extreme pain or suffering as a result of unforeseen accidents must also be considered. The astronaut should therefore be able to elect a state of unconsciousness if he feels it to be necessary. Prolonged sleep induced either pharmacologically or electronically seems the best solution.

Other Problems

There obviously exists an equally large number of medical problems amenable to pharmacological influence which have not been discussed here for lack of space. Among these are such conditions as nausea, vertigo, motion sickness, erotic requirements, vibration tolerance, etc.

However, those selected for discussion offer an indication as to what the Cyborg can mean in terms of space travel. Although some of the proposed solutions may appear fanciful, it should be noted that there are references in the Soviet technical literature to research in many of these same areas. Thus we find the Russians proposing prior oxygen saturation as a solution to the problem of respiration during the first few minutes after space vehicle launchings; reporting on alterations of the vestibular function both by drugs and surgery; studying perception and carrying out research on the laws of eye motion in vision; finding that lowering of temperature can aid in solving pressure problems; etc.

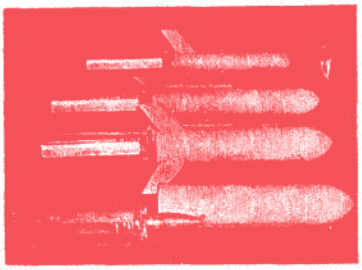
Solving the many technological problems involved in manned space flight by adapting man to his environment, rather than vice versa, will not only mark a significant step forward in man's scientific progress, but may well provide a new and larger dimension for man's spirit as well. ♦♦

A complete list of references for this paper may be obtained by writing to the Editor, Astronautics, 500 Fifth Ave., New York 36, N.Y.

Army Missile Transfer

August 1 the Army transferred seven surface-to-surface missile systems—Honest John, Little John, Corporal, Sergeant, Light Antitank Weapon (LAW), Missile A, and Missile B—from ARGMA to ABMA, which has had Redstone, Jupiter, and Pershing. ARGMA will continue responsibility for Nike-Zeus, Nike-Hercules, Nike-Ajax, Hawk, Mauler, Redeye, Lacrosse, and Shillelagh, and for field service activities related to management of the transferred weapons.

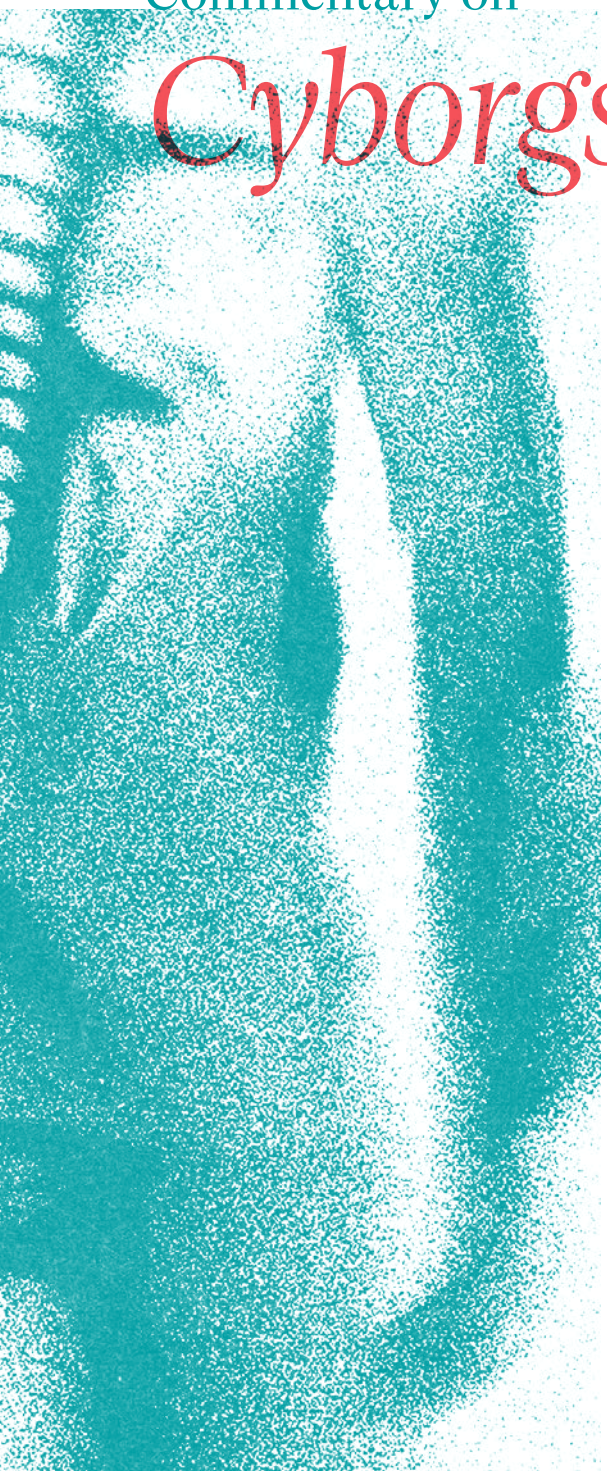
Rotary Wings For Re-entry



The AF's Wright Air Development Div. recently awarded Kaman Aircraft a contract for nearly a half-million dollars to develop and test a guided recovery device based on Kaman's Rotochute, shown above fixed to three payloads weighing from 100 to 200 lb and strung by a cable to the bottom one. The development will aim at a re-entry aid for manned space capsules, nose cones, and rocket boosters.

Commentary on

Cyborgs and Space

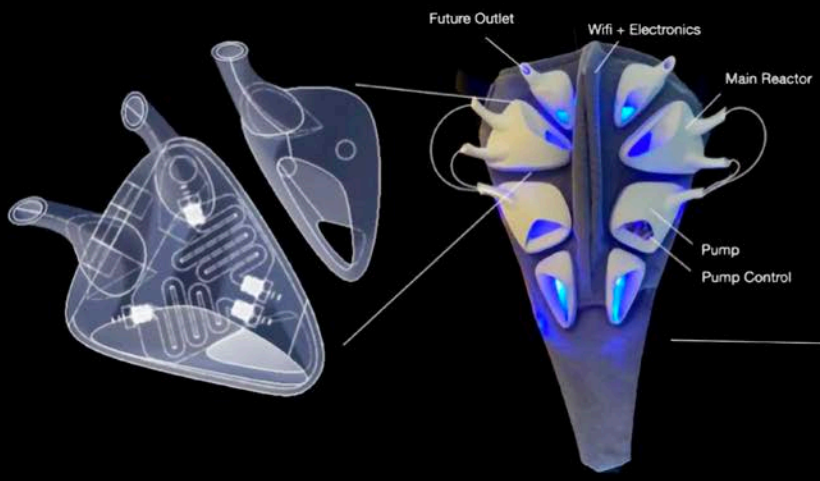


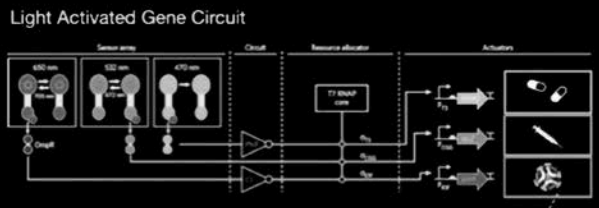
Pat Pataranutaporn

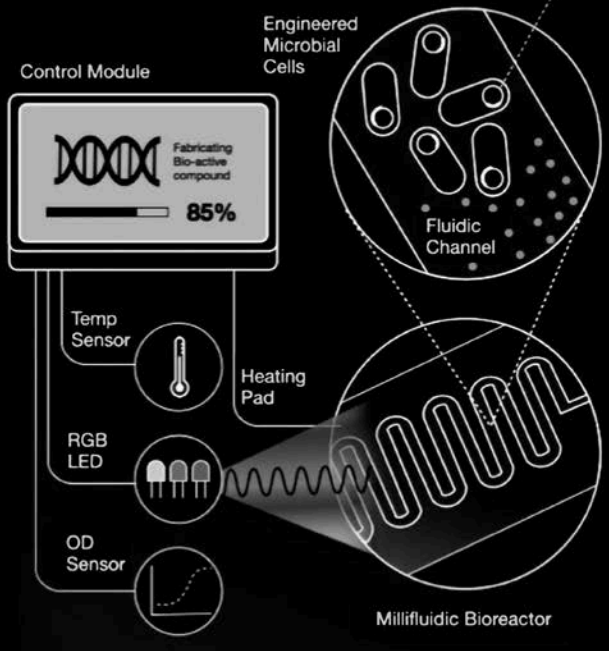
When Dr. Manfred E. Clynes and Dr. Nathan S. Kline first wrote about cyborgs and space in 1960, they envisioned using cybernetic principles to transform the human body to help us reach the stars and beyond. What they couldn't have imagined was how their concept would become woven into everyday life on Earth—from AI that precisely calibrates social media content to maximize engagement to wearable sensors and medical technologies that empower patients to live independently. Their grand vision deserves special attention. We shouldn't focus solely on what technology *could* do but also on what technology *should* do. Unlike today's science-fictional portrayals of cyborgs as dehumanizing transformations of people into machines, Clynes and Kline proposed using technology to make humans more human than ever by "leaving [humans] free to explore, to create, to think, and to feel." This enchanting vision—of technology enhancing rather than diminishing our humanity—is one we should not forget.



Pat Pataranutaporn and collaborators' digital rendering of *CyberBiome* (2021), a wearable, programmable organ for the personalized, on-demand production of therapeutics and biomolecules in space. Photo: © MIT Media Lab.


Future Outlet
Wifi + Electronics
Main Reactor
Pump
Pump Control


Light Activated Gene Circuit


Control Module
Fabricating Bio-active compound
85%
Engineered Microbial Cells
Fluidic Channel
Temp Sensor
Heating Pad
RGB LED
OD Sensor
Millifluidic Bioreactor



Wearable Lab on Body:

Combining Sensing of Biochemical and Digital Markers in a Wearable Device

Pat Pataranutaporn, Abhinandan Jain, Casey M. Johnson, Pratik Shah, and Pattie Maes



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Abstract

Wearables are being widely researched for monitoring individuals' health and well-being. Current-generation wearable devices sense an individual's physiological data, such as heart rate, respiration, electrodermal activity, and electroencephalogram (EEG), but lack in sensing their biological counterparts, which drive the majority of individuals' physiological signals. On the other hand, biosensors for detecting biochemical markers are currently limited to one-time use, are noncontinuous, and don't provide flexibility in choosing which biomarker they sense. We present Wearable Lab on Body, a platform for active continuous monitoring of human biomarkers from biological fluid. Our platform contains digital sensors such as inertial measurement units (IMU) for activity recognition as well as an automated system for continuous sampling of biomarkers from saliva by leveraging already-existing paper-based biochemical sensors. The platform could aid with longitudinal studies of biomarkers and early diagnosis of diseases.

I. Introduction

A. Wearable Augmentation and Digital Sensing

Wearable technology has enabled on-body, real-time sensing and computing of human physiological information. Researchers have developed a variety of sensors to sense the internal (EEG, EOG, EMG, skin conductivity, heart rate, etc.) and external state (movement, location, interaction, etc.) of a person.[1] This information collected from the body can be used to provide real-time feedback and assistance to the person through multimodal actuators including audio,[2] visual,[3] olfactory,[4] electrical,[5] and haptic stimulation.[6] Thus the wearable technology becomes a closed-loop platform for augmenting human capabilities.[7]

With the advancement of radio and wireless sensing, researchers have also demonstrated the ability to monitor human physiological changes without placing any sensor on the human body.[8] This kind of research is enabled by the combination of high-resolution wireless sensing technology and advanced machine learning algorithms. Researchers have demonstrated the applications of wireless sensing to detect body movement,[9] breathing cycle,[10] heart rate,[11] emotion,[12] and sleep



Fig. 1. The overview of the Wearable Lab on Body platform, combining biochemical and digital sensing in a wearable device

stages[13] without any on-body monitoring devices. This digital sensing of physiological signals provides information about the higher-level state of the individual rather than capturing the molecular-level biological processes that drive physiological states.

B. Biological Sensing

Beyond the digital sensing of human physiology, biochemical markers are molecules used to indicate certain biological phenomena related to behavior, disease, infection, or environmental exposure.[14] These molecular biomarkers include organic and nonorganic compounds that are released or secreted as part of the human metabolism. In medicine, these biochemical markers reveal insights into human health at the molecular level, which can be used for personalized medicine that is either prognostic or predictive.[15]

Saliva is an emerging biological fluid for sensing of biomarkers and diagnostics.[16] Saliva is a clear, slightly acidic, complex solution, and is composed of secretions from major salivary glands; about 0.75–1.5 L is produced daily in the human body. Similar to blood, saliva contains various biomarkers including hormones, enzymes, antibodies, and antimicrobial and growth factors.[17] Many of these biochemicals enter saliva from the blood by passing through the spaces between cells. Therefore, the major compounds found in blood are also detectable in saliva. Thus saliva is functionally homologous to serum in reflecting the physiological state of the body, including emotional, hormonal, nutritional, and metabolic variations.[18]

In this paper, we propose that the next generation of wearable technology must bridge the gap between digital physiological sensing and biochemical sensing to capture a holistic model of the individual's internal and external state. We present our approach by developing Wearable Lab on Body, a platform for semi-invasive and minimally obtrusive biological wearable sensors that continuously monitor biomarkers from saliva. Our platform contains digital sensors such as IMU for activity recognition as well as biosensors for continuous monitoring of biochemical markers by leveraging already-existing paper-based sensors. Our platform could aid in early diagnosis of diseases by analyzing trends of biomarkers in saliva, as well as improve human health.

II. Related Work

The development of biomarker sensors has evolved from an invasive to a noninvasive approach.[19] Low-cost biosensor platforms have enabled the detection of the biomarkers in body fluids by coating chemical receptors on a flexible substrate such as a paper strip or a microfluidic channel.[20] The individual spits or takes a swab of their body fluid (saliva, sweat, urine, or blood) and places it on the platform. Chemical receptors on the sensor bind and react to the biomarker molecules, reporting the presence of the biomarker through a chemical reaction, such as a change in color,[21] fluorescing,[22] or sending out an electrochemical signal.[23]

The use of colorimetric reaction is one of the key methods for reporting the presence of the markers in paper-based sensors. Researchers have developed Dermal Abyss, a smart tattoo created with colorimetric and fluorescent biosensors that change color according to the interstitial fluid.[24] Further, researchers have used capillary flow for detection of biomarkers in saliva.[25] The concept of microfluidics on paper has been used to create Ampli, a plug-and-play set of paper-based blocks that can be arranged in various configurations to test biochemical reactions in real time for personalized diagnostics.[26]

A few researchers have begun to develop wearable methods for monitoring molecular biomarkers by integrating colorimetric sensors into the human body.[27] For example, researchers have designed a wearable microfluidic device for the capture, storage, and colorimetric sensing of glucose, chloride lactate, and pH from sweat.[28] In addition, researchers have developed a

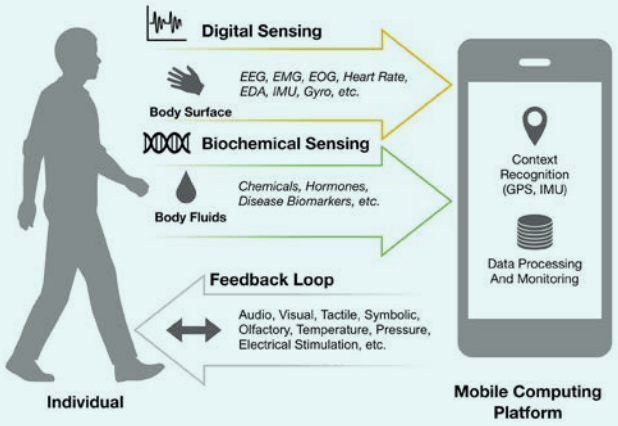


Fig. 2. Our vision for a biodigital wearable platform that bridges the gap between biochemical sensing and digital sensing

nanoporous membrane–based wearable sensor that detects cortisol in sweat.[29] However, these wearable sensor platforms are limited to one-time use and don't provide flexibility in choosing which biomarker they sense.

In terms of saliva, paper-based sensors have been widely developed to sense multiple biomarkers such as cortisol,[30] glucose,[31] nitric oxide,[32] pH,[33] and more.[34] These biomarkers have been used to detect signs of depression,[35] diabetes,[36] heart failure,[37] and periodontal diseases.[38] However, these paper-based sensors are generally limited to one-time use,[39] are noncontinuous, and do not connect with digital platforms for data recording, analysis, and building interventions.

III. Bridging Biodigital Sensing

Looking at the current literature, most of the biochemical sensing platforms lack the ability to monitor the context and activity of the individual, whereas the digital sensing platforms can only sense physiological signals but are not able to sense the molecular dynamics of the human body. Here, we present a vision for the future biodigital wearable device that bridges the gap between biochemical sensing and digital sensing. Our approach consists of four modules: biochemical sensors, digital sensors, mobile computing module, and feedback modality, as illustrated in figure 2.

The main advantage of such a biodigital wearable platform is that it enables the continuous monitoring of behavior and well-being of the individual in real-world settings. Using digital sensors such as IMU and GPS, the system can recognize the context of the individual regarding location and activity, while physiological sensing such as EEG can help the system to recognize the cognitive performance of the individual in terms of attention and emotion. The biological sensors could help quantify the molecular response of the body, for example by measuring changes in cortisol for stress. The information from both the biochemical and digital sensors can contextualize one another and provide insights on the effects of an individual's behavior, which in turn can be used to develop healthier lifestyles. With the closed-loop system, the platform could also provide real-time feedback to the individual when recognizing unhealthy behavior.



Fig. 3. The position of the Wearable Lab on a user

IV. Implementation

To illustrate our vision, we prototyped a biodigital platform for sensing the body fluid saliva. Our novel platform can 1) perform real-time continuous monitoring of biochemical markers on the body, 2) integrate plug-and-play paper-based flexible biosensors with digital sensors, and 3) convert colorimetric information from the biochemical sensing reaction to the digital readout.

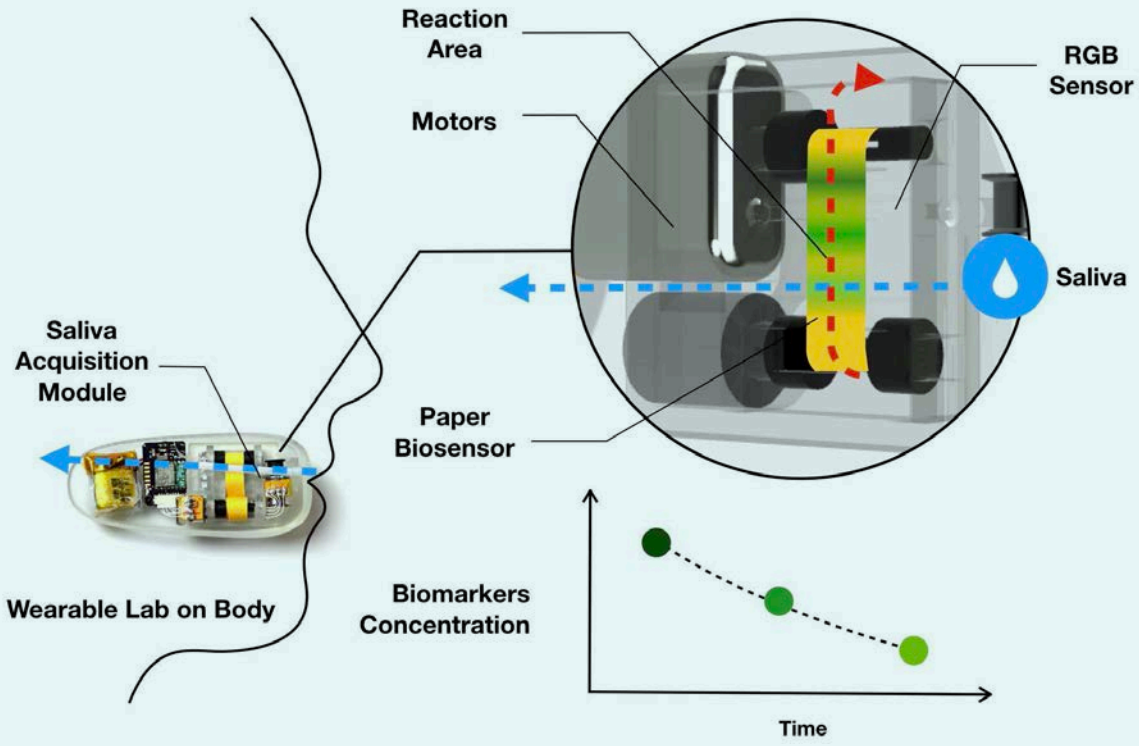


Fig. 4. The mechanical arrangement of saliva acquisition and rotating biosensor strip

Our platform is designed to continuously sample saliva from the individual and analyze it using a roll of multiplexed biochemical sensors. A small portion of the sensor is exposed to the acquired saliva at a point in time. Once the saliva reacts with a biochemical sensor, the RGB color sensor on the device reads the output and converts the value into the concentration of the biomarker based on the color concentration model. The used sensor is then switched with a new sensor in the roll. The platform consists of three main components: a paper-based biochemical sensor cartridge, a saliva acquisition and sensing module, and a smartphone application to store and analyze the data.

A. Paper-Based Biochemical Sensor Cartridge

The paper sensor cartridge is a roll of paper-based biochemical sensor strips that can be installed in the module. The paper sensor type is dependent upon the type of biomarker the individual wants to monitor. For monitoring multiple biomarkers, multiple biochemical paper sensors could be interleaved in the cartridge. The paper sensor strips have a thin film of impermeable transparent plastic on the backside to prevent cross-contamination from already-sensed or -acquired saliva. The width of the paper sensor that the current version of the device supports is 5.5 mm. One can vary the number of samples collected for a specific biomarker by varying the number of paper-based sensors for that biomarker on the tape. Sample RGB profiles of the medical-grade, commercially available saliva pH (biomarker for periodontal disease) sensor and nitric oxide (biomarker for heart failure) sensor are shown in figure 5.

B. Saliva Acquisition and Sensing Module

The saliva acquisition and sensing module consists of a mechanical arrangement for acquiring

a small quantity of saliva from buccal mucosa (inside of the cheek). It consists of two stepper motors, a small polytetrafluoroethylene (PTFE) tube, a length of braided nylon cord, a paper sensor cartridge, and the electronics for digital sensing. The arrangement is illustrated in figure 4. The PTFE tube of 2 mm diameter is held against the inside part of the cheek while the rest of the device sits outside the cheek. A stepper motor is used to circulate the cord against the cheek and through the device, collecting a small amount of saliva. The gathered saliva is then transferred onto the paper sensor by contact. Another stepper motor is then used to advance the paper sensor cartridge. A new portion of the paper sensor is rolled out and swabs the saliva from the cord. This motion is repeated several times to get the appropriate amount of saliva onto the paper sensor. The synchronous motion of the paper sensor and the collection mechanism allows the saliva to be transferred from the cord to the sensor without contaminating an unused sensor.

A color RGB sensor is mounted orthogonal to the paper sensor to track the color changes. We used the TCS34725 RGB color sensor with white LED light for illumination. The system is controlled by a Bluetooth low energy (BLE)–enabled microcontroller (BC832) mounted on a printed circuit board (PCB) inside the casing. The system also has a 9-axis inertial measurement unit (MPU9250) to track orientation as well as actions of the individual. The system is powered by a single-cell LiPo battery of 100 mAh capacity.

C. Smartphone Application

The smartphone application accompanying the device captures and processes the sensed saliva and the IMU data. It uses the wearable's IMU data to infer the individual's activities, including eating, drinking, speaking, or no activity. Sample signals of these activities are given in figure 6. Additional activities such as walking, sleeping, and running are inferred from the smartphone's IMU sensor and are also used to decorrelate it from the device's IMU sensor.[40]

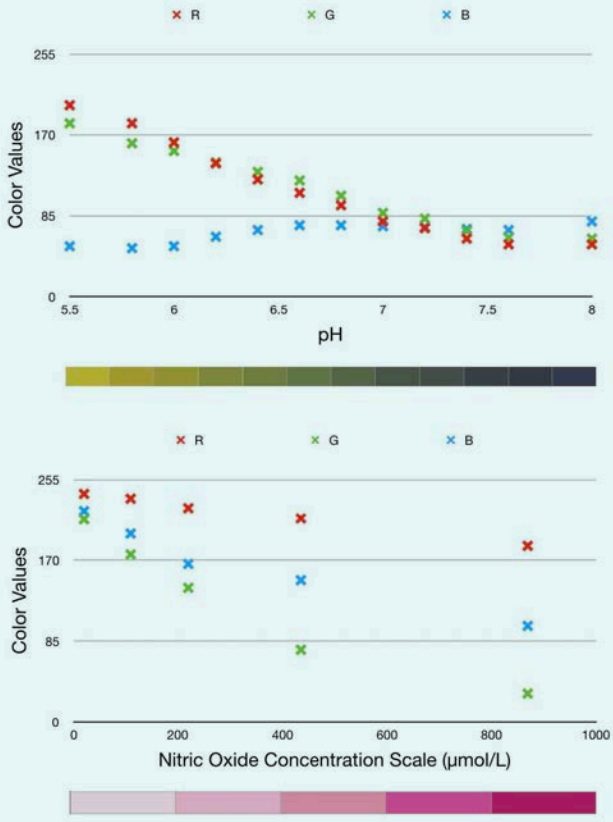


Fig. 5. The color concentration model of pH and nitric oxide strips

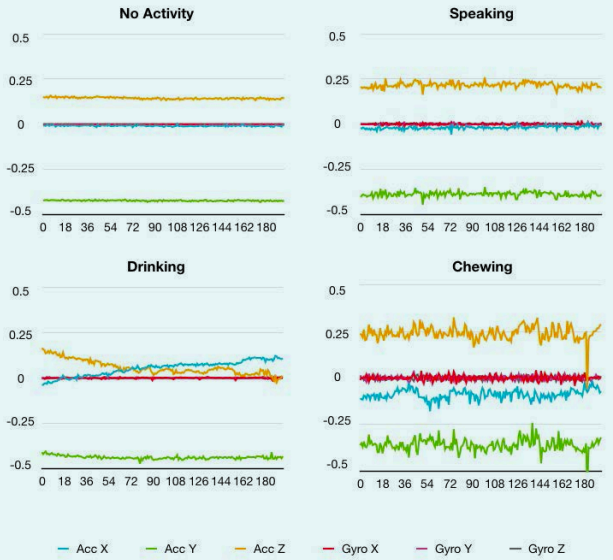


Fig. 6. Distinct IMU signals for activity recognition acquired from the user wearing the platform

Based on the context, the application models individual behavior and decides to sample the saliva after a certain time point to reduce contamination from an individual's eating or drinking. Finally, the saliva data acquired could be stored, analyzed for user feedback, or sent to a physician for additional investigation or diagnosis.

V. Applications

The ability to continuously monitor saliva in a semi-invasive and minimally obtrusive wearable form factor permits diagnostics and applications that were not possible before. This section describes some possible interventions enabled by the platform.

A. Medical and Well-Being

Previous research has shown the variability of biomarkers used for diagnosing several diseases. Variability in salivary biomarkers such as pH has been shown as an indicator of periodontal disease.[41] Different cortisol levels have been found between morning and afternoon,[42] and new biomarkers are emerging for early detection of Alzheimer's.[43] Furthermore, salivary diagnostics have been found to provide a diagnosis of cancer, HIV, and cardiovascular and possible neurological diseases such as Parkinson's and Huntington's.[44] The ability to continuously monitor saliva would enable studying dynamic range, frequency, and concentrations of biomarkers that have not been studied in longitudinal assays in humans. The method may allow detection of intricacies with the associated biomarker variations. Furthermore, the system being personal and user-specific may allow exploration of fundamental differences in biomarkers statistics between individuals. The trends found in the biomarkers could then serve to identify disease buildup. Given the diagnosis of a disease, a similar configuration of the system could also be used for scheduling the optimal time and quantities of drug delivery.

B. Human-Computer Interaction

Researchers have developed various context-aware, closed-loop feedback systems that provide real-time information based on an individual's physiological signals, such as heart rate, respiration, electrodermal activity, and temperature.[45] Several biomarkers in saliva allow for comprehensive sensing of an individual's affective state.[46] Our platform enables comprehensive sensing for developing closed-loop systems for mitigating pain, stress, and anxiety, and for enhancing sleep. The biological data coupled with the digital data would allow for better modeling of the individual. Coupling other sensory modalities, such as the voice of the user, with the biomarkers would allow for a better understanding of an individual's lifestyle and could aid in developing interventions to improve human well-being. This research also highlights the concept of biological human-computer interaction (Bio-HCI), a vision for future interfaces that bridge the gap between human and computer through biodigital systems.

VI. Discussion and Future Work

Our platform allows for continuous sensing of an individual's biological state by leveraging already-proven biochemical paper-based sensors with an individual's saliva as well as contextual sensing through digital and mobile computing. In future work, we hope to perform user testing to determine the efficacy of the system in real time. Testing the system in a longitudinal run would allow us to see and address possible issues. We would like to incorporate a paper sensor roll only to acquire saliva samples throughout the day. As an alternative to the real-time readout of biomarkers, the roll could be sent to a lab for analysis of complex biomarkers that currently aren't available in the form of paper colorimetric analysis. We also hope to incorporate machine learning into the smartphone application for classification of individual activities. Finally, we would also like to extend the system to use other

types of biomarker sensing techniques, such as electrical impedance.

VII. Conclusion

We presented a novel approach and platform for a combined biodigital wearable device. The semi-invasive, minimally obtrusive platform allows for the continuous monitoring of biomarkers from an individual's saliva. The platform also supports sensing the individual's biological data to infer individual body responses and digital data (IMU) to infer individual context, thereby bridging the gap between biological and digital sensors in wearable technology. This platform could be used for various applications such as early diagnostics and creating closed-loop feedback systems. We also hope that our biodigital wearable will inspire future research in wearable biological computing for improving human health and well-being.

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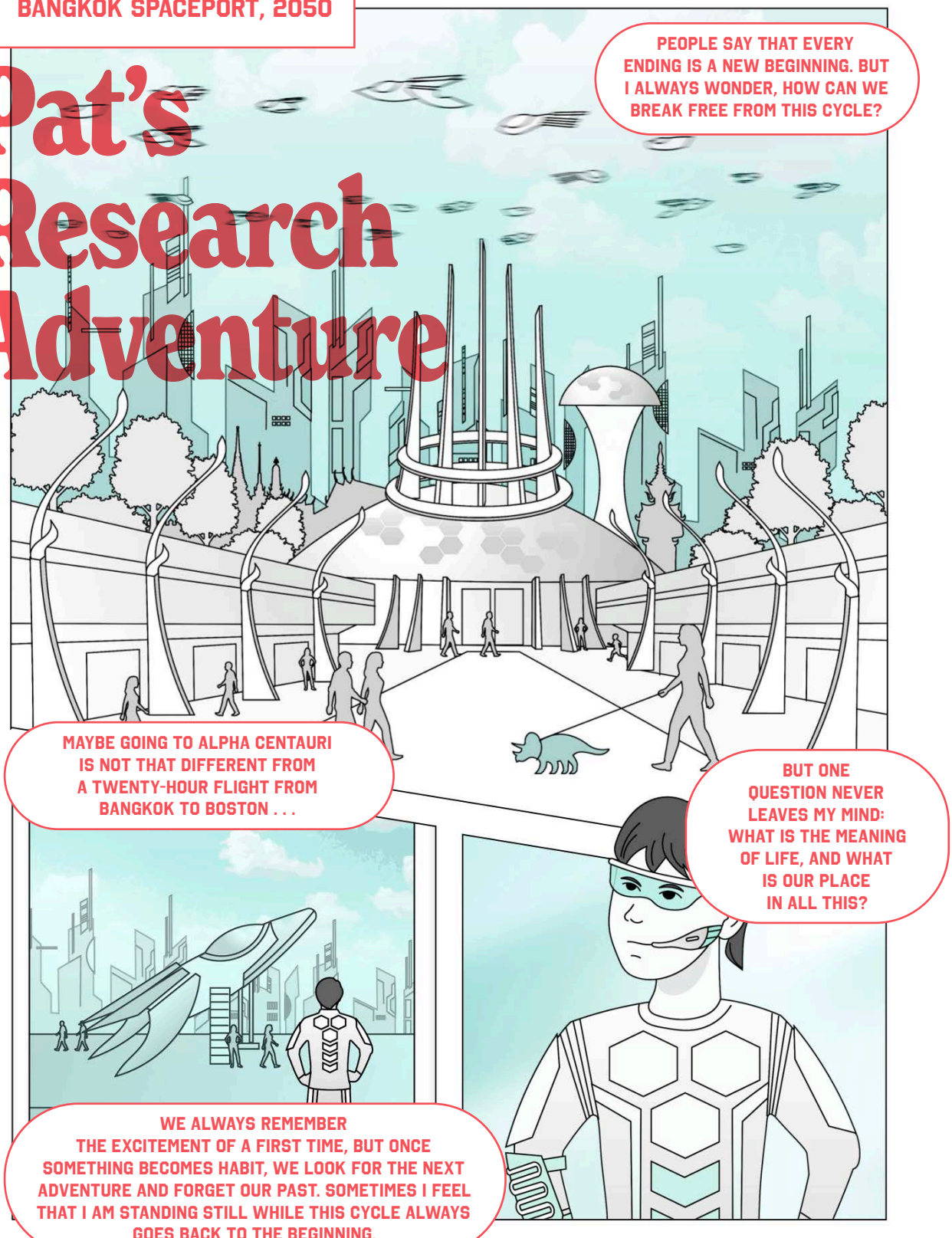
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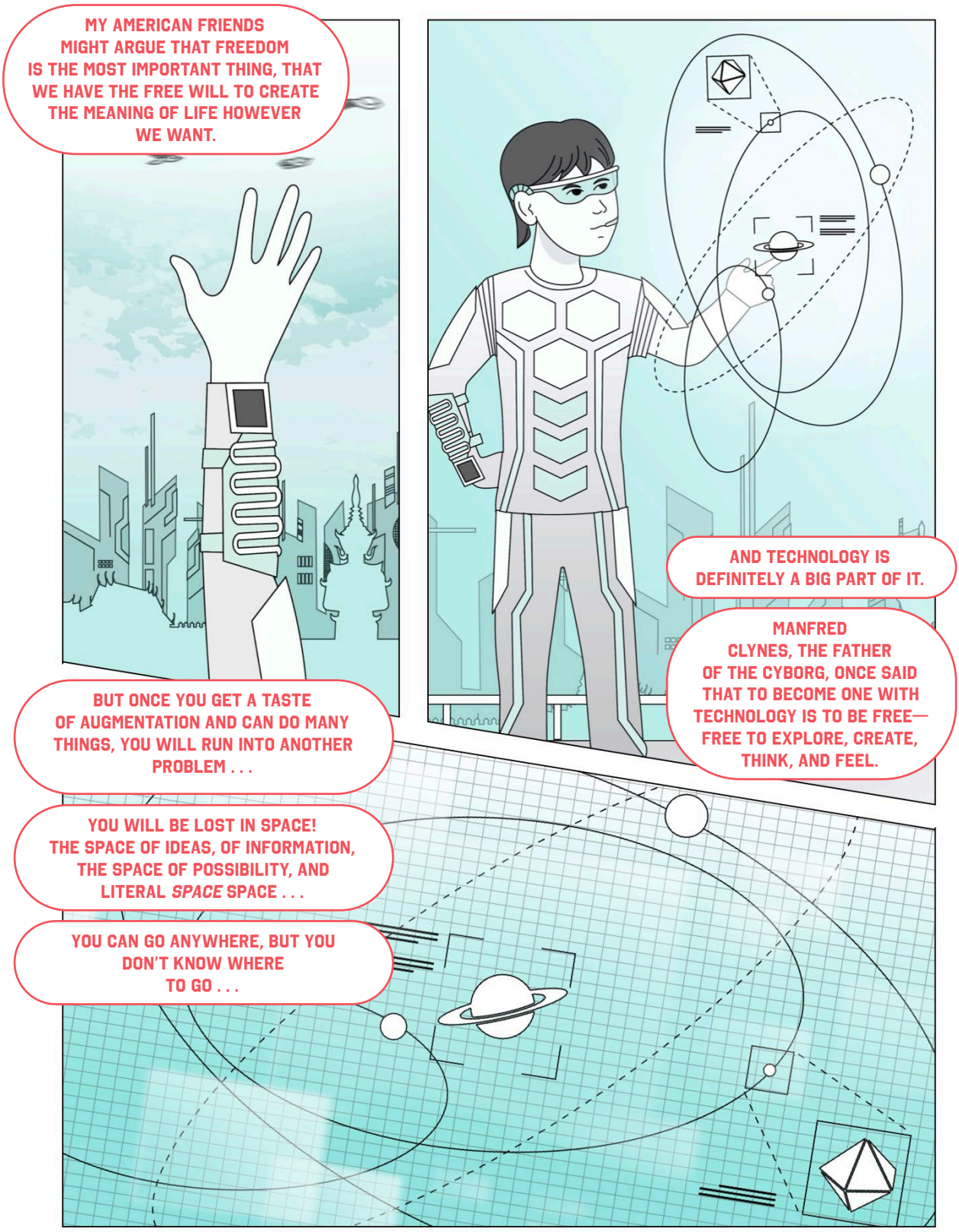
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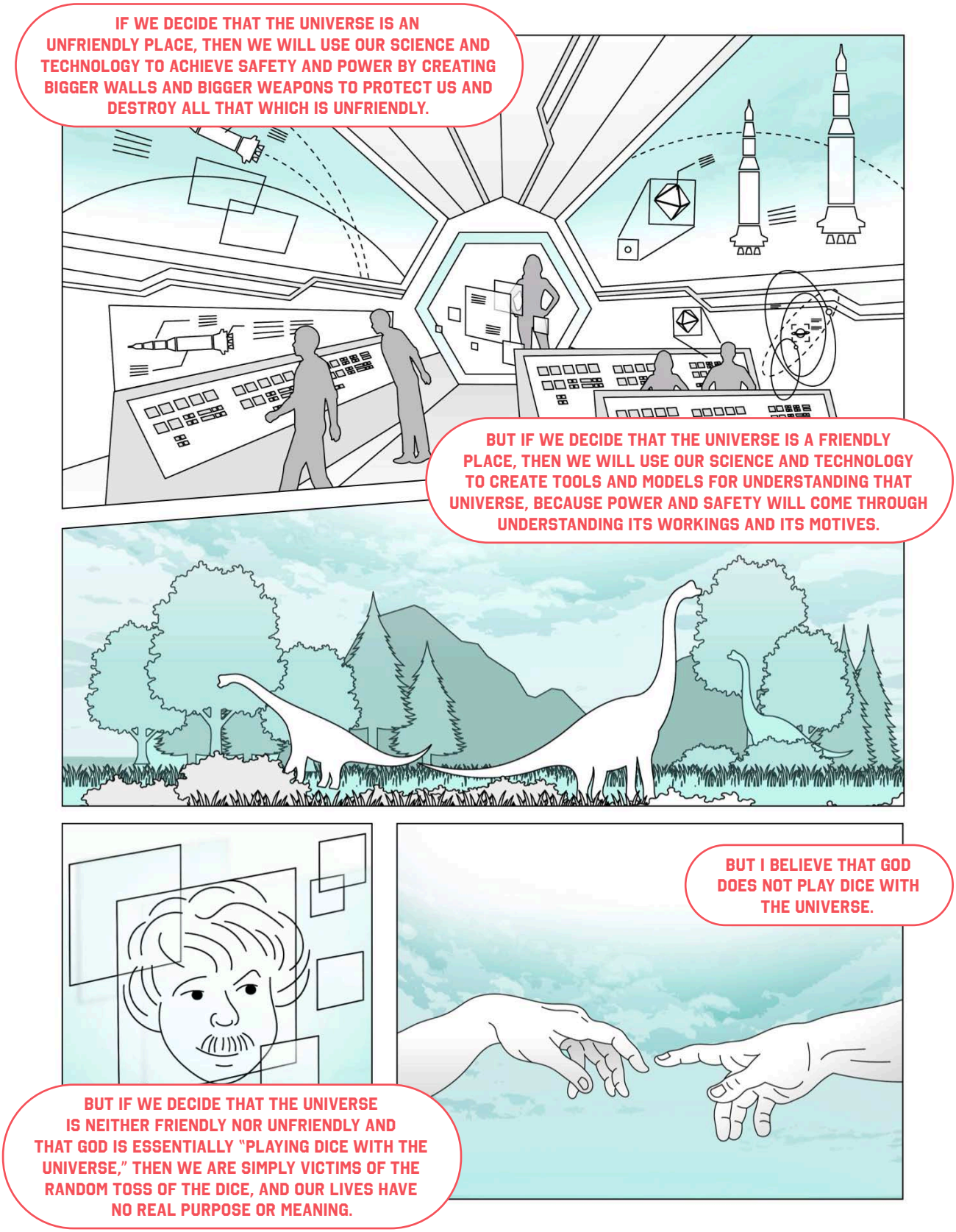
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Pat's Research Adventure

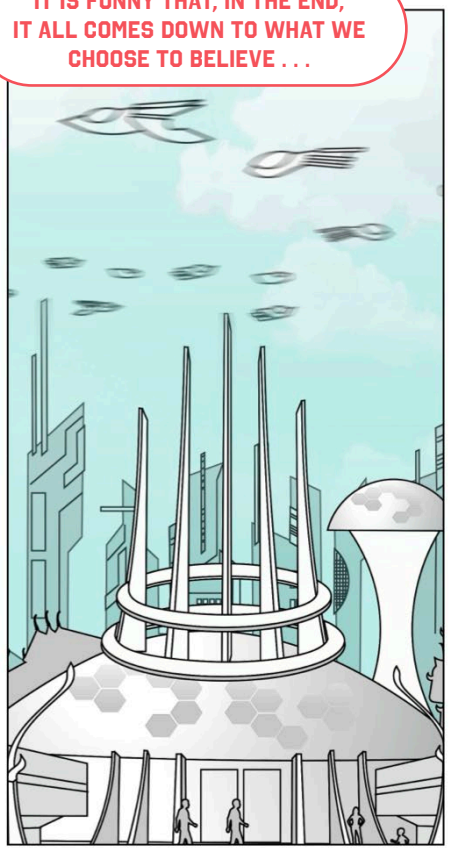



MY AMERICAN FRIENDS MIGHT ARGUE THAT FREEDOM IS THE MOST IMPORTANT THING, THAT WE HAVE THE FREE WILL TO CREATE THE MEANING OF LIFE HOWEVER WE WANT.
AND TECHNOLOGY IS DEFINITELY A BIG PART OF IT.
MANFRED CLYNES, THE FATHER OF THE CYBORG, ONCE SAID THAT TO BECOME ONE WITH TECHNOLOGY IS TO BE FREE—FREE TO EXPLORE, CREATE, THINK, AND FEEL.
BUT ONCE YOU GET A TASTE OF AUGMENTATION AND CAN DO MANY THINGS, YOU WILL RUN INTO ANOTHER PROBLEM . . .
YOU WILL BE LOST IN SPACE! THE SPACE OF IDEAS, OF INFORMATION, THE SPACE OF POSSIBILITY, AND LITERAL *SPACE* SPACE . . .
YOU CAN GO ANYWHERE, BUT YOU DON'T KNOW WHERE TO GO . . .

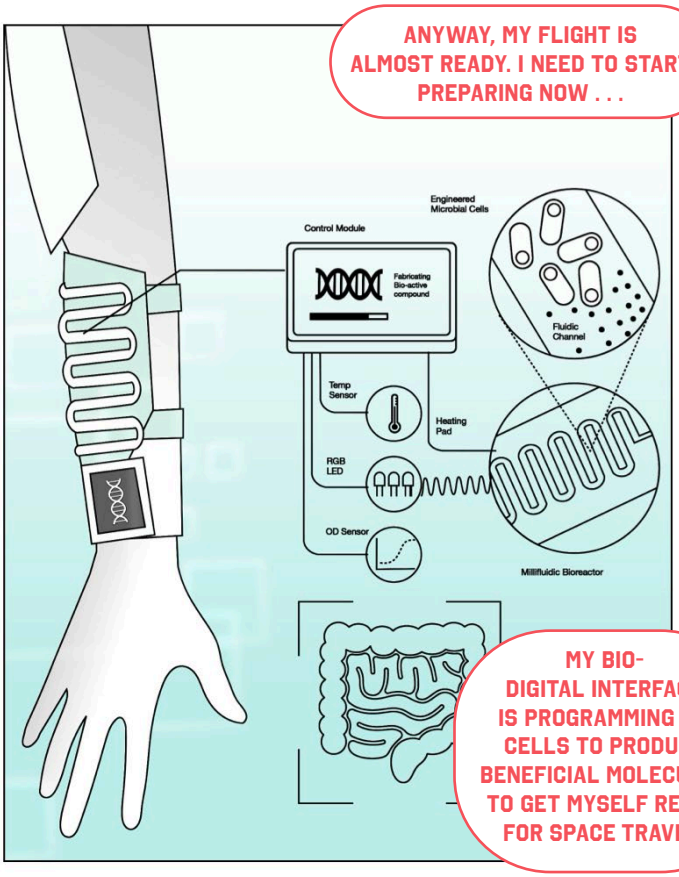

I DON'T KNOW IF I WILL EVER HAVE SATISFACTORY ANSWERS TO ALL THESE QUESTIONS. AS EINSTEIN ONCE SAID, "WE CAN'T SOLVE PROBLEMS BY USING THE SAME KIND OF THINKING WE USED WHEN WE CREATED THEM."
AS MY BIOLOGICAL BRAIN WORKS HARD, MY SECOND BRAIN MIGHT BE ABLE TO INSPIRE ME FURTHER . . .
"HEY EINSTEIN, WHAT IS THE MOST IMPORTANT QUESTION TO THINK ABOUT?"
"I THINK THE MOST IMPORTANT QUESTION FACING HUMANITY IS WHETHER THE UNIVERSE IS A FRIENDLY PLACE."


IF WE DECIDE THAT THE UNIVERSE IS AN UNFRIENDLY PLACE, THEN WE WILL USE OUR SCIENCE AND TECHNOLOGY TO ACHIEVE SAFETY AND POWER BY CREATING BIGGER WALLS AND BIGGER WEAPONS TO PROTECT US AND DESTROY ALL THAT WHICH IS UNFRIENDLY.
BUT IF WE DECIDE THAT THE UNIVERSE IS A FRIENDLY PLACE, THEN WE WILL USE OUR SCIENCE AND TECHNOLOGY TO CREATE TOOLS AND MODELS FOR UNDERSTANDING THAT UNIVERSE, BECAUSE POWER AND SAFETY WILL COME THROUGH UNDERSTANDING ITS WORKINGS AND ITS MOTIVES.
BUT I BELIEVE THAT GOD DOES NOT PLAY DICE WITH THE UNIVERSE.
BUT IF WE DECIDE THAT THE UNIVERSE IS NEITHER FRIENDLY NOR UNFRIENDLY AND THAT GOD IS ESSENTIALLY "PLAYING DICE WITH THE UNIVERSE," THEN WE ARE SIMPLY VICTIMS OF THE RANDOM TOSS OF THE DICE, AND OUR LIVES HAVE NO REAL PURPOSE OR MEANING.

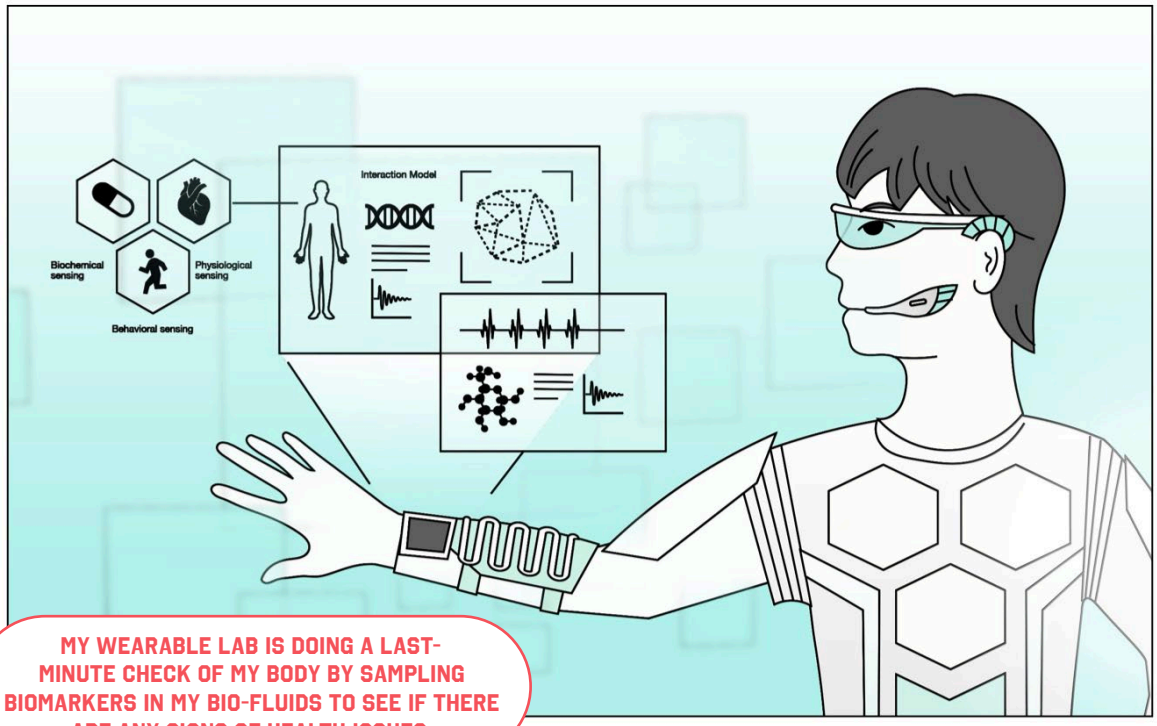
IT IS FUNNY THAT, IN THE END, IT ALL COMES DOWN TO WHAT WE CHOOSE TO BELIEVE . . .



ANYWAY, MY FLIGHT IS ALMOST READY. I NEED TO START PREPARING NOW . . .

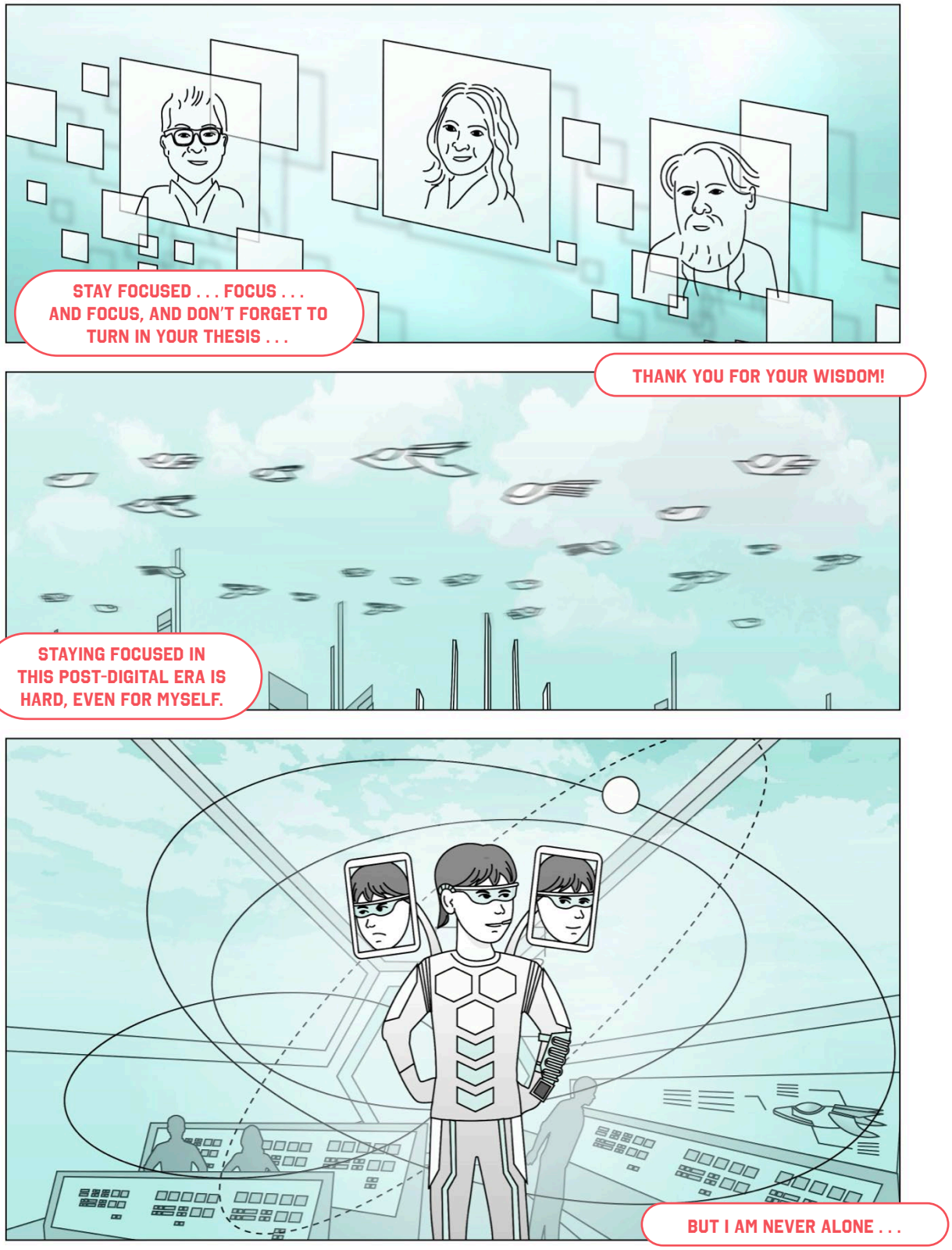


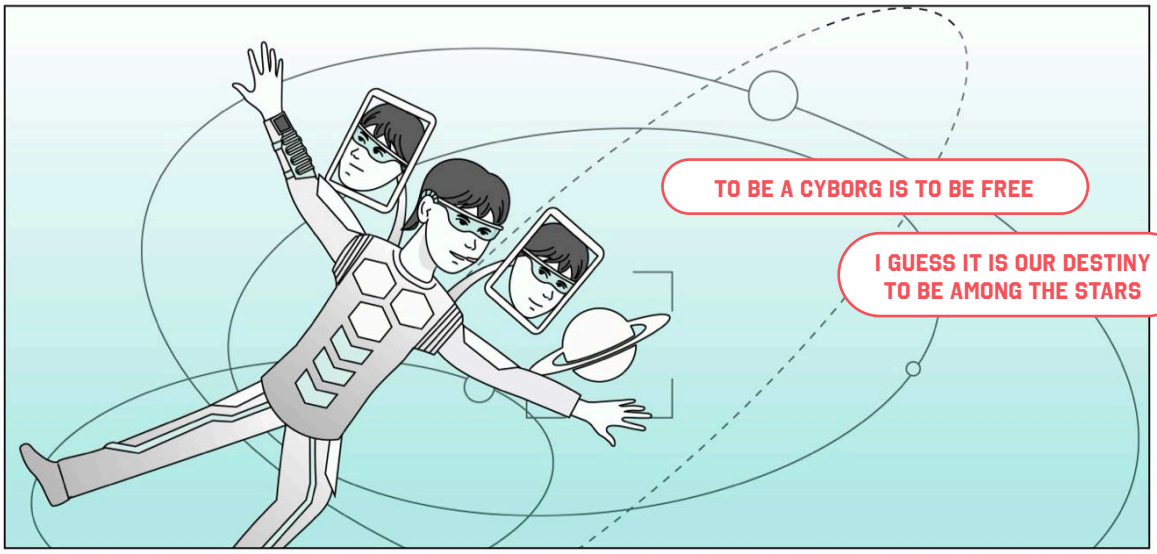
MY BIO-DIGITAL INTERFACE IS PROGRAMMING MY CELLS TO PRODUCE BENEFICIAL MOLECULES TO GET MYSELF READY FOR SPACE TRAVEL.

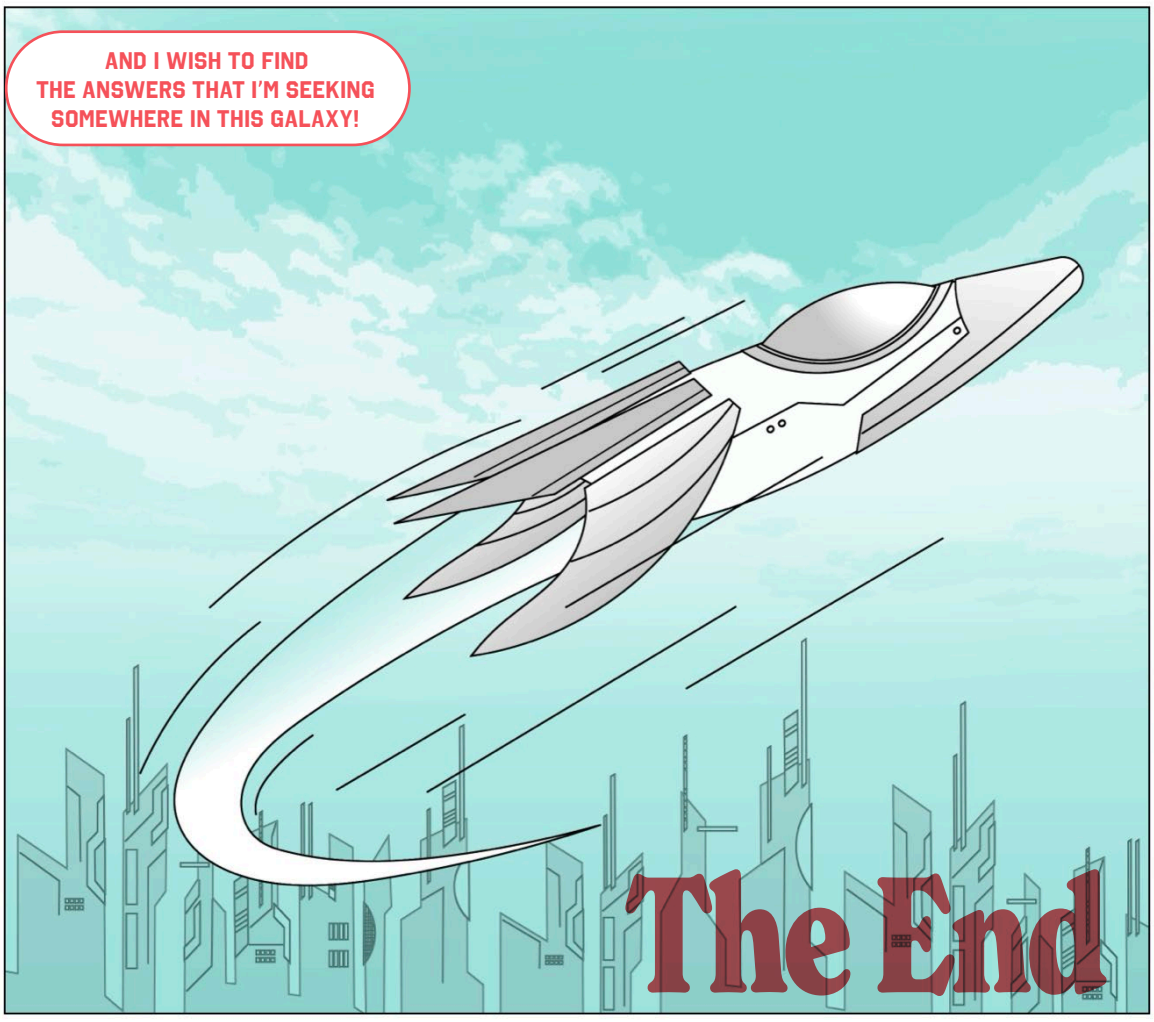


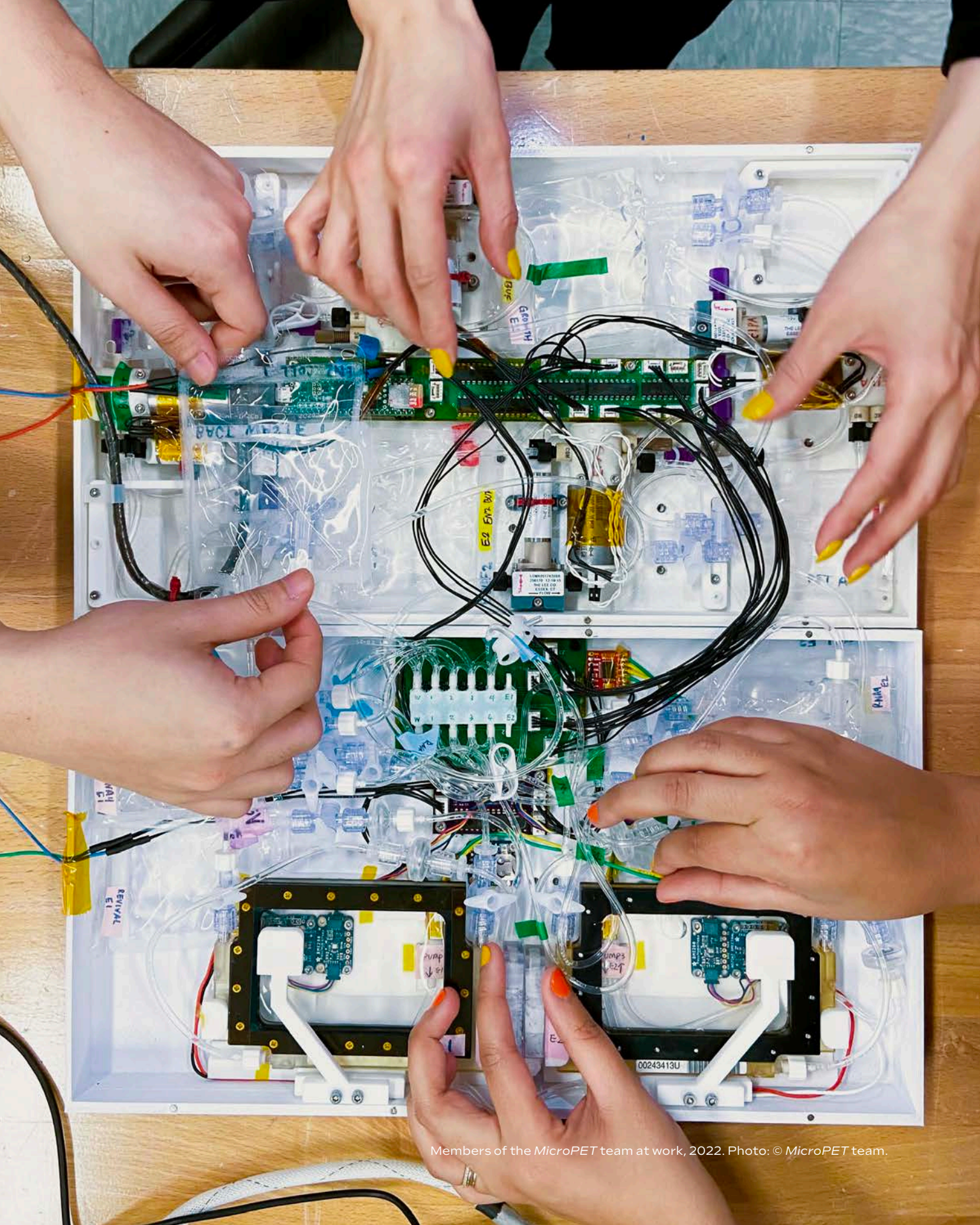
MY WEARABLE LAB IS DOING A LAST-MINUTE CHECK OF MY BODY BY SAMPLING BIOMARKERS IN MY BIO-FLUIDS TO SEE IF THERE ARE ANY SIGNS OF HEALTH ISSUES.


I HOPE THAT ALL OF THESE DEVICES WORK WELL AND MY SPACE FLIGHT WILL GO SMOOTHLY . . .
BUT BEFORE I BOARD MY SHIP, I HAVE ONE LAST THING TO DO . . .

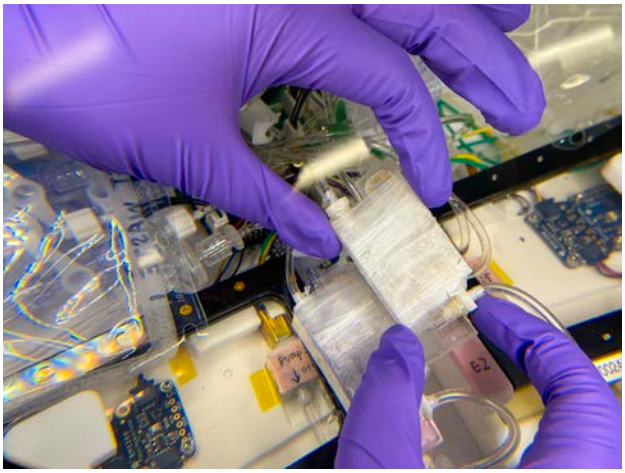

STAY FOCUSED . . . FOCUS . . . AND FOCUS, AND DON'T FORGET TO TURN IN YOUR THESIS . . .
THANK YOU FOR YOUR WISDOM!
STAYING FOCUSED IN THIS POST-DIGITAL ERA IS HARD, EVEN FOR MYSELF.
BUT I AM NEVER ALONE . . .


TO BE A CYBORG IS TO BE FREE
I GUESS IT IS OUR DESTINY TO BE AMONG THE STARS

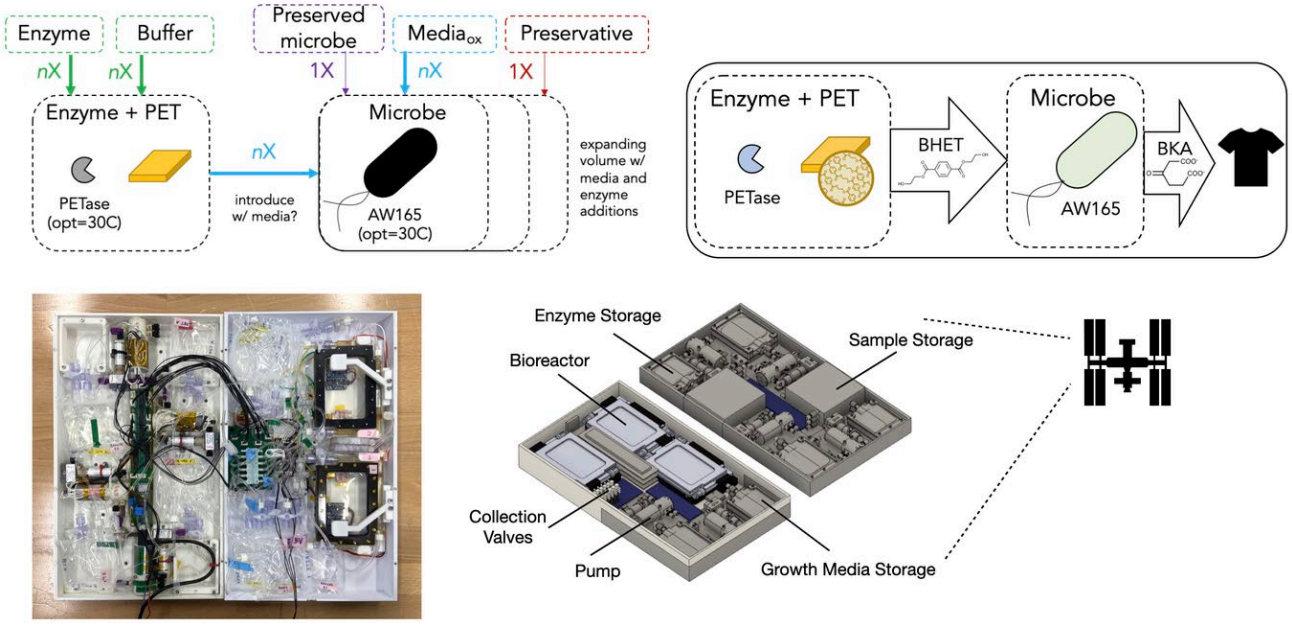

AND I WISH TO FIND THE ANSWERS THAT I'M SEEKING SOMEWHERE IN THIS GALAXY!
The End



Members of the *MicroPET* team at work, 2022. Photo: © *MicroPET* team.



Members of the *MicroPET* team at work, 2022.
Photo: © *MicroPET* team.



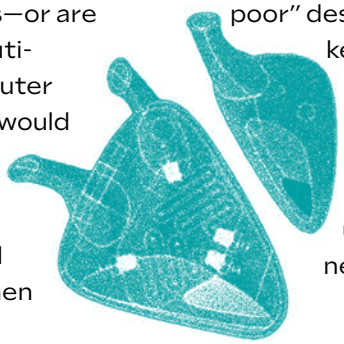
This flow chart demonstrates how *MicroPET* enzymatically degrades and microbially upcycles polyethylene terephthalate (PET) into beta-ketoadipic acid (BKA). BKA can then be transformed into nylon, which is used in textile production. Photo: © *MicroPET* team.

(How) Are Bacteria Resources?

Erika Szymanski

What is a resource, and what does it mean to utilize one? Are bacteria utilized as a resource in a wearable cyberbiome engineered to produce drugs for reviving flagging astronauts on demand? What about a box that automates the testing of how quickly engineered soil bacteria can digest plastic into useful molecules—or are those molecules better described as utilizable? Will bacteria fuel our future in outer space? And what kind of science fiction would this be?

I began asking such questions after becoming fascinated with the microbial world. I turned to the social sciences when I realized that microbiology alone couldn't explain how human choices—such as language—shape our perception of microbes and what we can do with them. My friend Tarsh Bates, an Australian bioartist who is also in love with microbial life, recently reminded me that phrases like "resource-poor" describe lands by what they lack, a deficit key to defining a hierarchy of more and less desirable places. This hierarchy is mobilized to describe people who live in "less desirable" places as deprived and underdeveloped in ways that undervalue place-specific cultural richness and political agency.



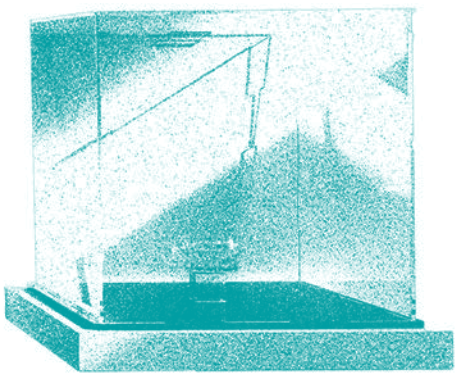
I wonder what happens when the earth is labeled as resource-poor in comparison to the resource-rich expanse of space. These words suggest a future laid out along the same lines that have patterned the past, full of colonialist conflict, races for territory, and wars for resources. As someone who wants to believe that exploration can be driven by curiosity and generosity, I also want to believe that space exploration is rich in room for imagination—enough to envision a future where a few privileged humans don't simply reproduce patterns of earthly violence and exploitation wherever they go next. I think about those divergent possibilities when I look at *CyberBiome* (2021) and *MicroPET* (2023)—the work of Dr. Pat Pataranutaporn and his team—because they're all about resource utilization.

In ruminating about the future of bacterial resources, one could get hung up on how "utilize" technically differs from "use": To utilize something is to use it for a purpose other than its typical one. This raises the question, Do bacteria have an intended or typical use? To answer this, we'd need to examine the distinction between teleological reasoning, which views living things as having purposes, and biotechnical reasoning, which views them as having functions. "Use" and "utilize" are both verbs through which humans connect to the world or the solar system. The slipperiness between the two verbs is a call to be vigilant about how we mobilize them. And then we might question whether such a discussion is a good utilization of use! For the purpose of this essay, I want to focus on the resource half of the question.

It's a social science truism that resources are made, not found. Resources are constructed when they come to satisfy a need and that need becomes institutionalized. Even urine has been a resource when employed as a fixative to help dyed fibers retain their color or as a readily available source of nitrogen for fertilizing crops. It might become a widely valued resource again if human composting takes off. Gravity could become a resource if humans start living in places where gravity is weak and its provision is a technical accomplishment to which not everyone has equal access. Silicon dioxide, the major component of most sand and an essential ingredient in cement and semiconductors, can seem like a resource in endless supply. But on a planet where stealing sand has become an organized criminal activity, mining stony asteroids for their abundant silica—making asteroids resource deposits—becomes plausible.

The social construction of materials or life-forms as resources goes hand in hand with a normative view of the world—and its solar system—as being principally a collection of resource deposits to be extracted, carried home, and used up. This is a good description of how exploration has often gone in the past. When this becomes an assumption about the future, it does a disservice to humanity and to exploration.

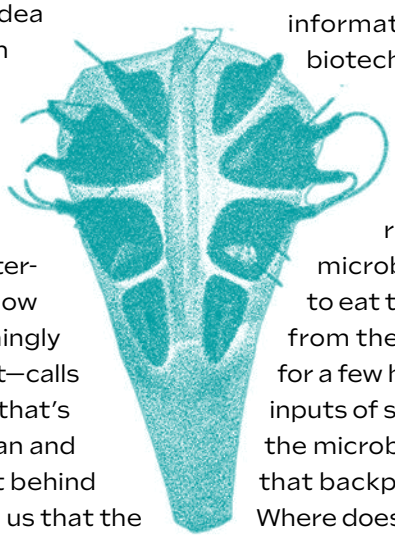
All humans do not share the same attitude toward resources that Western settler colonialists tend to take for granted. As Indigenous researchers such as Max Liboiron note, there is no such thing as "we" in global crises, because all humans are not equally responsible for or affected by them.[1] Traditional Indigenous cultures do not demand unsustainable resource supplies, yet they are disproportionately affected by the damage caused by those who do. Exploration can



Bacteria may be resources, technologies, and organisms all at the same time.

be a learning exercise, a curious and generous invitation to the possibility of new connections. Yet the ease with which space exploration is framed in terms of universal human needs is an argument for why alternatives need to be actively entertained. "Resource utilization" is one of those phrases that becomes so well codified that it's easy to ignore the work it does. Words are worldbuilding tools. They bring bits of our imagination into being as social phenomena and reinforce or remodel everyday institutions, relations, and normative orientations that fill our shared reality. "Resource utilization" is a phrase that argues for a particular set of human relationships with the world—and maybe with outer space. And though we invoke it casually, "utilization" points to how resources always involve making choices. No future is inevitable.

Our relationships—to our conspecifics and otherwise—are what make us human. The idea of an autonomous individual is its own kind of science fiction, unmasked by science studies scholars who point to how sustaining one human life invokes myriad more-than-human interdependencies.[2] Microbial biotechnologies for living in space reiterate this lesson, as they make explicit how supporting the life of even that seemingly most isolated individual—an astronaut—calls for multispecies relationships.[3] (And that's in addition to the multitudinous human and other lives supporting that astronaut behind the scenes!) Relationships also teach us that the process of becoming human is always ongoing and changing as the texture and direction of those relationships change. Attending to how we build them becomes especially exigent as we imagine becoming new kinds of humans in environments where humans haven't dwelt before.



As we explore possibilities for constructing both resources and relationships in space, an exciting thing about making bacteria into resources is that conventional extractivist logics don't necessarily apply. Extracting them from soil, for example, doesn't leave the soil with fewer of them. Bacteria may be resources, technologies, and organisms all at the same time. Unlike fossil fuels, microbes reproduce on human-relevant timescales. They have been constructed as informational resources rather than material ones—valuable for their genetic contents, which might teach new biochemical tricks to human bioengineers. The Nagoya Protocol developed by the Convention on Biological Diversity aims to ensure that benefits from such genetic resources are distributed fairly and equitably.[4] Its implementation is imperfect—notably, the United States has yet to sign on—but no one can ignore that the fair and equitable development of bioinformation resources is a conversation the biotech community must continue having.

Conversely, it is easy to ignore how microbial resources continue to depend on (other) material resources precisely because microbes are creatures. Bacteria have to eat to work. An astronaut might benefit from the outputs of a microbiome backpack for a few hours or days. But without regular inputs of sugar and micronutrients to feed the microbes that power the technology, that backpack becomes a literal dead weight. Where does the sugar come from? Who or what else might otherwise eat these bacteria's dinner? Microbial biotechnologies replace one kind of power—fossil fuels digested by combustion engines—with another—sugars digested by microbes—but they don't erase the need for power. As a social scientist who studies microbial

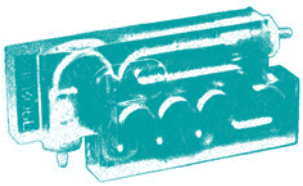
biotechnologies, I want us to talk about how that power is configured.

The hope-filled promise of understanding the world as made and not found, as constructed in practice rather than given and fixed, is that we can make it differently. Worldbuilding practices are discursive and material, shaped by how we communicate and how we manipulate physical stuff. So nouns like "resource utilization" aren't neutral. Experimenting with language tools can build alternative values into conversations and question dominant ones. We can use stories to direct attention to how science-fictional ideas and new technologies might play out. And we can work to ensure that stories play a role in shaping policies and systems that mobilize physical resources in ways consistent with our values.

So here's my offering as someone whose worldbuilding medium is words rather than engineered microbes or 3D-printed plastics: We need to talk about how innovations in resource utilization construct demand by also constructing conceptions of utility, especially for the sugar that feeds the bacteria that feed human needs. We need to talk about the nose-to-tail, cradle-to-grave, germination-to-compost multispecies metabolic life cycles of these technologies.

That suggestion raises one more resource question, this time looking back at ourselves: How do interested audiences distribute the resources of our time and attention—renewable, but invariably in limited supply? What are we doing here, responding to these microbe-in-the-sky visions? Do we simply read and respond to them at face value, as discrete current-future technologies that exist as they are displayed? Do we respond to a wider technofuturist imaginary premised on these devices' success and the broad availability of microbial drug-delivery prosthetics and plastic upcycling? Should we ground our response in a wider view of these projects' goals and their federal mandate to benefit life on earth as well as in space and then ask, What kinds of earthly capacities are being built here? Or do we call the bluff on a nice bit of technoscience that justifies its existence through a science fiction never really meant to be taken seriously, a high-tech ouroboros that exists to keep feeding itself without necessarily providing solutions to the problems that sent it spinning?

The best thing about showing microbial biotechnology in an art-science context may be that we don't have to choose. We can enjoy these projects as aesthetic phenomena and technical marvels, feats of imagination and engineering that speak to us in the present without needing to promise anything more than that. No one has a definitive road map to what microbial life should become. But if the violent histories of resource extraction on earth tell us anything, it's this: We might start by prioritizing relationships over things.

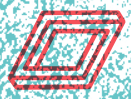


1 Max Liboiron, "There's No Such Thing as 'We,'" *Discard Studies*, October 12, 2020, https://discardstudies.com/2020/10/12/theres-no-such-thing-as-we/.

2 Marisol de la Cadena, *Earth Beings: Ecologies of Practice Across Andean Worlds* (Duke University Press, 2015); Donna J. Haraway, *Staying with the Trouble: Making Kin in the Chthulucene* (Duke University Press, 2016).

3 Rosa Santomartino, Nils J. H. Averesch, Marufa Bhuiyan, Charles S. Cockell, Jesse Colangelo, Yosephine Gumulya, et al., "Toward Sustainable Space Exploration: A Roadmap for Harnessing the Power of Microorganisms," *Nature Communications* 14 (March 2023): https://doi.org/10.1038/s41467-023-37070-2.

4 Secretariat of the Convention on Biological Diversity, *Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization to the Convention on Biological Diversity* (Montreal, 2011), https://www.cbd.int/abs/doc/protocol/nagoya-protocol-en.pdf.



FATHOMERS

Emergence
創発
Art from Life

October 8–December 15, 2024

Japanese American Cultural & Community Center, Los Angeles

Featuring the work of

AfroRithm Futures Group: Ahmed Best, Dr. Lonny J. Avi Brooks, and Jade Fabello, in collaboration with Dr. Drew Endy, Jesse Gilbert, Raquel Horsford, Malaya, and Oguri

Dr. Marie Bannier Hélaouët, Organoid Group, Hubrecht Institute of the Royal Netherlands Academy of Arts and Sciences and Oncode Institute, The Netherlands; and Dr. Albert Wu, Ophthalmic Stem Cell and Regenerative Medicine Laboratory, Stanford University, with lab members Dr. Aditi Swarup, Dr. Hala Dhowre, Dr. Sanja Bojic, and Julietta Picco

Dr. Callie R. Chappell and Dr. Nasa Sinnott-Armstrong

Michael Jones McKean, with assistance from Dr. Stephen Fong, Professor of Chemical and Life Science Engineering, Virginia Commonwealth University, in cooperation with the Museu de Leiria, Portugal

Eduardo Padilha

Dr. Pat Pataranutaporn

Corinne Okada Takara

Henry Tan, Masato Takemura, Pakchira Chartpanyawut, Weeratouch Pongruengkiat, Woraporn Pongsamart, Dr. Pat Pataranutaporn, Jirapat Thaweechuen, Tanis Phongpisantham, Pongsakorn Wechakarn, Sumeth Klomchitcharoen, and Kookpedz Studio

Tissue Culture & Art Project: Oron Catts and Ionat Zurr, with assistance from the UCLA Art|Sci Center and the California NanoSystems Institute

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Presented by Getty





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FATHOMERS





Passage

This project is part of *Emergence*, an exhibition organized by Fathomers that ran from October 8 through December 15, 2024, at the Japanese American Cultural & Community Center in Los Angeles.

Emergence assembles artists, scientists, and artist-scientists working at the forefront of synthetic biology and contemporary art. Documentation of their projects as well as relevant writings and interviews, planning sketches, and other contextualizing materials are collected in this catalog. Some contributors draw from their work in medical or transdisciplinary research laboratories, where they confront new categories of life that destabilize our understandings of sentience, hybridity, and artificiality. Others engage the tools of synthetic biology as materials for creative experimentation and studio-based inquiry. Many contributors argue for decolonizing science and expanding access to biotechnologies through DIY and community science initiatives. Across *Emergence*, audiences and participants are invited to contemplate our human capacities for creation, destruction, recklessness, renewal, and hope. The exhibition prompts us to ask: Who has agency in this moment of making, learning, and living with? What forms of life are we choosing to cultivate? What will we nurture, and what might we leave behind?

Projects in the Exhibition

AfroRithm Futures Group
MultiPlanetary Garden

Marie Bannier Hélaouët and Albert Wu
Crying Organoids

Callie R. Chappell and Nasa Sinnott-Armstrong
IndiGROW

Michael Jones McKean
of kin and bone

Eduardo Padilha
Apoptotic Bodies

Pat Pataranutaporn
CyberBiome and *MicroPET*

Corinne Okada Takara
Floating Future Gardens

Henry Tan and Masato Takemura
Pillars of Creation

Tissue Culture & Art Project
The Use of Life (in Relation to the Industry of Men)

Fathomers is a creative research institute dedicated to producing sites and encounters that challenge us to live and act differently in the world. Fathomers cultivates the ideas of diehard dreamers, commissions projects that seem far-fetched, and collaborates with thinkers across disciplines to expand the limits of scale, scope, and support for artist-led projects.

Emergence was presented as part of PST ART: *Art & Science Collide*. PST ART is presented by Getty.

Michael Jones McKean

of bio and bone

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Michael Jones McKean



of kin and bone

Michael Jones McKean

Introduction by Natasha Boyd

Michael Jones McKean is a sculptor of mixed media: prismatic rainbows, algorithms, meteorites, raw clay, ancient textiles, and now, for *Emergence*, bone. His installations explore what might be called anti-anthropocentric timescales, refusing the linear progression of human history in favor of a planetary register of events. Deep time—billions of years of geologic and cosmic evolution—shapes the rhythm of McKean's sculptural provocations, which themselves take years, even decades, to adopt their final form. His work for *Emergence*, *of kin and bone* (2024), draws on his

ongoing planetary-scale sculpture *Twelve Earths*, which began in 2017 with Fathomers' support. *Twelve Earths* connects twelve global sites dispersed along a perfect ring encircling our planet—including a fifteen-million-year-old impact crater, a former nuclear testing ground, a primeval forest, and an underwater mountain range—to create a complex portrait of the planet.

One site on the ring, Abrigo do Lagar Velho, is a limestone rock-shelter located in the Lapedo Valley of present-day Portugal. It contains one of the most significant archaeological findings of the past century: the twenty-nine-thousand-year-old remains of a child with both *Homo sapiens* and Neanderthal ancestry. Known as the Lapedo Child, the skeleton forms a morphological mosaic that rewrites our understanding of the cultural and biological processes leading to the emergence of modern humankind. Red stains on the upper and lower surfaces of the bones suggest that the body was wrapped in a shroud painted with ocher. A young rabbit, the pelvises of two red deer, a perforated shell pendant, and a headdress made of four canine teeth decorate the remains. Before the child was laid to rest, a branch of European red pine was burned at the site. Such burial rituals place this ancient child within a continuum of death, grief, mourning, and ceremony that spans millennia.

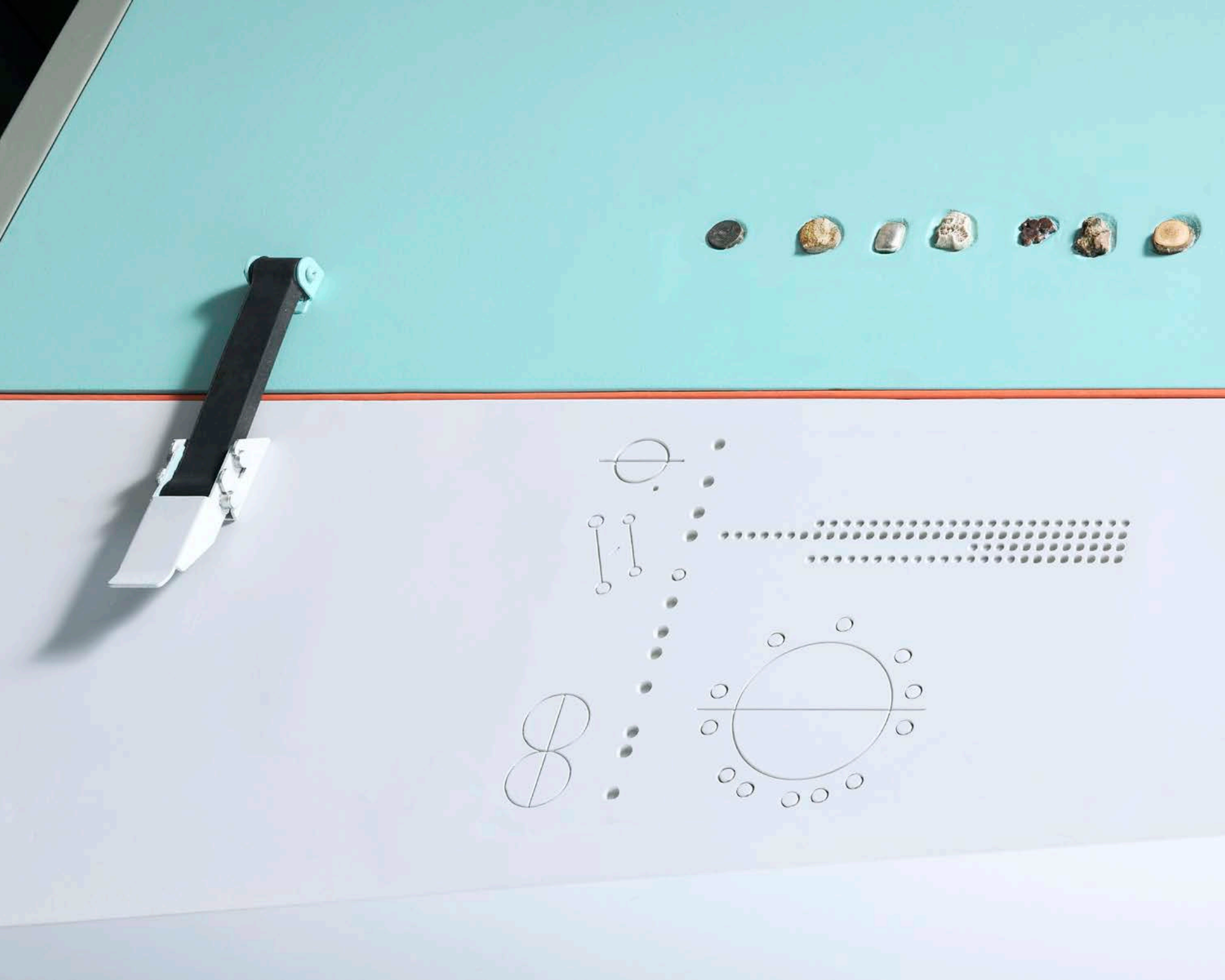
McKean and Dr. Stephen Fong, a synthetic biologist at Virginia Commonwealth University, coated a replica of these hybrid human-Neanderthal bones in biosynthetic mother-of-pearl, also known as nacre. Nacre naturally occurs in bivalves, gastropods, and cephalopods—some of the most ancient life-forms on Earth—and scientists studying certain freshwater mussels have found that the production of their silky, luminous interior is surprisingly

tumultuous: In every case, the earliest nacreous secretions contained abnormal microscopic spiral formations that powerfully distorted the architecture of the nacre layers. These divergent elements were drawn toward each other with increasing force until they merged, abruptly harmonizing. The term *mother-of-pearl*, by contrast, derives from an obsolete sixteenth-century definition of the word *mother* to mean dregs or scum. Yet our planet likewise rose from an inchoate, electrified eddy of matter, and from its violent nascent seas came the first living beings.

For McKean, the sculptural medium circumvents human temporal conventions, yielding a form capable of sustaining multilinear existences: "Without an originating point and a totalizing conclusion, a sculpture exists as an inherently unstable device for narration, forever swirling around in medias res," he has remarked. "Sculpture is a strange communication outlier, almost mystical by design." His large-scale diorama embeds the nacre bones among an array of symbolic objects referencing birth, burial, and the interconnectedness of materials and life-forms on our planet. The nacre gives the bones a soft glow. The rest of the child's family has been lost to time, but their parentage has not. Protected by the rock-shelter, the child's body remained safely cradled within the earth for nearly thirty millennia—long enough for their descendants to forget what the child's world was like and then discover it anew.



Opposite page: Michael Jones McKean with assistance from Stephen Fong and in cooperation with the Museu de Leiria, Portugal, *of kin and bone*, 2024 (detail). Wood, brass, steel, biomineralized synthetic nacre, glass, river pebble, basalt, ocher, suevite, oak, concrete, copper, coral, silver, fossilized whale bone, and titanium, 179 × 30 × 98 in. Courtesy of Fathomers. Photo: Carson Davis Brown.





Michael Jones McKean with assistance from Stephen Fong, *of kin and bone*, 2024. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Photo: Carson Davis Brown.

Michael Jones McKean



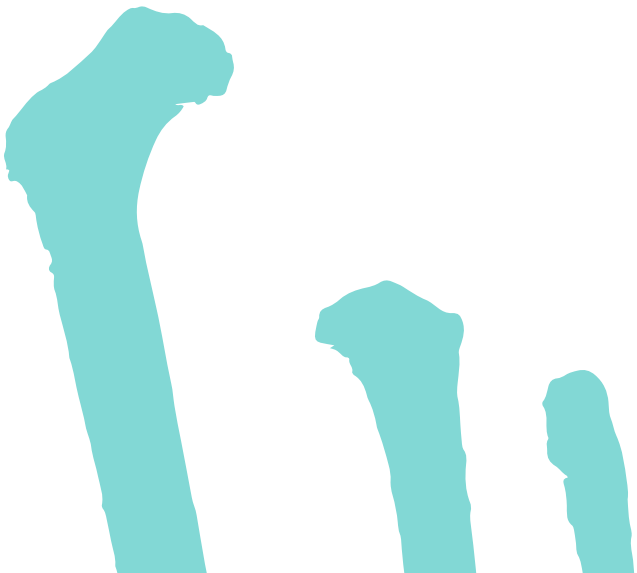
Photo: Brad Ogbonna

Michael Jones McKean is a Richmond, Virginia–based sculptor whose work explores the nature of objects in relation to folklore, technology, anthropology, and geography. His practice engages an interest in deep time as well as timescales and their collapse, in the process decentering anthropocentric registrations of events, distances, and meaning. Through his working process, he challenges stable binaries such as real and replica, natural and synthetic, and past and future, employing matter as diverse as ancient meteorites, of-the-moment technologies, raw clay, psychotropic medicines, decaying boats, prismatic rainbows, and the earth itself. This is exemplified by *Twelve Earths* (c. 2017–28 | 2029–40), a currently un-folding planetary sculpture exploring interconnectivity along a twenty-five-thousand-mile circular path, linking twelve diverse locations around the world. McKean is the recipient of numerous awards, including a Guggenheim Fellowship, a Nancy Graves Foundation Award, and an Artadia Award.

and

Stephen Fong





Dr. Stephen Fong is an associate professor in the Department of Chemical and Life Science Engineering and a fellow at the Center for the Study of Biological Complexity at Virginia Commonwealth University in Richmond. Fong has expertise in systems biology and metabolic engineering, with a background in strain development for chemical production and computational modeling. As a graduate student, Fong completed the first-ever study using large-scale metabolic modeling to design and implement novel chemical production into organisms.





Top and bottom: Artificial nacre deposited on bone casts, created for *of kin and bone*, 2024. Courtesy of the artist.

Experiments in the Deposition of Artificial Nacre on Bone Casts

Stephen Fong

In this text, adapted from an email from Dr. Stephen Fong to Fathomers, Fong details the process by which he and Michael Jones McKean experimented with artificial nacre production to fabricate the bones in McKean's sculpture *of kin and bone* (2024).

Based upon the previously published work of Spiesz et al.,[1] Michael and I were trying to determine if artificial nacre could be stably deposited on the casts of the bones and what the resulting bones would look like aesthetically. Most previous scientific work on artificial nacre is focused on the mechanical/structural properties of the artificial coating, not necessarily the aesthetics.

Artificial nacre is made of calcium carbonate. Certain bacteria can naturally produce calcium carbonate as a result of their normal growth and biochemical functions. The specific appearance and function of the calcium carbonate produced by the bacteria varies based upon the size and patterning of the calcium carbonate particles. We used the same bacterial strain (*Sporosarcina pasteurii*) as Speisz et al., and we grew the bacteria on SP2 liquid culture media. A separate crystallization medium (10 g/L tryptone, 5 g/L yeast extract, 10 g/L NH_4Cl, 60 mM $CaCl_2$, 20 g/L urea) was used when we were producing the artificial nacre.

Each layer of artificial nacre was created as follows: *S. pasteurii* was grown overnight in the SP2 medium. The bone casts were submerged in the crystallization medium, and 1 milliliter of the *S. pasteurii* culture was added to the crystallization medium and left undisturbed overnight to produce a layer of artificial nacre. The bone casts were then removed from the crystallization medium, rinsed with deionized water, and dried at room temperature.

We tested two key variables: the material for the bone casts and the temperature at which the artificial nacre was generated. Our concern with the material for the bone casts was centered around the need to have the artificial nacre adhere to the bone cast. Initial tests used polyurethane and Hydrocal for the bone casts. Typically, bacterial growth and the rate of artificial nacre deposition will be slower at lower temperatures, so we tested the amount and aesthetics of the artificial nacre when it was generated at refrigerated temperature (4°C), room temperature (23°C), and the normal growth temperature (28°C). The look and function of artificial nacre will differ depending upon the microscale of the particles created, so by adjusting the temperature and thus the rate at which particles are generated, we were able to produce particles at three different sizes and compare the three resulting versions of artificial nacre. Ultimately, we chose to use room temperature for the final product.

1 Ewa M. Spiesz et al., "Bacterially Produced, Nacre-Inspired Composite Materials," *Small* 15, no. 22 (2019): 1805312, https://doi.org/10.1002/smll.201805312. An abridged version of the article also appears on pages 41–45 of this volume.

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Fathomers associate director David Kim spoke with Michael Jones McKean about the artist's sculpture *of kin and bone* (2024). Part biosynthetic skeleton, part diorama, and part reliquary, *of kin and bone* reframes archaeology as mythopoetic labor. In McKean's words, the discipline has the potential to be something "extradimensional"—to enable time travel along the path made by our planet's physical memory and the ephemera generated by our species' history and prehistory.



Archaeology, Ritual, and Communion

Michael Jones McKean in Conversation with David Kim

David Kim

As a way to begin, perhaps you could describe some of the major parts of the sculpture *of kin and bone*.

Michael Jones McKean

This might not be the best way to begin an interview, but I'm actually not sure how to answer. There are so many elements and backstories and connections that bind the object together—bind it to places, people, events, and times all around the world. I suppose, in the simplest terms, it's a freestanding sculpture made of two stacked-together, slablike sections that hold some bones, some archaeological scales, and something like a reliquary . . .

DK

I was struck by what you call a reliquary—in part because it's a fairly unusual element in the broader context of your practice.

MJM

Yes, it *is* unusual. I haven't made a miniature in probably twenty-five years, and never one like this. There's a special, very weird spatial compression that comes with shrinking scale while also flattening out dimensional space. As the details of the sculpture kept growing and compounding, my own sensitivity readjusted inside these miniaturized worlds. The sculptural language seemed to naturally morph into something baroque-ish.

Michael Jones McKean, *of kin and bone*, 2024 (detail). Photo: Carson Davis Brown.

DK Perhaps you could tell me more about the archaeological scales.

MJM Right, it might not be entirely obvious what these objects in the sculpture are. For me, making them was really a moment to build a parallel world where the labor of archaeologists could be seen as something more poetic, more mythical. At its core, an archaeologist's process is about courting new belief and meaning in hidden things, building communion with the Earth and the objects contained within it. I wanted to think of their labor as something beyond science—something extradimensional. For me, the scale is an archaeologist's tool of communication, of finding and transmitting relationships.

DK This reminds me of a theme that we have talked about from time to time over the course of your project *Twelve Earths* (c. 2017–28 | 2029–40): archaeology as a secular practice full of spiritual and ritual echoes. In that conception, the scales might also assume new potencies and begin to resemble other sorts of objects.

MJM Yes, that's right. In Portugal, at Abrigo do Lagar Velho, I've been shadowing the archaeological team for the last four years, but they've been working this small patch of ground—about the size of a living room—for twenty-five years. There are moments when, if I just squint my eyes slightly, their work takes on a poetic dimension. All the verbs that we might use to describe an excavation—digging, scraping, brushing, shifting, cleaning, measuring, molding, casting, mending, scanning, cataloging—can be reconceived as a long-form communion with time, with the Earth, with our ancestors. I started to see what they were doing, huddled over a square of inverted earth, as a practice of reconnecting—healing, perhaps—things that have fragmented over vast expanses of time. At every turn, the process feels intimate to me: slow, attentive uncovering, building an intimacy of "place" that would be impossible to create any other way. In some way, the archaeological process is also psychedelic; it's the only time travel we have.





Michael Jones McKean, *of kin and bone*, 2024. **Top:** Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. **Bottom:** Detail. Photos: Carson Davis Brown.





Michael Jones McKean, *of kin and bone*, 2024. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Photo: Carson Davis Brown.

DK I'm curious, too, about the decision to sculpt scales rather than, for example, brushes or trowels or picks—rather than any other archaeological instrument.

MJM I suppose the decision had as much to do with avoiding the possibility of miscommunication as with communicating something in particular. When an object leaves the studio, it begins a process of living on its own, of transmuting all its embedded contents and forms and references into messages. As much as artists go to pains to ensure that their work speaks their intention, the work enters the world as something to be endlessly interpreted. With this in mind, if I were to have sculpted, say, brushes instead, the sculpture might have mistakenly alluded to painting. That said, there is still something so mysterious about the scales—they seem to speak the language of cuneiform. A lost language.

DK There is also a puncture in the sculpture: A tunnel runs between the two sections. On one side of the sculpture, an archaeological scale hovers above the bones of the child and is painted in the colors of the rainbow.

MJM Yes, the rainbow. For me, every new sculpture exists as part of a long crumb-trail of works connected together. The sculptures record a lineage of thinking. Many times, ideas, shapes, and symbols continue to echo, becoming part of a shared language. This is the case with the rainbow, a form that I've been thinking about and working with for over twenty years.

Opposite page: Michael Jones McKean, *of kin and bone*, 2024 (detail). Photo: Carson Davis Brown.



Photo Credit: Carson Davis Brown

Michael Jones McKean with assistance from Stephen Fong, *of kin and bone*, 2024. Photo: Carson Davis Brown.





DK I'm struck by other features of the presentation of the bones. For example, the skeleton in its entirety and each single bone are set in a concavity.

MJM The elements of this sculpture—many, many individual objects in aggregate—are all held in suspension, something like lo-fi sculptural levitation. But in the case of the bones, it felt important to add an additional degree of specificity—of place. Carved below every bone is a sculpted depression corresponding to its shape. I think this nesting says something very simple: "Here is where this object belongs." If a bone is moved, turned even slightly, something is ruptured. This is a sensitivity I hope to build in my work.

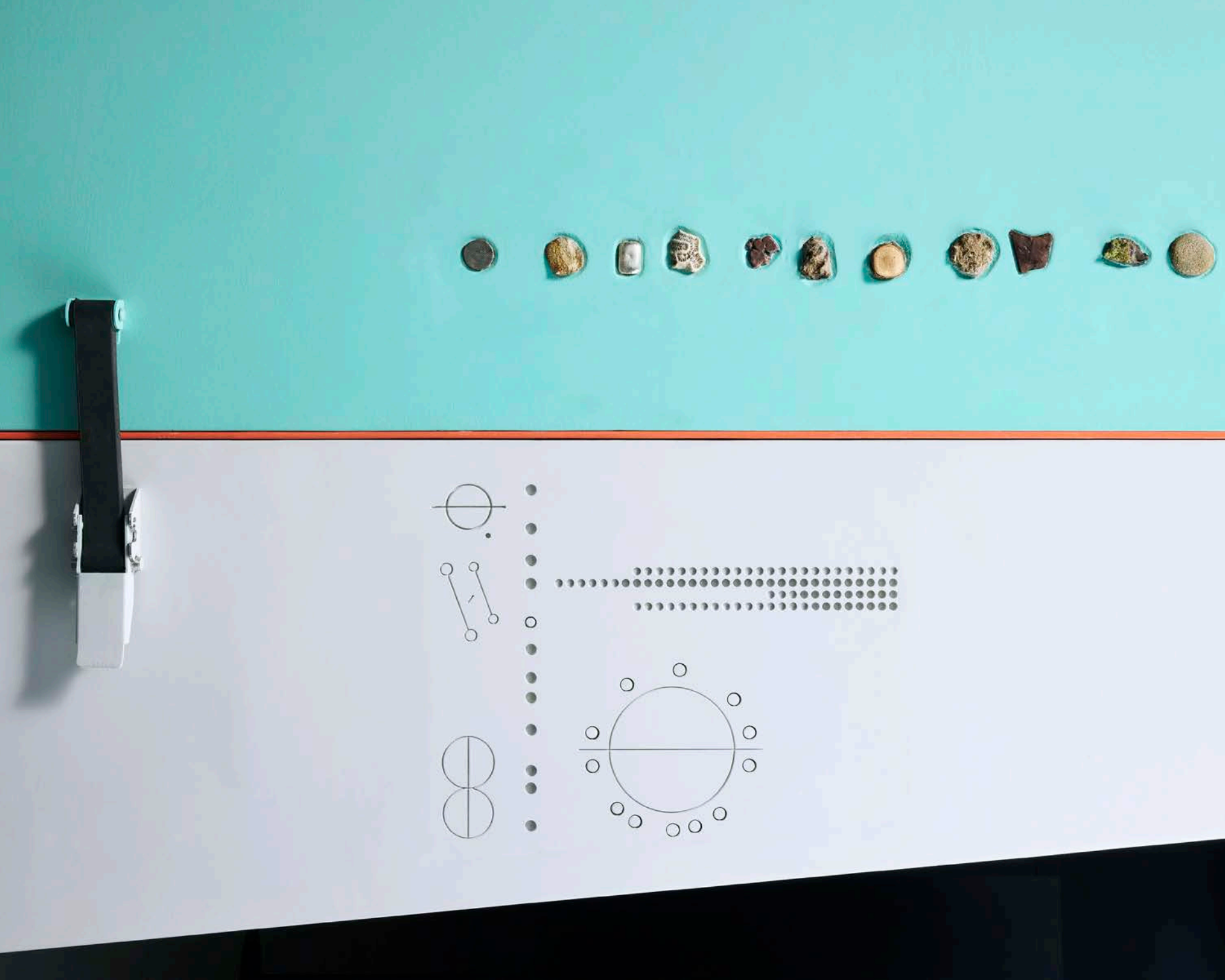
As I was working, I realized some sort of conjuring was slowly occurring. Against many odds, I was returning the bones *back into the shape of the child's body*. I became hyperconscious that the child's gestalt form—her body—was returning as a form on Earth.

DK And the bones are at a particular angle—neither flat nor vertical and parallel to the viewer, but somewhere in between. Like the inclination of an open palm.

MJM I really love the reference to an open palm. There was a lot of play in the studio to find the right placement. One element of the child's discovery that has fascinated me is that the bones were found tucked under a large limestone overhang. It was as if the people burying the child were using the rock face as a geological burial marker—a gigantic tombstone. I wanted to mimic this loosely with the placement of the bones tucked within the cavity of the sculpture, itself a grey slab mimicking the shape of a tombstone.



Above and opposite page: Michael Jones McKean with assistance from Stephen Fong, *of kin and bone*, 2024 (details). Photos: Carson Davis Brown.



DK Perhaps we could speak about how you fabricated the bones and how you chose synthetic mother-of-pearl, or nacre, as your material.

MJM An important concept in my studio is the overlapping and surprising connections among matter, objects, and living things across scales and time. *Twelve Earths* is really a vehicle to explore this in long-form and also to materialize some possibilities, some improbable connections that an artwork's inner logic system can insist on.

To flesh this out, Abrigo do Lagar Velho, where the child was discovered, is the geographic antipode of another *Twelve Earths* site: a watery sister-site just off the western coast of New Zealand. I was imagining these two pole-sites in perpetual, silent communion over thousands and millions of years. With bone and mother-of-pearl, I was trying to build a material relationship that bound these two places together. Materially, it's a small, small shift from bone to mother-of-pearl—from calcium phosphate to calcium carbonate—but that shift allows us to trace great arcs of evolutionary transformation across the Earth and across time. It's a shift that reminds us of the relationship of our living bodies to earthen rock and mollusks: You and I are earthen.

A scientist at the University of Rochester named Dr. Anne Meyer originated this research with nacre, and with Anne's trust, I began working with Dr. Stephen Fong, a faculty member at Virginia Commonwealth University, where I teach, to implement and extend the techniques that Anne had explored. Steve has been such a generous and wonderful collaborator. But as science goes, it turns out that this process is not easy! We obtained bacterial strains from a few sources, some from Japan, and ran experiments for months to optimize the process. At a basic level, bacteria consume a feeding solution and excrete calcium carbonate, which deposits on the surface of any object in the solution—in this case, the bones I made from MRI scans. We are still very much refining, but we have learned so much from this initial effort.

Opposite page: Michael Jones McKean, *of kin and bone*, 2024 (detail). Photo: Carson Davis Brown.

DK What does it mean to re-present the bones? I know this is something that you have thought about quite a lot and discussed at length with your collaborators in Portugal.

MJM There are many questions and concerns about the presentation of any kind of human remains. Display of this sort can be vulgar, violent, and a continuation of very troubling historical practices. The archaeological teams in Portugal have discussed these concerns for a long time, and a consensus is emerging to never show the bones themselves. Yet at the same time, there is a strong desire for the story of the Lapedo Child to be shared and live on—so, how to do this?

Perhaps I could say something first about the process of printing and forming the bones. There is a much longer story about obtaining the scans, and that's for another day. Just on a technical level, the scans were made in 2008 with what was then some of the most advanced technology available, but by 2024 standards, the resolution is comparatively coarse. Practically, this just means that, when we 3D-printed the scans, the bones were full of artifacting: stepped surfaces, sharp edges. From afar, they appeared to be bones, but at any close distance, the eye would quickly register that something was off; the hand would know immediately. So, over many months, I undertook a long, slow process of smoothing, sanding, touching, considering, comparing, measuring, coating, shaping, again and again.

During this gradual process, something happened: These copies began to morph. On the one hand, I knew—intellectually, rationally—that these were just duplicates and not the real bones of a human child. But somehow, through the process of work, they shed their life as anonymous facsimiles and they morphed into an undefinable third thing—something special, and *real*. This is the sleight-of-hand transformation that sculpture can perform. You keep working, trusting that the effort will transform the object. But through the back door, unwittingly, the process begins to change you as well. What arrives is a new object, one full of its own life and dignity, however fragile.

But perhaps the moment the bones transformed fully was a few weeks ago. I had a dream about them. I was at the archaeological site, wading through the small river that carved the valley over millions of years. In the water, I found the bones. An astonishment of light seemed to gleam from the surface of the water. Or, within the logic of dreams, was it actually the bones glowing, coming alive with light?



Michael Jones McKean with assistance from Stephen Fong, *of kin and bone*, 2024 (detail). Photo: Carson Davis Brown.



Composite photograph showing a selection of the Lapedo Child's long bones.

Courtesy Cidália Duarte, João Zilhão, et al. Printed, taped, and scanned by Michael Jones McKean.



Antipodal world map.
Printed, taped, and scanned by Michael Jones McKean.



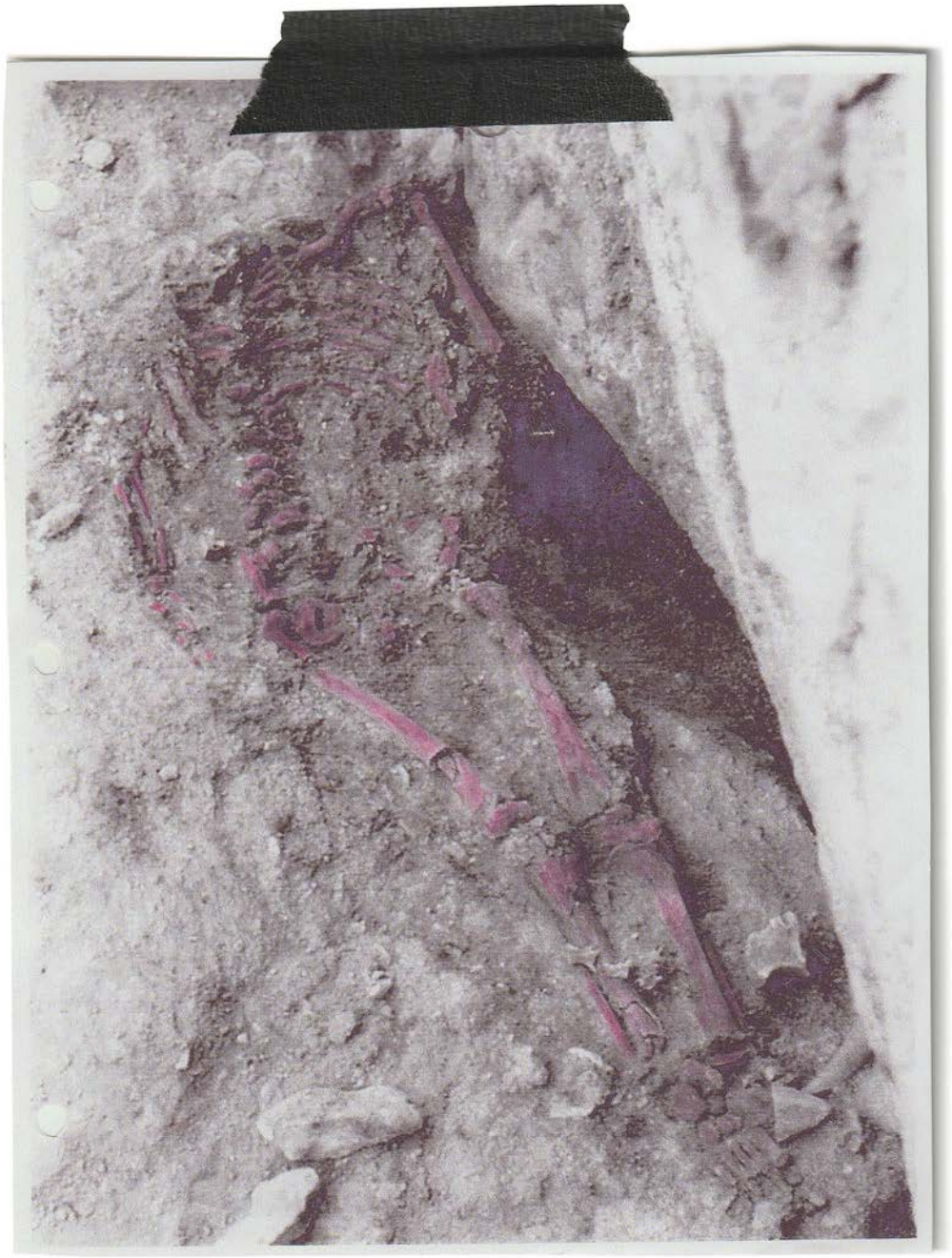
Field photograph documenting progress at the famed Abrigo do Lagar Velho archaeological site in Portugal. The photo was taken on December 20, 1998, as the Lapedo Child's skeleton was first being revealed.

Photo: Cidália Duarte. Printed, taped, and scanned by Michael Jones McKean.



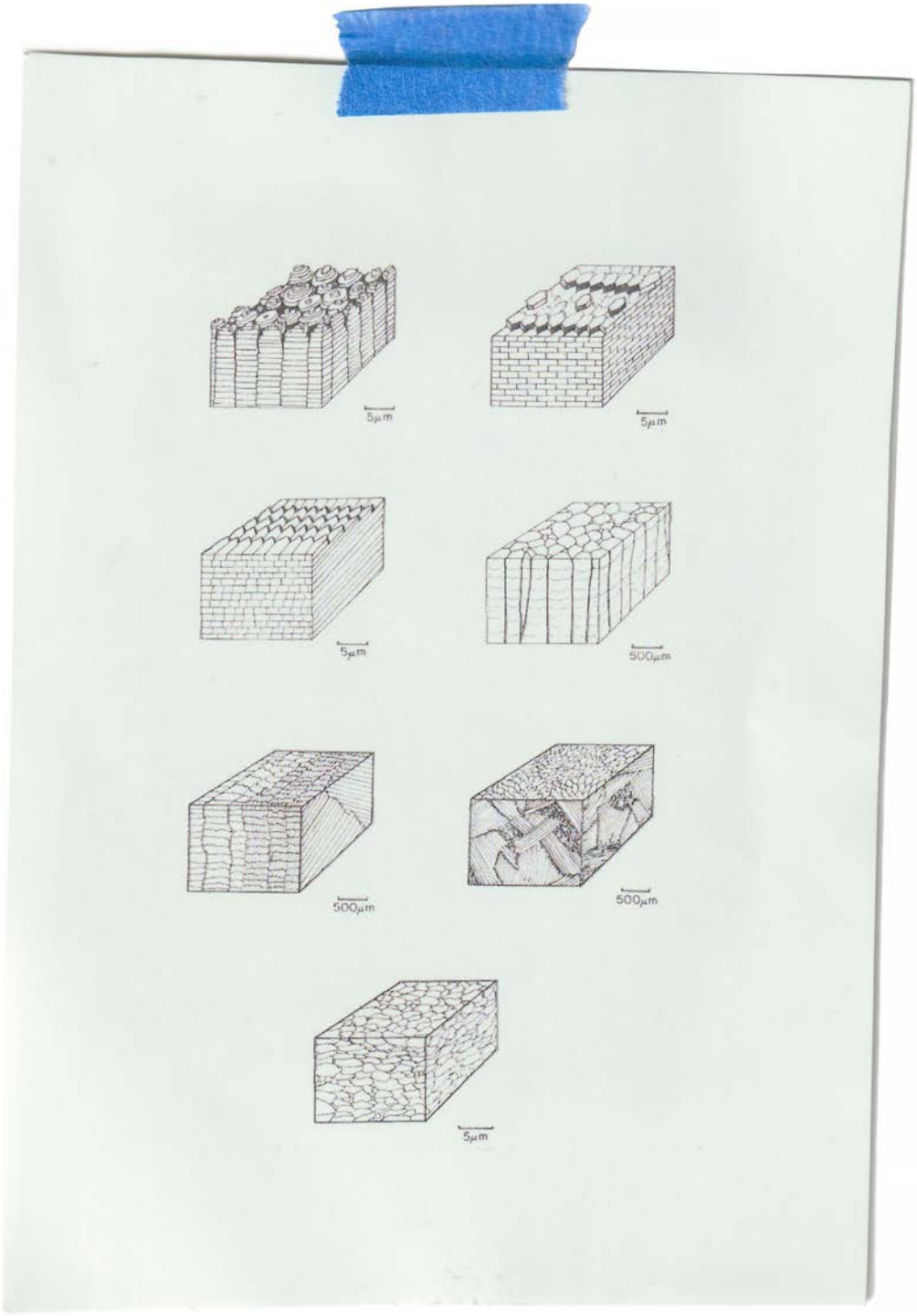
Still from a Hi8 video documenting the original excavation at Abrigo do Lagar Velho with archaeologist Cidália Duarte, December 1998.

Video: Pedro Souto. Printed, taped, and scanned by Michael Jones McKean.



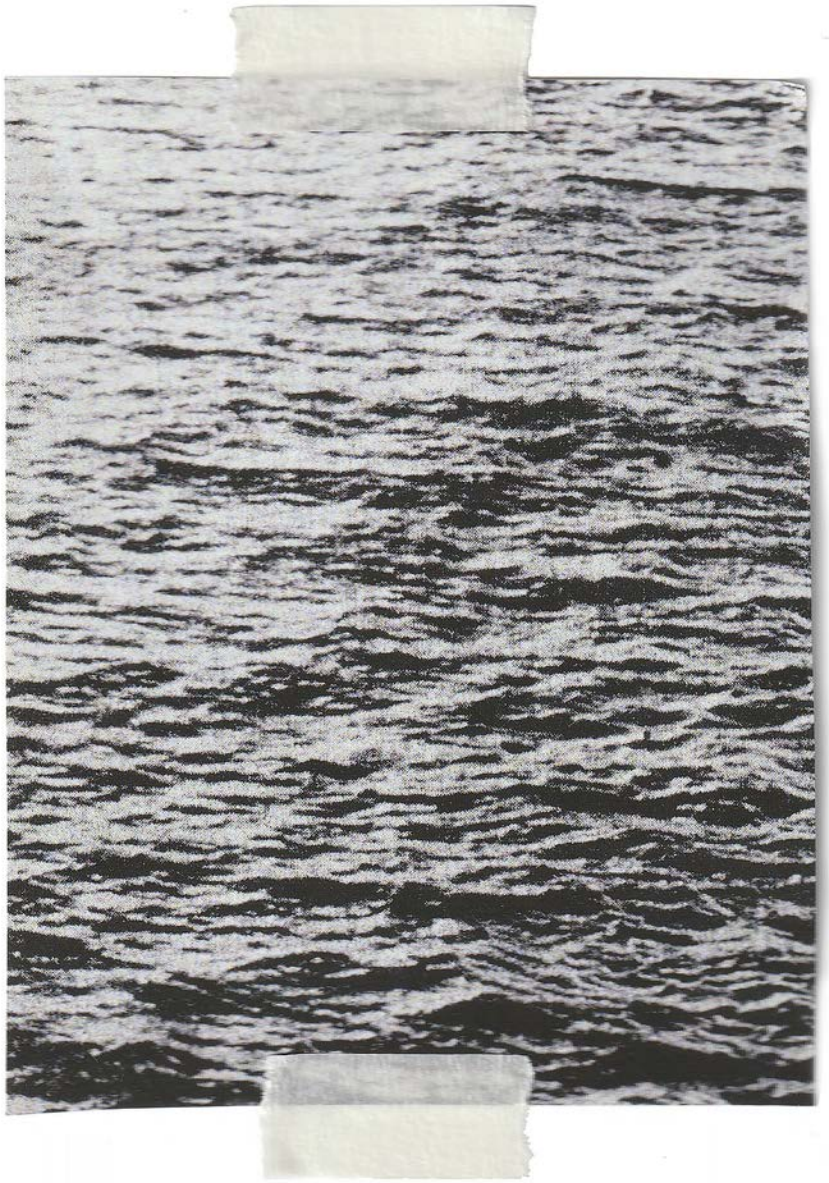
Photograph of the Lapedo Child at Abrigo do Lagar Velho, 1998.

Photo: João Zilhão. Shifted to greyscale, printed, taped, and scanned by Michael Jones McKean. In McKean's version, the child's bones are outlined in a subtle magenta hue, loosely echoing the use of red ocher pigments during the burial nearly thirty thousand years ago.



Diagrammatic illustration depicting the mineral structures found in seashells, including that of columnar nacre.

Originally published in J. D. Currey and J. D. Taylor, "The Mechanical Behaviour of Some Molluscan Hard Tissues," *Journal of Zoology*, 1974. Printed, taped, and scanned by Michael Jones McKean.

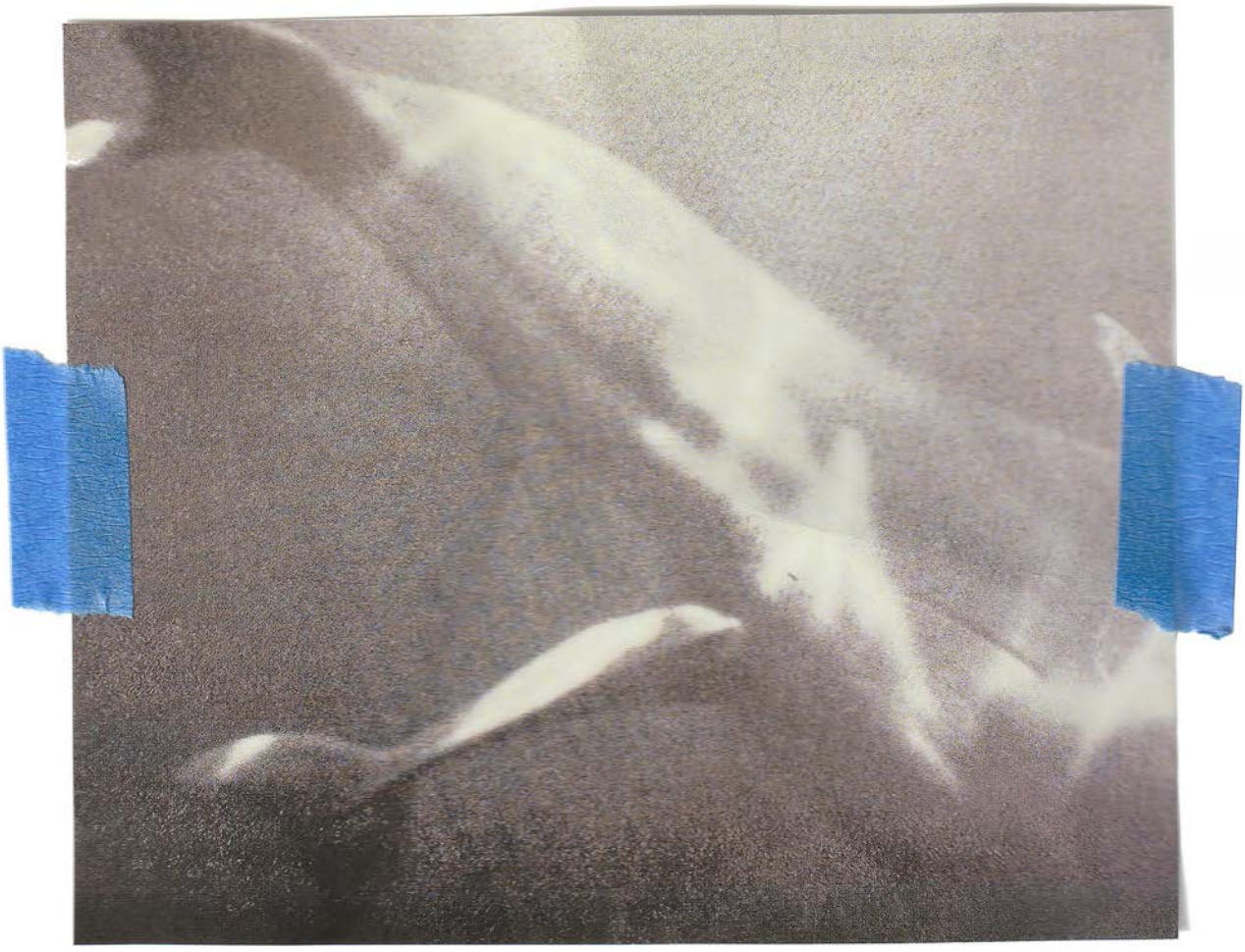


Highly degraded photocopy of a photograph depicting the surface of the Atlantic Ocean a few meters from Donald Crowhurst's abandoned trimaran, the *Teignmouth Electron*.

The photo was taken by a sailor aboard the RMV *Picardy* in July 1969 and originally published in Nicholas Tomalin and Ron Hall, *The Strange Last Voyage of Donald Crowhurst*, 1970. Photocopied, cropped, taped, and scanned by Michael Jones McKean.

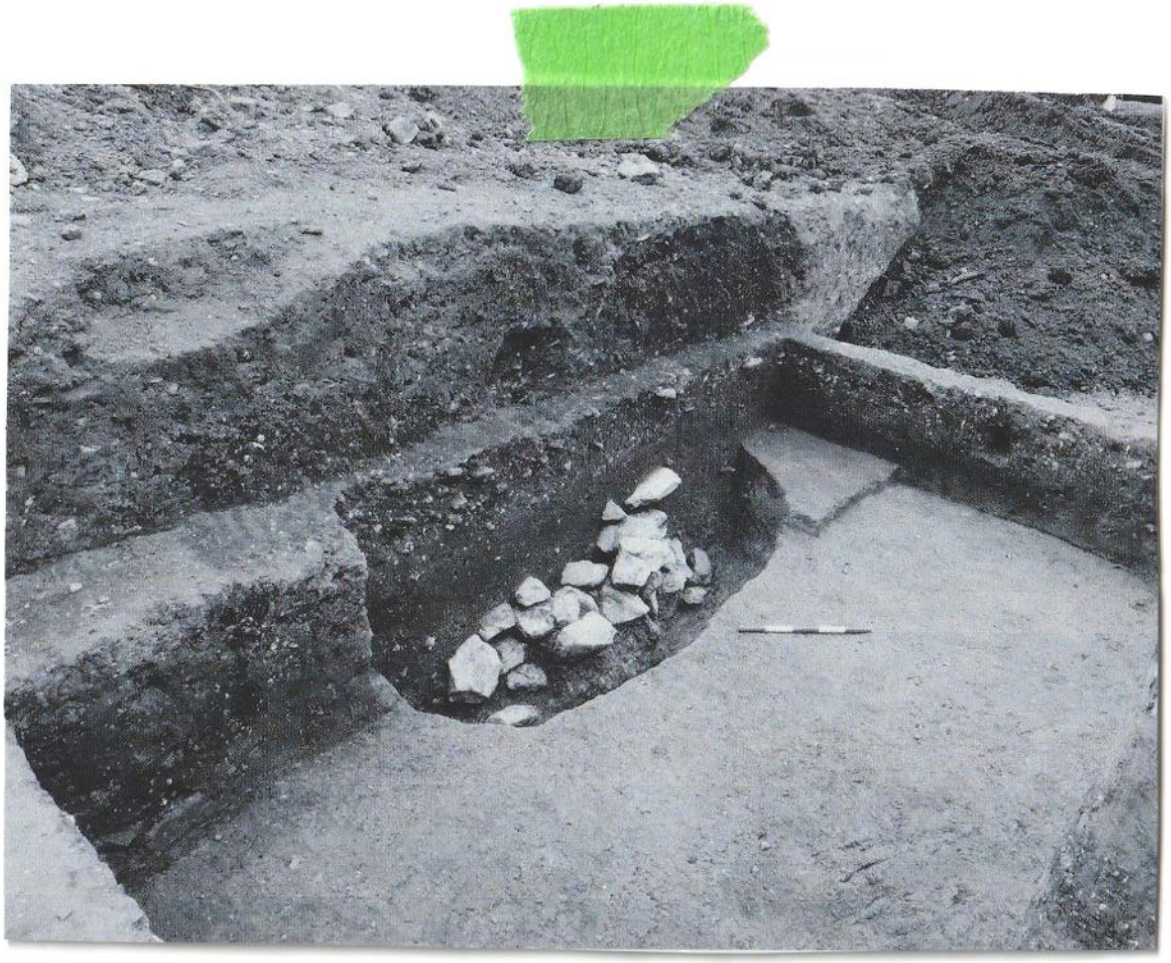


Found photograph of an arranged assortment of shells.
Printed, taped, and scanned by Michael Jones McKean.



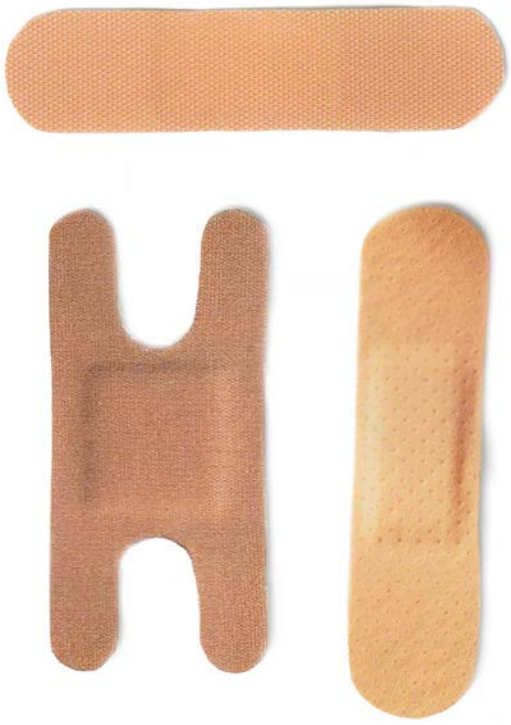
Rare photograph documenting a cetacean birth in the wild.

Originally published in Tre Tryckare, *The Whale*, 1968. Printed, taped, and scanned by Michael Jones McKean.



Black-and-white photograph of an unknown archaeological dig site, n.d.

Shifted to greyscale, printed, taped, and scanned by Michael Jones McKean.



Three bandages, scanned and printed by Michael Jones McKean.

Courtesy of the artist.



Illustration of common oyster anatomy by Henry Frank Moore, 1896/1897.

Printed, taped, smeared with ball-milled pearl powder, and scanned by Michael Jones McKean. Bivalve shells are built of slowly mineralized calcium secretions, in close proximity materially to our own lithic scaffold—our bones.



Seventeenth-century illustration of a fetus leaving the womb, still connected by the umbilical cord, by Cosme Viardel.

Published in 1748. Printed, taped, and scanned by Michael Jones McKean.



Found image of a newborn baby still submerged after a water birth.

Altered, printed, taped, and scanned by Michael Jones McKean.

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Excerpts from

Bacterially Produced, Nacre-Inspired Composite Materials

The development of simple, environmentally friendly methods for the production of advanced structural materials is becoming increasingly important. The use of bacteria as cell factories is a well-established and cost-effective biotechnological process for industrial-scale production of compounds such as polymers . . . , cellulose, and inorganic materials (e.g., calcium carbonate).[1] Such bacterially produced materials are typically far simpler than the complex hierarchical materials made by living organisms in nature, which in turn results in poorer mechanical properties.

Natural materials such as tooth enamel, nacre, or bone attain their superior mechanical properties from combining organic and inorganic components into hierarchical composite structures spanning across different length scales.[2] For instance, nacre, the tough, iridescent layer constituting the inner surface of mollusk shells, consists of a tessellated structure of layered calcium carbonate platelets interconnected by an organic matrix to create a hierarchical composite structure.[3] . . . The high toughness of nacre derives from its diverse mechanisms for effective energy dissipation, including crack deflection, organic components that act as a viscoelastic matrix, and nanoasperities (nanospheric texture) that resist inelastic shearing.[4] These features enable the composite material of nacre to withstand dramatically higher loads than the equivalent bulk calcium carbonate material, which in turn enables nacre's function as a mechanical shield against predators.[5]

As a response to the selective pressures in their ecological niches, mollusks have evolved the ability to produce nacre from easily attainable, renewable components under ambient conditions, and with a relatively low expenditure of energy. . . . Biological production methods that could not only successfully reproduce nacre's superior mechanical properties but also mimic the environmentally friendly production process would be a substantial asset for fields including medicine, space exploration, and civil and aerospace engineering.

In this work, we used two strains of bacteria to assemble a bioinspired, layered, nacre-like composite material via alternating deposition of calcium carbonate and γ-polyglutamate (PGA) layers. Calcium carbonate was generated by microbially induced calcium carbonate precipitation with the bacterium *Sporosarcina pasteurii* in a crystallization medium containing urea. *S. pasteurii* expresses urease, an enzyme that cleaves urea into ammonia and carbonate ions.[6] The resultant increase in pH shifts the equilibrium of carbonate, causing precipitation of calcium carbonate.[7] *Bacillus licheniformis* was used to produce the anionic polymer PGA to act as an organic matrix between the calcium carbonate layers, as well as to provide equally distributed negative charges as nucleation centers for $CaCO_3$ crystallization.[8]

The deposition process (fig. 1) began with the formation of a layer of calcium carbonate on polymethyl methacrylate (PMMA) slides by horizontal suspension of the slides within a culture of *S. pasteurii*. This step was followed by placing the calcium carbonate–covered PMMA slides into a solution of PGA collected from *B. licheniformis* cultures. The process was iteratively repeated to produce layered composites, here called "bacterial composite," with a thickness of ≈200 μm. A bacterially produced $CaCO_3$ material without PGA ("bacterial $CaCO_3$") and a purely inorganic calcium carbonate material precipitated via a chemical slow diffusion method ("chemical $CaCO_3$") were also deposited on PMMA slides and used as controls.[9] . . .

The mechanical properties of the bacterially produced materials were determined at different length scales: nanoscopically with nanoindentation, microscopically with microindentation, and macroscopically with three-point bending tests.[10] . . . Remarkably, we could not identify any macroscopic cracks in the bacterial composite at high strains, at strain regimes prior to where the crystallization substrate (PMMA) begins to dominate the mechanical response (fig. 3A). This behavior contrasted with that of the other two sample

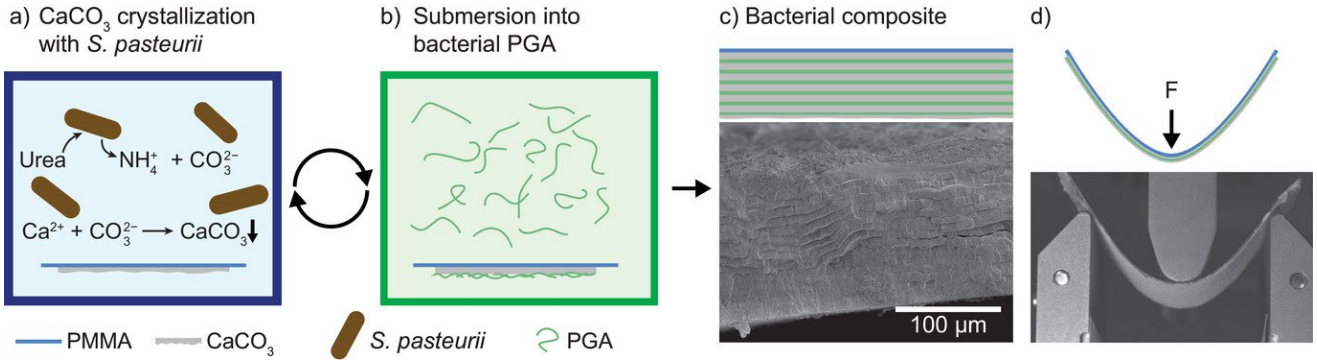


Fig. 1. Production of bacterial composite.

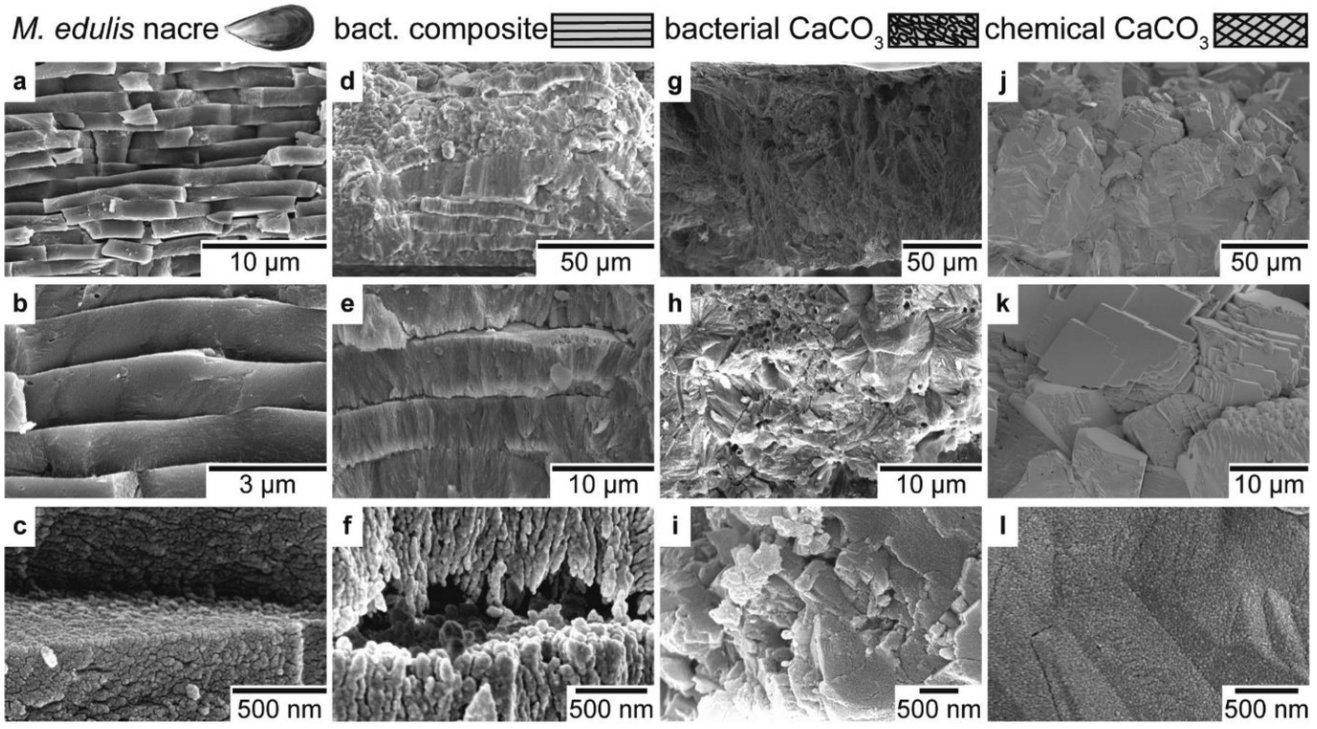


Fig. 2. Bacterially produced composite contained calcium carbonate layers similar to natural nacre. Samples were fractured, and cross sections were imaged by scanning electron microscopy. a) *Mytilus edulis* nacre showed a characteristic layered structure with b) layer irregularity enabling interlocking and c) nanoasperities (nanospheric texture) that resist inelastic shearing, both acting as toughening mechanisms. d) Bacterial composite, produced through alternate deposition of calcium carbonate by *S. pasteurii* and submersion in PGA produced with *B. licheniformis*, also displayed e) irregular layers and f) nanoasperities (nanospheric texture), which might contribute to increased toughness. g–i) Bacterial calcium carbonate material produced by repeated deposition with *S. pasteurii* without PGA showed few-layered structures. j) Chemically produced calcium carbonate material generated by slow diffusion of ammonia and CO_2 into a $CaCl_2$ solution showed k) no layers and l) no nanoasperities.

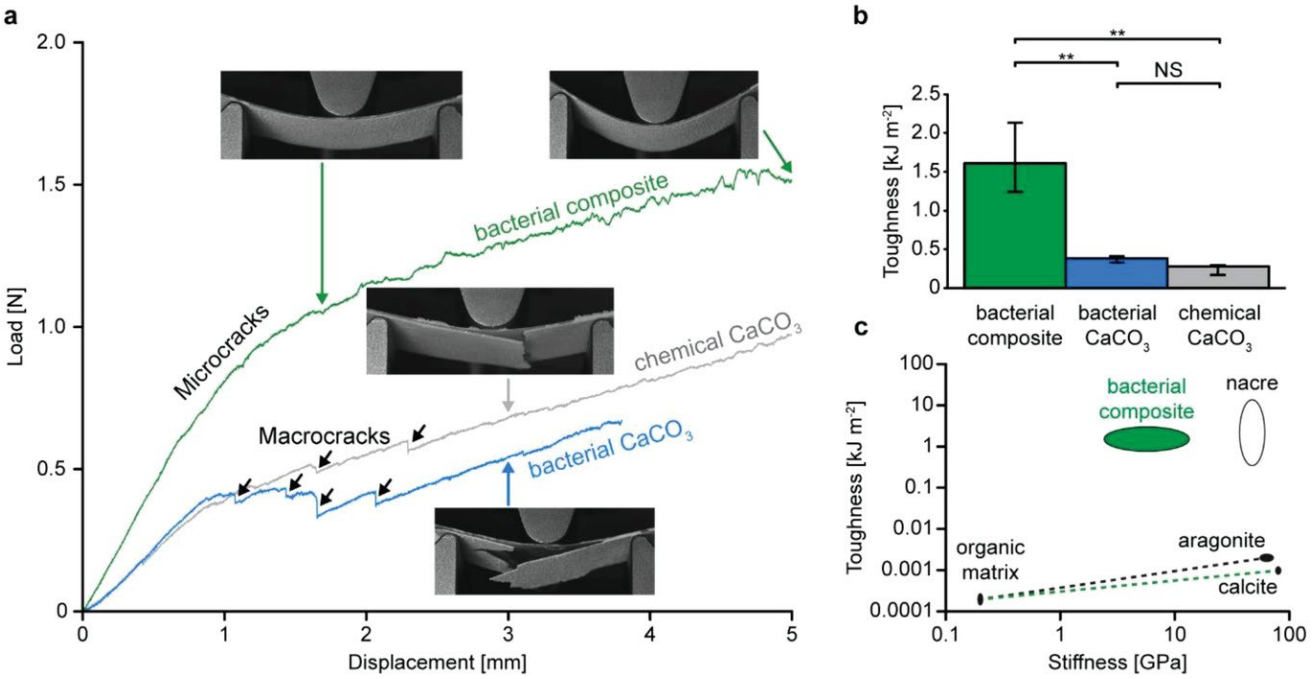


Fig. 3. Bacterial composite shows a substantially higher toughness and distinct cracking behavior from both chemically and bacterially produced $CaCO_3$.

types not containing PGA (bacterial $CaCO_3$ and chemical $CaCO_3$), where large cracks were detected (fig. 3A). . . . The bacterial composite developed here demonstrates improved toughness and extensibility without sacrificing stiffness (fig. 3C), a combination of properties that is difficult to achieve in man-made materials.[11] . . .

One key advantage of our method of bioinspired materials production is that it is performed exclusively with bacteria: under ambient conditions, using only ecologically friendly and renewable components, and without producing toxic waste. The alternative production processes involve high temperatures (e.g., 80°C) and pressures (e.g., 100–200 MPa) or the use of toxic organic solvents.[12] Our bacterially based PGA production is significantly cost-effective compared to industrial PGA production (€1 vs. €800–2000 per gram).[13] These costs could be further decreased in the future by utilizing bacteria strains that do not require supplemental glutamic acid in order to produce PGA or by streamlining the PGA purification procedure. Bacteria are readily available for genetic engineering, show an enormous diversity of metabolic activities, and are already used extensively in biotechnology and synthetic biology for the production of chemicals.[14] Moreover, complex or irregular (3D-printed) structures made from, for example, PLA can be easily covered with the bacterially deposited materials, which constitutes a rare feature of the bacterial composite compared to the other tough nacre-mimicking materials available.[15]

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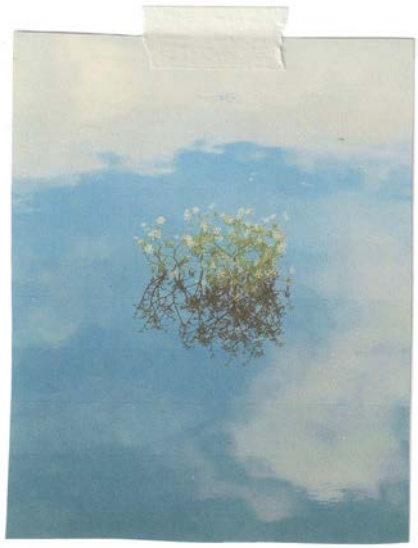
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Michael Jones McKean with assistance from Stephen Fong, *of kin and bone*, 2024 (detail). Photo: Carson Davis Brown.

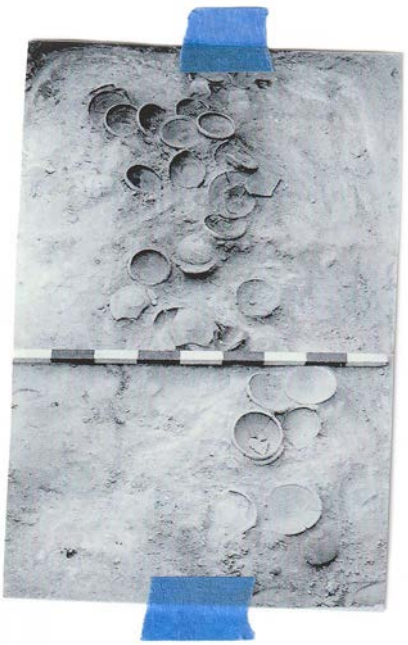
Glossary

Michael Jones McKean



Ancestors

We descend from others. Ancestors are our shared antecedents, tracing an unbroken chain of survival linking ourselves to our parents, their parents, their parents' parents, and so on. This leads us back to sometime during the Cambrian explosion, to a single common ancestor for every living being on Earth.



Archaeology

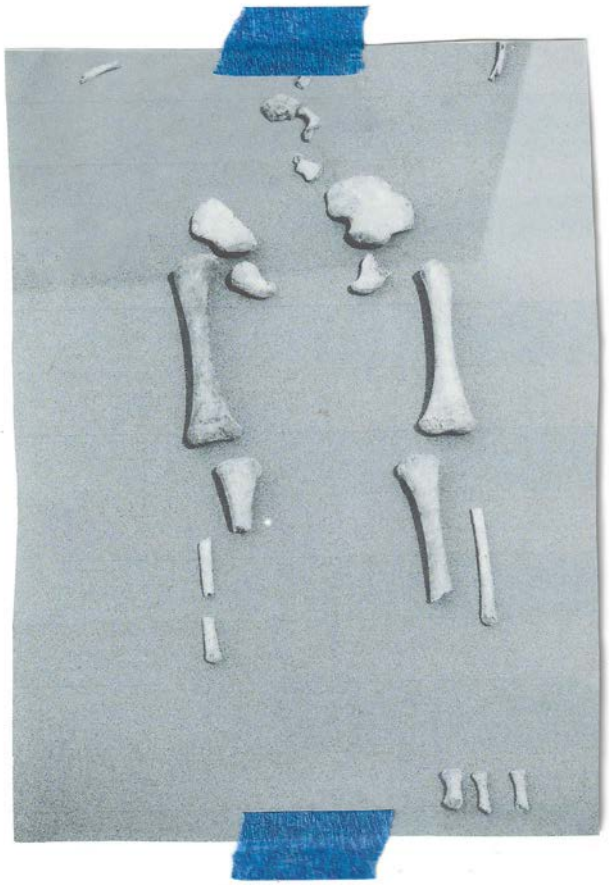
Archaeology is the study of history and pre-history using materials that have been excavated from Earth. Anchored by material culture, the field uses everything from organic remains to manufactured objects in order to grasp at the deep timelines and stories congealed in our present. Archaeology is an umbrella, encompassing an entire subset of disciplines dedicated to uncovering time across registers, such as archaeo-astronomy, acoustic archaeology, experimental archaeology, future archaeology, and processual archaeology. Historically, the discipline has been extractive, rubbing against the many ethical quandaries related to excavating burial remains and sacred artifacts. Embedded in the practice is also the sensitivity of deciding who will steward objects, tend to their material conditions, and properly contextualize and share their cultural meanings.

Blue Whale

The blue whale is the largest animal ever to have existed on Earth. There are four blue whale subgroups, with the largest growing to nearly one hundred feet in length and 173 tons in weight. Hunted nearly to extinction by the twentieth century, blue whale populations have since rebounded, though they still face significant threats from illegal whaling, collisions with vessels, ocean contamination, and global heating.

Although researchers agree upon many biological facts about blue whales, little is understood about their behavioral lives. Further, much working knowledge of whales has now been reevaluated, revealing false understandings based on our own myopic anthropocentrism. For instance, because blue whales are generally found alone or in small groups, early researchers surmised inaccurately that they must be asocial. In actuality, echolocation and their excellent sense of hearing—amplified by their status as one of the loudest animals on Earth as well as by the vast distances sound can travel in salinic ocean water—enable blue whales to communicate with friends, lovers, and relatives up to a thousand miles away.





Bone

Bone is the mineral, lithic internal scaffolding of all vertebrate animals, including humans. Bone anatomy is strikingly similar among seemingly disparate species living in diverse habitats. It is composed of regular features: cranial system, vertebral system, ribs for the protection of organs, and bones for limbs. Over time, when conditions are right, bones can transmute into stone, becoming part of a fossil record.



Child

Childhood is an interstitial zone of early development in humans, historically bracketed by infancy and the onset of puberty. However, this designated bookending is perpetually in flux as cultures continue to segment out additional psychological zones of adolescence within human development. This remodeling, combined with the effects of vast generational wealth inequalities and longer lifespans that extend the terms of parental support, has effectively feathered out the boundaries of preadulthood. To combat this, government entities have sought to delineate the beginnings of legal adulthood (typically between ages fifteen and eighteen) and have determined by proxy the temporal envelope of the child and the distinct rights of children. Childhood, or more precisely the concept of *the child*, exists politically as a perpetual horizon, an abstraction of innocence and hope contained by futurity and unrealized potential. In this way, the child is often weaponized as leverage within political theater.





Emergence of Water

How water emerged on Earth has been a mystery to researchers, though a number of theories exist. One posits that water didn't so much emerge on Earth as accumulate through trillions of meteorite impacts, each containing some amount of water. The Allende meteorite, which fell in Mexico in 1969, has helped support the science behind the theory of asteroidal water. The idea that water—the defining substance of Earth, from which all biotic life has evolved—is actually extraterrestrial in origin challenges a set of presumptive origin myths and links all earthly life more directly to the larger cosmos.

Horizon

The horizon is an unattainable limit perceived as perpetually at the edge of the witnessable world, where the earth and sky appear to touch. As our planet is spherical, the horizon is an ever-shifting threshold. Throughout time, people have gone to extreme measures to see and commune with the horizon. The Aguada Fénix site in the Maya Lowlands is a massive earthen platform—it rises thirty-three to fifty feet above the surrounding area—that frames a volume bigger than the pyramids of Egypt and reaches just above the Yucatán tree canopy. From this open expanse, people can see the horizon in any direction. For the Korowai people of southeastern West Papua, the horizon is all but invisible in the dense overstory of the rainforest. Ingeniously, the Korowai build elaborately engineered structures among the treetops, at seemingly impossible heights, to gain views of the horizon.



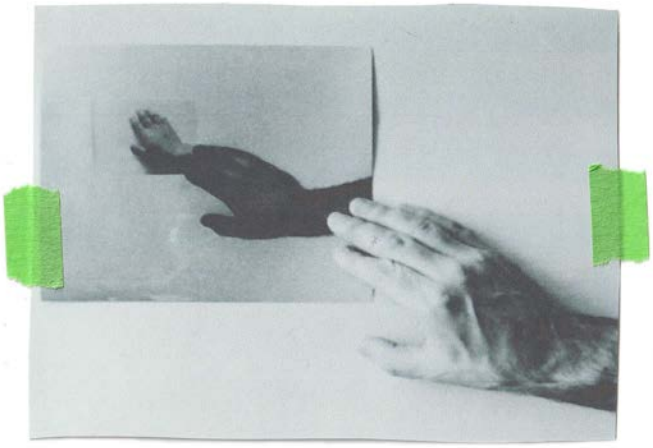
Interbelonging

Our existence is not singular because nothing makes itself in isolation. We are always accompanied and accompanying, always interconnected. Even our bodies are microcosms, composed of a nearly unthinkable number of microorganisms that make every process within ourselves possible, crafting material stories within and without our bodies. Looking outward, this multiplicity extends across all kinds of species boundaries: We only belong insofar as we interbelong, being and unfolding in everyday acts of symbiosis, knitting a dense meshwork of embodied perspectives.

Lapedo Child

The Lapedo Child, also known as Lagar Velho 1, was an Upper Paleolithic, Gravettian child who died at around four or five years of age, twenty-eight thousand years ago. Their remains were discovered in the Lapedo Valley, in present-day Portugal, in 1998. The child provided important clues into human evolution, complicating fixed notions about evolution by displaying characteristics of both Neanderthals and early modern humans. Due to its unique circumstances of burial, the child continues to hold clues to a long lineage of ritualistic burial and community mourning. The child's remains, now held at the Museu de Leiria in central Portugal, have been designated a National Treasure of Portugal.





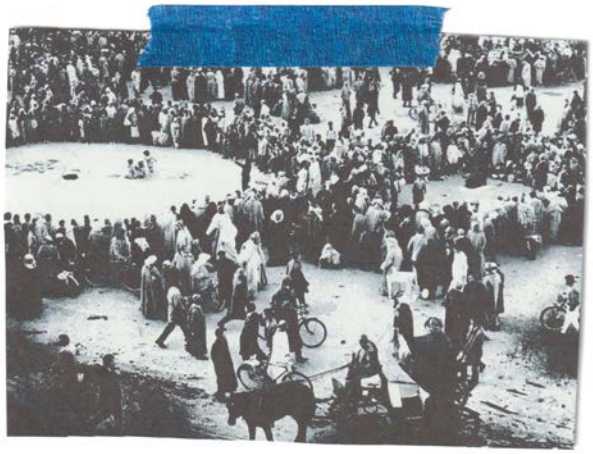
Mourning

Mourning is the nonlinear practice of processing the passing of a being. While it is often ritualized with rites and conventions to ensure the safe passage of a being and to honor the tender transition between life and death, mourning is a process that typically cannot be predicted or circumvented. Despite attempts to contain it within a distinct envelope of time, mourning can bend across time and over lifetimes, etching stages of emotion, affect, and ritual into its course. Mourning is often experienced socially, as an externalization of feelings of sorrow and grief, inviting these to be held communally. The depths of one's grief often parallels the love one has for the deceased, and calls for complex devotional untanglings commensurate with that care.

Oceans

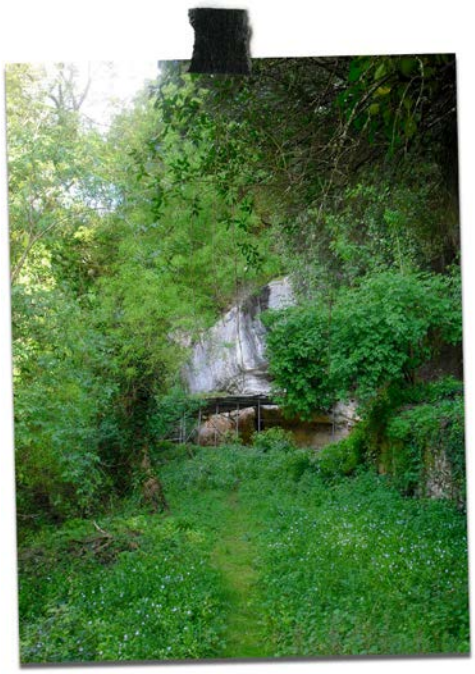
Oceans comprise the fluid, dynamic, and still largely unknown aquatic world. It is well known that 71 percent of Earth is covered in salinic water, yet this fact conveys little of the ocean's true gestalt, its incomprehensible living volume. Although partitioned into discretely named zones—Atlantic, Pacific, Indian, and Arctic—Earth's oceans are an interconnected body, 350 million trillion gallons of liquid continuously circulating at a global scale. Imagined differently, the ocean surface's meniscus is an unbroken plane wrapping around Earth, yet this membrane is also a psychic divide, splitting the world into atmospheric and aquatic realms—essential partners forever alien to each other.





Ritual

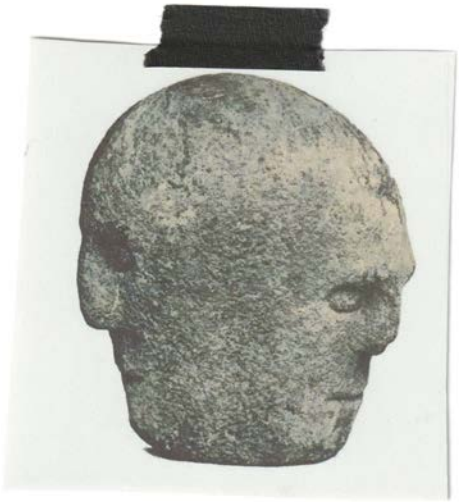
A ritual is an iterative act, cocreated and renewed by those choosing to enact it. Rituals can be either private, community-based, or institutional. They can be performed for any number of purposes, including but not limited to good luck, superstition, spiritual or religious communion, social cohesion, or the simple act of finding pleasure and purpose in continuity and codified repetition. As containers of spiritual entanglement, rituals are often enforced through gestures that are handed down and take on symbolic significance. However, there is always a risk here: Should a ritual be simply "performed" through repetition, the very acts that once produced meaning could become flat, robotic gestures, thoroughly devoid of real, embodied meaning.



Rock-Shelter at Lagar Velho

A rock-shelter is a naturally occurring architectural structure formed when a series of large rocks create an eave or vault, protecting people under it from the elements. Through time, this simple lithic morphology has magnetized humans, becoming a place of habitation. As a result, in more recent times, rock-shelters have frequently become sites of archaeological excavations.

The rock-shelter at Lagar Velho is made of limestone, a sedimentary rock composed of calcium carbonate and formed from primordial organic remains. Because of its unique composition, limestone acts alchemically to preserve bone matter and fossilized objects. This, in part, created the conditions for the bones at Abrigo do Lagar Velho to be preserved.



Talisman

A talisman is an enchanted object that has acquired extramaterial properties, which seem to exist beyond its here-and-now physical reality. Customarily, a talisman has a highly specific purpose: protection from a defined threat, a blessing for a deliberate act, or an invocation of a specific element, for instance. However, it is also common for talismans to exist as wholesale charms, channeling a battery of powers—such as healing, protection, good fortune, and enlightenment—in the broadest sense. In popular culture, the use of talismans is often misrepresented as blind faith in the occult rather than a rational appeal to an incomprehensible universe. Talismans exist firmly within the ancient practice of sculpture-making, crafting matter into other while imbuing the material world with new resonance beyond the optical.

Water Birth

Water birth is a birthing style adopted by some humans, in which the expectant parent is intentionally immersed in water for some or all of the labor and delivery process. It is believed that water, with its natural buoyancy, lowers physical and emotional stress for both parent and baby during labor, thereby alleviating pain naturally while increasing oxygen flow and improving the effectiveness of contractions. For some, the decision to give birth in water is linked to the urge to provide the baby a more hospitable transition between the womb and the world; warm water becomes an interstitial zone between the amniotic fluid and the atmosphere of Earth.



The first documented water birth occurred in 1803 in France, but there is anecdotal evidence of water births being practiced for millennia all over the world—from South Pacific Islanders giving birth in shallow seawater to Egyptian pharaohs born in the Nile, women of Guyana going to a special zone along a local river to give birth, and many other examples.



FATHOMERS

Emergence
創発
Art from Life

October 8–December 15, 2024

Japanese American Cultural
& Community Center,
Los Angeles

Featuring the work of
AfroRithm Futures Group: Ahmed Best, Dr. Lonny J. Avi Brooks, and Jade Fabello, in collaboration with Dr. Drew Endy, Jesse Gilbert, Raquel Horsford, Malaya, and Oguri

Dr. Marie Bannier Hélaouët, Organoid Group, Hubrecht Institute of the Royal Netherlands Academy of Arts and Sciences and Oncode Institute, The Netherlands; and Dr. Albert Wu, Ophthalmic Stem Cell and Regenerative Medicine Laboratory, Stanford University, with lab members Dr. Aditi Swarup, Dr. Hala Dhowre, Dr. Sanja Bojic, and Julietta Picco

Dr. Callie R. Chappell and Dr. Nasa Sinnott-Armstrong

Michael Jones McKean, with assistance from Dr. Stephen Fong, Professor of Chemical and Life Science Engineering, Virginia Commonwealth University, in cooperation with the Museu de Leiria, Portugal

Eduardo Padilha

Dr. Pat Pataranutaporn

Corinne Okada Takara

Henry Tan, Masato Takemura, Pakchira Chartpanyawut, Weeratouch Pongruengkiat, Woraporn Pongsamart, Dr. Pat Pataranutaporn, Jirapat Thaweechuen, Tanis Phongpisantham, Pongsakorn Wechakarn, Sumeth Klomchitcharoen, and Kookpedz Studio

Tissue Culture & Art Project: Oron Catts and Ionat Zurr, with assistance from the UCLA Art|Sci Center and the California NanoSystems Institute

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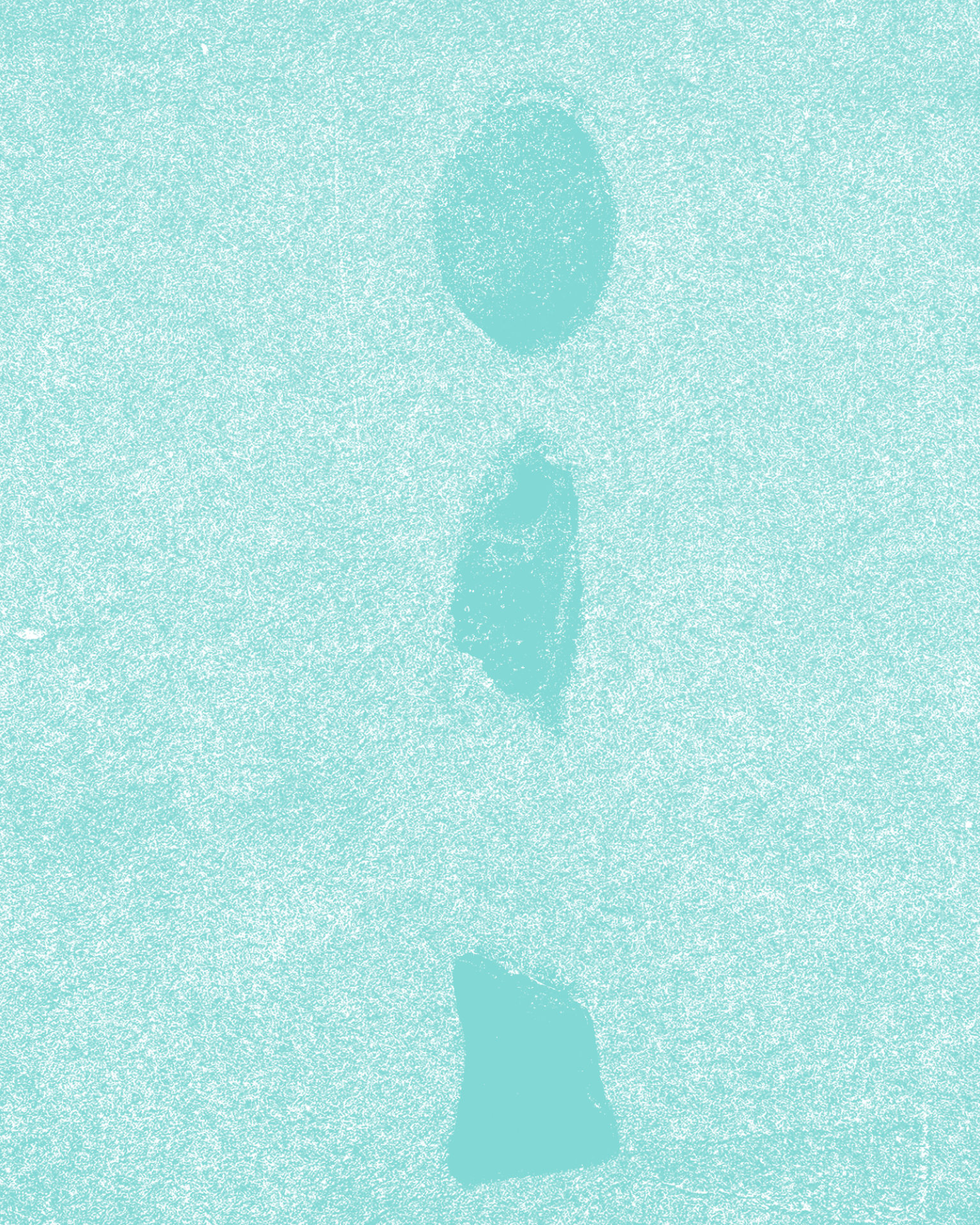






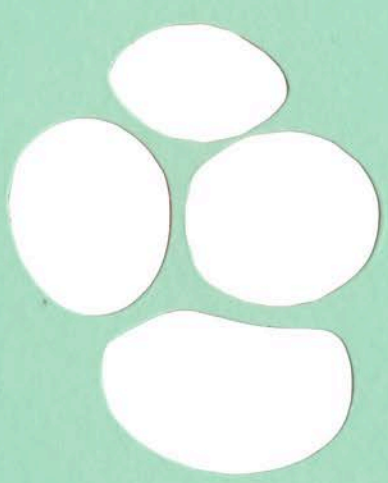


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FATHOMERS



Bureaucracy

This project is part of *Emergence*, an exhibition organized by Fathomers that ran from October 8 through December 15, 2024, at the Japanese American Cultural & Community Center in Los Angeles.

Emergence assembles artists, scientists, and artist-scientists working at the forefront of synthetic biology and contemporary art. Documentation of their projects as well as relevant writings and interviews, planning sketches, and other contextualizing materials are collected in this catalog. Some contributors draw from their work in medical or transdisciplinary research laboratories, where they confront new categories of life that destabilize our understandings of sentience, hybridity, and artificiality. Others engage the tools of synthetic biology as materials for creative experimentation and studio-based inquiry. Many contributors argue for decolonizing science and expanding access to biotechnologies through DIY and community science initiatives. Across *Emergence*, audiences and participants are invited to contemplate our human capacities for creation, destruction, recklessness, renewal, and hope. The exhibition prompts us to ask: Who has agency in this moment of making, learning, and living with? What forms of life are we choosing to cultivate? What will we nurture, and what might we leave behind?

Projects in the Exhibition

AfroRithm Futures Group
MultiPlanetary Garden

Marie Bannier Hélaouët and Albert Wu
Crying Organoids

Callie R. Chappell and Nasa Sinnott-Armstrong
IndiGROW

Michael Jones McKean
of kin and bone

Eduardo Padilha
Apoptotic Bodies

Pat Pataranutaporn
CyberBiome and *MicroPET*

Corinne Okada Takara
Floating Future Gardens

Henry Tan and Masato Takemura
Pillars of Creation

Tissue Culture & Art Project
The Use of Life (in Relation to the Industry of Men)

Fathomers is a creative research institute dedicated to producing sites and encounters that challenge us to live and act differently in the world. Fathomers cultivates the ideas of diehard dreamers, commissions projects that seem far-fetched, and collaborates with thinkers across disciplines to expand the limits of scale, scope, and support for artist-led projects.

Emergence was presented as part of PST ART: *Art & Science Collide*. PST ART is presented by Getty.

Tissue Culture & Art Project

The Use of Life

(in Relation to the Industry of Men)

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The Use of Life (in Relation to the Industry of Men)

Tissue Culture & Art Project

Introduction by Natasha Boyd

Established in 1996 by artists Oron Catts and Dr. Ionat Zurr, the Tissue Culture & Art (TC&A) Project is a pioneering collaboration that explores bioengineering as a medium for artistic expression. At the University of Western Australia, Catts and Zurr cofounded the first combined art-and-life-science research laboratory, SymbioticA, which they ran for almost three decades. TC&A's body of work includes many actual body parts, such as lab-grown human ears and pig wings, dolls and meats developed in vitro, tissue-cultured clothing, and other evocations of the ambiguous distinction between the living and the nonliving, organic and artificial. These pieces cast a curious, critical eye on novel developments in the field of biotechnology as much as they embody its manifold possibilities. "Rather than celebrating the technological approach to 'life,' we look at how life asserts itself as a context-based materiality, defying human and technological controls," Catts and Zurr have

remarked. "We celebrate failure and embrace futility, we rejoice in life."[1]

Since the material used by TC&A is literally alive, individual pieces are prone to change radically over time and in different contexts. This challenges the assumption that an artwork will be a fundamentally passive and static entity. The tissue-cultured *Victimless Leather* (2004), for instance, which was featured in the exhibition *Design and the Elastic Mind* at the Museum of Modern Art (MoMA) in New York, eventually outgrew its mechanical body and had to be terminated by MoMA curator Paola Antonelli. Cultivated from mouse stem cells on top of a miniature coat-shaped polymer structure, *Victimless Leather* resembled an embryonic, two-inch-tall version of the kind of leather jacket that someone in *Buffy the Vampire Slayer* or *The Matrix* might have worn—or a Polly Pocket accessory made out of raw meat. The jacket "started growing, growing, growing until it became too big" for its growth chamber, Antonelli told *The Art Newspaper* at the time. "I've always been pro-choice and all of a sudden I'm here not sleeping at night about killing a coat. . . . That thing was never alive before it was grown."[2]

Antonelli's musings attest to how *Victimless Leather* seemed to occupy a liminal state between inanimate object and sentient subject. Catts and Zurr call this troubling ontological category "the semi-living," in which cells and tissues are isolated from their original host organisms and coerced to develop into predetermined forms in the lab. Their survival is dependent on rigorous laboratory protocols, regular human intervention, and a steady supply of growth serum—often including up to 20 percent fetal bovine serum, one of the only natural materials that can grow and preserve living cells, which must be harvested from the heart of a calf embryo.

The semi-living already have plenty of potential medical and commercial applications. Some of the semi-living are being used to grow functional organs to replace failing human hearts and kidneys; other lab-grown tissues are used to liberate livestock from humanity's dependence on factory-farmed animal products. It's a vision of the future that's coming around the corner fast. The semi-living creations of the TC&A Project hold a mirror up to these developments, prompting an insurgent commentary on what forms of life we consider suitably beneath us to use for our own ends.

Semi-Living Steak (2000) explores another facet of "victimless" production. For the first version of this work, prenatal sheep cells were harvested in utero, so that the meat grown from these tissues was sourced long before the animal was born—a violence almost totally obscured, a blip in the lamb's development. Another version of *Semi-Living Steak* grew the steaks from a biopsy taken from an animal that was otherwise left alive and healthy; the steaks grew in the lab as the animal healed in its pen. *Semi-Living Steak* envisions a society in which human domination and manipulation encompass even the youngest, most miniscule slivers of life."
As urban culture seems to find it hard to stomach images of real violence . . . its obsession with ever-growing consumption inevitably creates increasing amounts of victims from the ecology to other animals and humans," note Catts and Zurr on *Semi-Living Steak*. "The victims are pushed farther away; they still exist, but are much more implicit."[3]

In *The Use of Life (in Relation to the Industry of Men)* (2024), Catts and Zurr refer to this impasse in terms of "metabolic rift technologies": the collection of scientific, economic, and cultural processes by which humans attempt to separate themselves

from the violence and unpredictability that results from their exploitation of the natural world. A vitrine displays traditional animal parts and products next to synthetic materials. Within the transparent cage of one glass refrigerator, Kerrygold Irish cow's butter revolves slowly alongside Vegan Buttery Spread, a butter alternative from Trader Joe's, while another refrigerated display case holds "Insta-chicken" and cell-cultivated "Nova lox." Catts and Zurr have also laid open two original-edition books by nineteenth-century zoologist Edwin Lankester, *On Food* (1861) and *The Uses of Animals in Relation to the Industry of Man* (1860), to which they pay ironic homage with their title. As Lankester enthuses, "It would seem, when we study these wonderful adaptations to the wants of man, as though either every creature was formed first for itself and then for man, or that man was so constituted that, in the course of his history, he should be able to render every creature by which he is surrounded subservient to the purposes of his existence."[4]

1 Oron Catts and Ionat Zurr, "'We Will Introduce Contestable Design into the Long History of Design at RCA,'" interview by Angus Montgomery, *Design Week*, July 31, 2015, https://www.designweek.co.uk/issues/27-july-2-august-2015/we-will-introduce-contestable-design-into-the-long-history-of-design-at-rca.

2 Helen Stoilas, "MoMA Stem Cell Exhibit Dies Five Weeks into Show," *The Art Newspaper*, April 30, 2008, https://www.theartnewspaper.com/2008/05/01/moma-stem-cell-exhibit-dies-five-weeks-into-show.

3 Oron Catts and Ionat Zurr, "The Tissue Culture & Art Project," *Interalia*, November 2017, https:// www.interaliamag.org/articles/tissue-culture-art-project-oron-catts-ionat-zurr/.

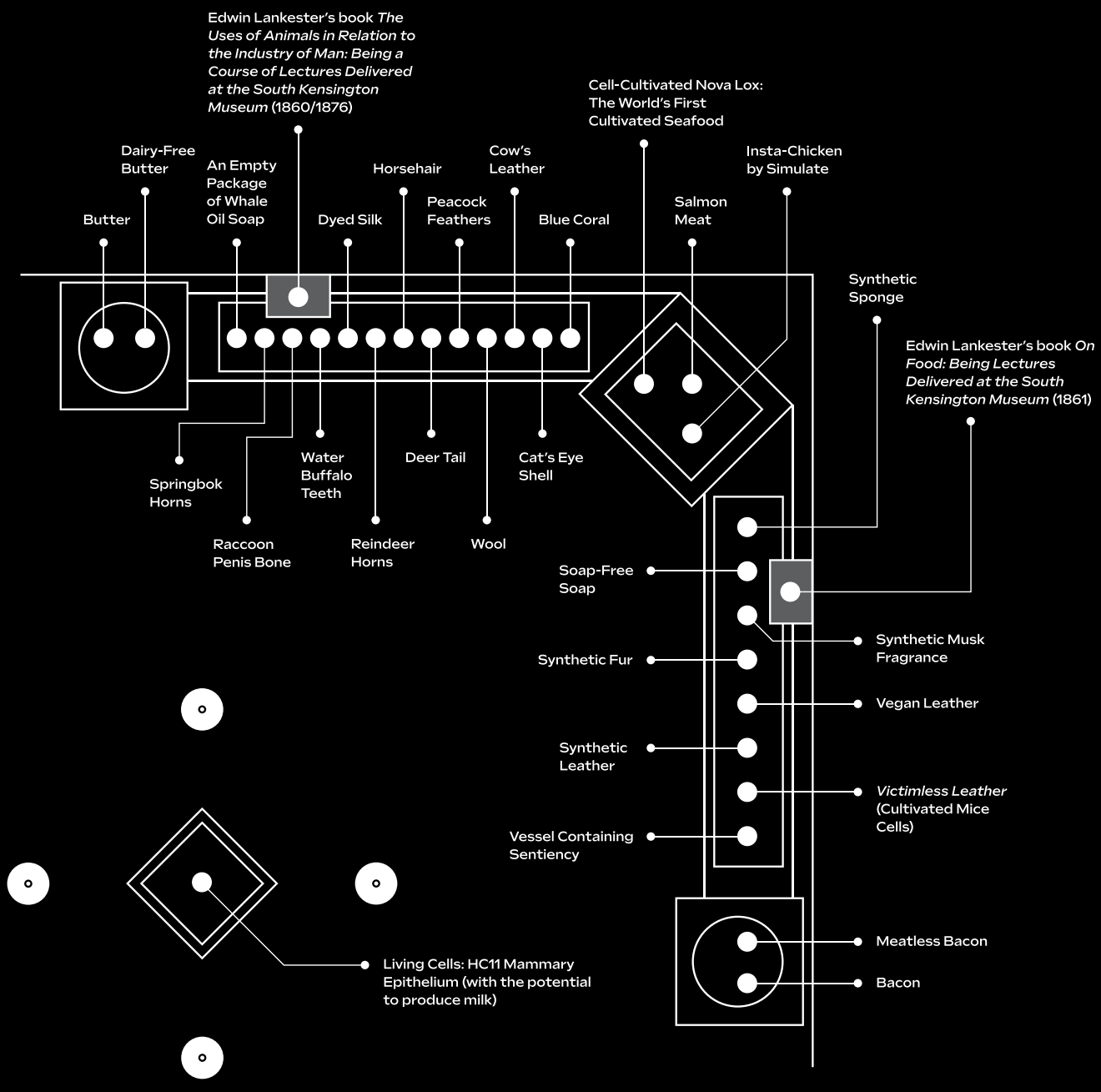
4 Edwin Lankester, *The Uses of Animals in Relation to the Industry of Man* (London: R. Hardwicke, 1860), 110.





Top: Tissue Culture & Art Project, *The Use of Life (in Relation to the Industry of Men)*, 2024. Cellular agriculture and bio-fabricated products, traditional animal products and parts, synthetic materials, custom-made bioreactor, HC11 Mammary Epithelium cell line and nutrient media, Edwin Lankester's book *The Uses of Animals in Relation to the Industry of Man* (1860/1876), cabinets, freezer, and fridge, dimensions variable. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.

Bottom: Tissue Culture & Art Project, *The Use of Life (in Relation to the Industry of Men)*, 2024. Details, from left to right: synthetic sponge, soap-free soap, synthetic musk fragrance, synthetic fur, and vegan leather. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.



Tissue Culture & Art Project, *The Use of Life (in Relation to the Industry of Men)*, 2024. Installation map. Courtesy of Fathomers. Design: Saturated Grey.



Oron Catts in the alkaline hydrolysis chamber. Tissue Culture & Art Project in collaboration with Steve Berrick, *Sunlight, Soil & Shit (De)Cycle*, 2022. Installation view: PS Art Space, Fremantle, Western Australia, 2022. Photo: Daniel Grant.

Tissue Culture & Art Project



Oron Catts

Photo: Daniel Grant



Ionat Zurr

Oron Catts and **Ionat Zurr** are artists, researchers, and curators based in Perth, Australia. Their pioneering Tissue Culture & Art Project, which they established in 1996, is considered a leading biological art project. Catts and Zurr's interest is *life*, more specifically the shifting relations and perceptions of life in light of new knowledge and applications. Their work has been exhibited and collected by museums such as the Centre Pompidou, Paris; Museum of Modern Art, New York; Mori Art Museum, Tokyo; National Gallery of Victoria, Melbourne; Gallery of Modern Art, Brisbane; Yerba Buena Center for the Arts, San Francisco; Ars Electronica; National Art Museum of China, Beijing; and more. Catts and Zurr co-authored *Tissues, Cultures, Art*, published in 2023 by Palgrave Macmillan.

A few months before the opening of *Emergence*, Dr. Yewande Pearse, director of science editorial and content for the exhibition, sat down virtually with Oron Catts and Dr. Ionat Zurr of the Tissue Culture & Art (TC&A) Project, the pioneering artists behind *The Use of Life (in Relation to the Industry of Men)* (2024). They discussed how Catts and Zurr's latest project critiques humanity's complex relationship with nature, exploring the historical context of industrial production and the philosophical implications of bio-fabrication. Their conversation delved into the ethical challenges of cellular agriculture, the narratives shaping technology, and the idea of "adversarial collaboration" in an era when art, science, and industry intersect. By examining the boundaries of life, sentience, and sustainability, Catts and Zurr invite audiences to question how we shape the future of nonhuman life—and our own.



Rethinking Our Relationship with Life

Oron Catts and Ionat Zurr in Conversation with Yewande Pearse

Yewande Pearse

You've titled your project *The Use of Life (in Relation to the Industry of Men)* after Edwin Lankester's 1860 book. How did you first discover this book, and how did its historical context influence your work?

Oron Catts I actually came across the book while browsing in an antique bookstore in Perth. We were working on another project at the time, one that critiqued museums and explored our shifting relationship with the idea of nature. The history of the natural history museum was of particular interest to us, especially its roots in nineteenth-century colonialism.

Ionat Zurr Yes, the natural history museum is very much a nineteenth-century institution that hasn't really adapted to the twentieth, let alone the twenty-first, century. It was established as a colonialist construction of reality, a place where the empire's spoils—geological, biological, and even human—were put on display.

OC Exactly. Especially the South Kensington Museum, which then became the Natural History Museum, the V&A, and the Science Museum [in London]. They were all based on Victorian notions of empire, showing off the spoils of the empire rather than providing an unbiased view of nature. They were unashamedly displaying what could be extracted from the empire: geological, biological, and even human resources.

Tissue Culture & Art Project, *The Use of Life (in Relation to the Industry of Men)*, 2024. Detail: Edwin Lankester's book *The Uses of Animals in Relation to the Industry of Man*. Courtesy of Fathomers. Photo: Carson Davis Brown.

YP Just stealing these artifacts, essentially.

IZ Yes, exactly. Actually, here in Australia, there's a TV show called *Stuff the British Stole*, which really goes over all those things.

YP I like how candid the title is.

IZ Yeah, that's Australia for you. We have a very interesting relationship with the "motherland." So when I saw this book, I thought it was amazing and that we needed to do something with it. We also found out that Lankester gave another series of lectures on food, which aligns with our interests, especially in our recent works on the idea of food production being separate from nature in the name of sustainability.

OC What's interesting about current industries is their fantasy of abundance without consequences—the idea that we can manufacture our needs and food separately from nature. But what this really does is use more layers of technology to obscure the real costs of our existence. The current idea of growing food outside of the bodies of animals or outside of fields is very much in line with the notion that there are no real costs involved. They even claim that consuming these products restores nature.

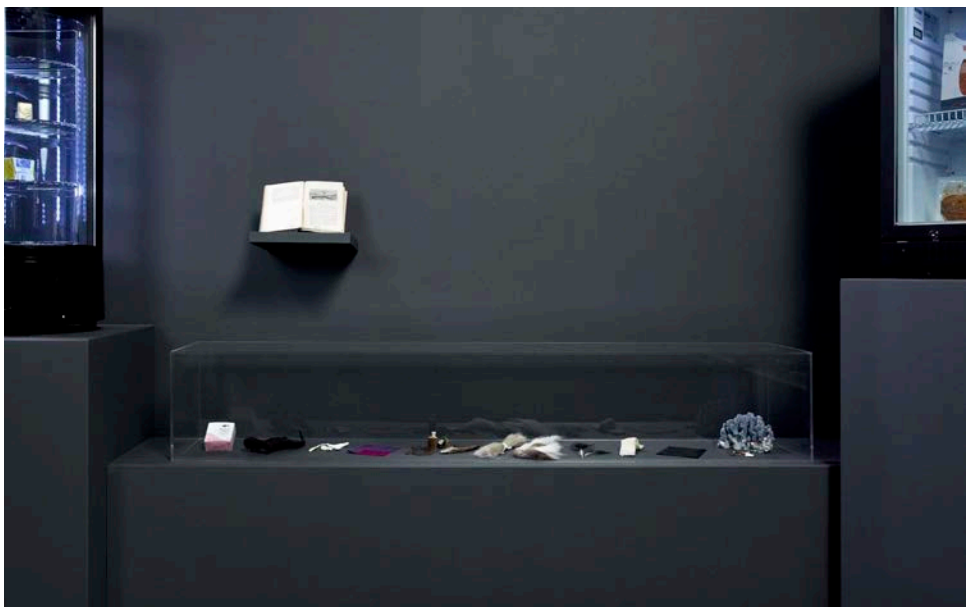


Tissue Culture & Art Project, *The Use of Life (in Relation to the Industry of Men)*, 2024. Details, from left to right: synthetic sponge, soap-free soap, synthetic musk fragrance, synthetic fur, vegan leather, synthetic leather, *Victimless Leather* cultivated from mouse cells, and vessel containing sentiency. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.

VP Do you think that as the technology becomes more sophisticated, those questions become easier to hide?

IZ Yes, definitely. First of all, going back to history is so rich because you realize that things are almost cyclical. But we forget, which is what we refer to as cultural amnesia. Using animals for industry, for both the needs and desires of humans, has been a constant throughout history. What's different today is the scale of what we're doing and the technologies that enable us not to see the exploitation we're doing. In the past, you would actually see where those materials came from. There was an understanding, and there was a flesh-and-blood experience of using organisms that had sentience and social lives. Now, to feel better about ourselves, we create this separation through layers of technology that enable us to believe these materials are victimless.

OC There's also a direct correlation between how human society organizes itself—becoming more urbanized and more removed from direct interaction with what we perceive as nature—and the damage to nature. The more removed humans are from nature and interactions with other lifeforms, the more damage is done. The notion that we can remove the means of production from nature itself, which is impossible, is a seductive narrative that's being promoted. But it's the same extractive mindset that led to the problems these solutions are trying to solve.



Tissue Culture & Art Project, *The Use of Life (in Relation to the Industry of Men)*, 2024. Details, from left to right: empty package of whale oil soap, springbok horns, raccoon penis bone, water buffalo teeth, dyed silk, reindeer horns, horsehair, deer tail, peacock feathers, wool, cow leather, cat's eye shell, and blue coral. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.



Tissue Culture & Art Project, *The Use of Life (in Relation to the Industry of Men)*, 2024. Details, from left to right: synthetic leather, *Victimless Leather* cultivated from mouse cells, and vessel containing sentiency. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.

VP That's a very profound reflection. With what you've both described, I see common themes in your work. This "victimless" narrative reminds me of *Victimless Leather* (2004) and *Biomess* (2018). How does this specific project relate to your previous works? Would you consider it a continuation, or perhaps a separate branch of inquiry?

IZ In many ways, all our projects are interconnected. Western science often adopts a reductionist approach, isolating elements to understand how they work. But once you put things back into context, their behavior changes. We can't disconnect things from their environments and relationships. This new project definitely relates to what we've done before, but it takes things to new extremes by engaging with more contemporary technologies.

OC This project tries to critique not just the technology but also the narratives and fantasies around it, especially the idea that we can produce all our needs and desires without having any impact on nature. We're putting this idea in a setup that's part museum, part retail, part entertainment, and part art, saying that the boundaries between art, fantasy, and necessities like food are now so mixed up that it's hard to separate them.

VP Industry often highlights the benefits of cellular agriculture and biofabrication, like reducing environmental impacts and addressing concerns about animal welfare. How do you balance those positive aspects with your concerns about the separation of nature and technology?

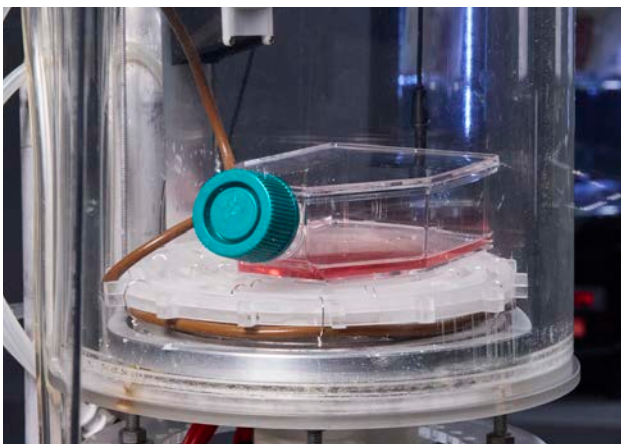
OC This project draws from over twenty years of history in our work, during which we've seen a major shift. When we did lab-grown meat in 2000 or *Victimless Leather* in 2004, there was no industry using it. Everyone was talking about it in science fiction terms at best. Our interest as artists is not in judging whether it's good or bad but in scrutinizing the mindset driving these developments and how this mindset needs cultural scrutiny to articulate where we're going.

IZ We try to avoid spoon-feeding our opinions because good art should avoid propaganda. There's already a lot of propaganda around this field, with companies dominating the narrative. We want to push the narrative that it's not all rosy; we need to rethink our relationship with nature and life.

VP That's important, especially with the idea of sentience, which seems to be a subtle yet significant theme in *The Use of Life*. When did your interest in the concept of sentience in relation to cellular agriculture and biofabrication first arise, and what message do you hope to convey about our moral responsibilities to nonhuman living beings?

OC The question of sentience has been with us since the early days of our work, back in the mid-'90s. One of our first projects involved growing neurons, which raised uncomfortable questions. Were we accidentally creating consciousness in a dish? It made us question what these neurons were actually experiencing. We decided not to pursue this project further because it was too disturbing. Fast-forward to a lab-grown meat conference, I was pushed to say something positive about lab-grown meat, and I mentioned that cells in culture are less complex and less sentient than, say, lettuce. As the words came out of my mouth, I realized I had just given the industry ammunition, which they now use as a major selling point.

IZ Sentience is more than a scientific question; it's a societal one. It's not just about whether we can remove sentience from living beings—it's about asking ourselves if we want to live in a world where we've done that. What kind of society are we creating when we sever these ties with sentient life? That's what a lot of our work is about: asking whether this is the society we want in the future.



Tissue Culture & Art Project, *The Use of Life (in Relation to the Industry of Men)*, 2024. Detail: cellular agriculture. Courtesy of Fathomers. Photo: Carson Davis Brown.

VP How do you navigate your relationship with the biotech industry, given that your work critiques it while also collaborating with it?

OC The industry has to acknowledge us because we've done this work long before them. We're often seen as misguided visionaries who didn't figure out how to make the world a better place using these technologies. But we share similar concerns about the environment, even if we approach them differently. Our relationship with the industry is one of mutual respect, but also one of critical engagement. We challenge their narratives while acknowledging that we need the tools they develop. They know we're not a threat because we're not interested in setting up a company or competing with them.

IZ We also promote the idea of "adversarial collaborations." This means working with people we don't necessarily agree with to achieve our own outcomes. This approach has worked well for us over the last twenty-five years, and it extends to industry as well. We don't see them as adversaries, but we do want to push them to think more deeply about the implications of their work.

VP That's a fascinating approach. Lastly, could you talk about the selection process for the elements in your installation? How do these pieces encourage audiences to engage with the deep philosophical and ethical questions you've been discussing?

OC The selection process is still ongoing, and we're quite opportunistic about it. We cast a wide net, looking for collaborations and materials that allow us to realize the concepts. The list of items isn't final yet, and that's often how we work—we make do with what we have to make the point. What matters is the broader idea we're communicating: the role of technology in separating us from life and the ethics involved in that separation.

IZ Aesthetics are important to us, but we give ourselves challenges by working with unknowns. We know some things will be there, like the bottle of sentience, and we'll have a custom bioreactor with mammary gland cell lines growing inside. There will be actual cells growing in the gallery, but unless you look through a microscope, you won't see them. This plays with the concept and the materiality, which is sometimes hidden but very real. We're playing with ambiguity. A lot of what we do is about creating opportunities for people to reflect on their relationships with living systems.

YP What impact do you hope your work will have on how people perceive cellular agriculture, biofabrication, and our relationship with nonhuman life?



OC There's been a major shift in the conversation over the last two decades. When we started with lab-grown meat in 2000, no industry existed for it. Now it's mainstream, and the rhetoric around it has shifted toward promises of environmental sustainability and ethical consumption. Our job as artists isn't to judge these technologies as good or bad but to scrutinize the mindsets driving them. We want people to question the seductive idea that we can produce food and other resources without any impact on nature.

IZ Exactly. There's a lot of corporate propaganda around cellular agriculture and biofabrication, and we want to provide a counternarrative. The reality is that these technologies are not victimless, and the separation between humans and other life-forms—whether through lab-grown meat or synthetic biology—raises important ethical questions about how we relate to the world around us.



Tissue Culture & Art Project, *The Use of Life (in Relation to the Industry of Men)*, 2024. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.

Acknowledgments The author would like to thank Yewande Pearse for inspiring the opening line of the piece, and Yewande Pearse, David Kim, and Dana Kopel for their editorial support throughout.

The Usefulness of "*Life*"

Joshua Evans

Milk without mammals. Honey without bees. Silk without silkworms. Wood without trees. Such promises, proffered by the intersecting and growing fields of cellular agriculture, biofabrication,[1] and synthetic biology, are the subject of Oron Catts and Dr. Ionat Zurr's *The Use of Life (in Relation to the Industry of Men)* (2024). The artists are concerned, here as elsewhere in their groundbreaking decades-long corpus, with the consequences, both potential and already real, of fabricating biological materials. In their works, including this one, the artists advance multiple related critiques: of the instrumentalization of life and the removal of sentience; of divorcing the product from the organism and the consequent abandonment of the more entangled, situated ecological relationships with whole organisms through which we have often coevolved; of the fallacies and inevitable failures of the will to total control;[2] and of the placement of the boundary between the living and the nonliving.

These critiques are not limited to synthetic biology but are general to the kind of modernist abstraction and decoupling—the imperative to separate "humans" from "nature"—that are by now so pervasive in industrialized societies as to appear inevitable. For this reason alone, not to mention the decoupling impulse's widely evidenced destructiveness, these critiques are worth continuing to mount. The work's juxtaposition of novel biofabricated products alongside their "original" organismal versions, preserved specimens the products come from, and parts of these organisms considered waste in biofabrication circles seems to invite this kind of critique based on difference.

I also see another, complementary, equally necessary but perhaps not yet as common kind of critique—understanding these various specimens not only in terms of their suggested difference but also their deeper similarity. We can focus here on the life/nonlife distinction, a central animating feature of the work, whose ambiguities and gradations the artists vigorously explore. What happens to the category of "life," they ask, when humans start to mold it into forms—often rationalized ones decoupled from organismal wholes—that have never existed before? The artists' response is to expand the binary into a continuum, through their development of the interstitial category of "semi-living," to account for these proliferating in-between cases.[3] This approach aligns well with the received critiques above, as the "semi-living" allows us to accommodate these creations as the forms of aliveness they undeniably are, while also distinguishing them from those that are "fully" or "truly" living. For any who feel a degree of caution about biofabrication's rapid developments—often driven by technological optimism and good intentions, to be sure, though also often by an implicit entitlement to human mastery and with a lack of sufficiently deep and prior ethical consideration—such an approach feels politically desirable, even necessary.

By specifying gradations of the life/nonlife distinction, however descriptively useful, the "semi-living" reifies it. There are reasons why we might also want to question the validity of drawing the distinction in the first place. The distinction between "living" and "nonliving," while a fixture of generally dualistic Western metaphysics, is neither universally practiced nor self-evident.[4] For example, many animisms around the world, which view all things—animals, plants, land formations, even human-made objects—as having a spirit or sentience, as well as Western philosophical "outliers" like Heraclitus, Parmenides, and Spinoza, are more monistic. They see everything as made of ultimately the same kind of stuff: not either mind or matter, living or nonliving, but as animate, vital materials that shimmer with agency and presence, each in different ways.[5] Even among scientists, there can be ambiguity and disagreement about what exactly constitutes "life."[6] Though on the surface it might appear intuitive—"I know it when I see it"—the category of life, upon scrutiny, is far from self-evident. It is heuristic at best; it shifts; it is a mystery.



None of this is particularly groundbreaking to say. The main objection to the life/nonlife distinction I want to raise here is not that it is not as universal or self-evident as it purports to be. It is that it also creates inequality, while pretending to merely describe. It does not just order the cosmos into two types of things; it enacts a hierarchy between them, making some kinds of entities—namely, living ones—more valuable, more deserving of care, than others. This life/nonlife binary is then echoed structurally in others—sentient/insentient, human/nonhuman, and man/woman, for example—that mutually reinforce each other.[7] The implication—and consequence—of the life/nonlife distinction is that some entities in the world are seen as more acceptable to control, or destroy, than others. When rapacious interventions into earth systems, for example, through mining, damming, and other extractive geoforming industries, face objections, it is less often for these systems' intrinsic worth and more often because of the harm that would come to living beings as a result.

While the "semi-living" is useful for describing novel entities that seem to exist in between the living and the nonliving, simply adding gradation does not address the inequality the distinction itself enacts. Rather than only interrogating the politics of where the life/nonlife boundary is drawn—and there is a politics worth interrogating here, as the artists do—we might simultaneously zoom out to interrogate the politics of drawing such a boundary at all. This is not to say that all categorization is bad. It is to say that it matters how we categorize, because how we categorize both organizes the world in different ways and brings different worlds into being. And while any scientific inquiry—even any intellectual one—certainly needs categories of some kind, it is not obvious to me that "life" and "nonlife" are best, or even necessary, for the job at hand.

In the absence of a life/nonlife distinction, how might we then relate to and value the specimens the work presents and, by extension, everything else? Instead of creating elaborate systems to proportionally allocate our care, there are other ways we can relate to the world: for example, by caring for and about everything simply because it exists. This *everything* includes all the entities we create, wherever they might otherwise lie on an erstwhile Great Chain of Being. We must "love our monsters" as we do our children, our pets, our charismatic megafauna, our sublime vistas; as we (sometimes) do each other.[8] Care may feel like a limited resource, which would then justify the fact that most of us do already allocate it in selective ways, however consciously or not. It feels natural to do so. But what if care is the sort of thing that begets more of itself the more we practice it, the more we receive it, the more it circulates? Then things start to look quite different.

I am not a synthetic biologist. And I am not always sure that synthetic-biological solutions are the ones we need most to address complex socio-technical problems. But in caring about the world, however partially, I find myself also wanting to care about and for synthetic biology's "monsters," its oddities, its new creatures, however living or not, that we are still figuring out how to make kin.[9] Which leads me to wonder: What might this more animistic, monistic orientation to the world, which obviates a life/nonlife distinction entirely and does not require it as a rubric for apportioning care, mean for how we practice and understand synthetic biology and its allied fields? How might we let the nonhuman actors in synthetic biology—the microbes, the model organisms, the "cell factories," the "chassis"—speak back? How can we open up more space for their agencies to be expressed, for ourselves in turn to be surprised, and for both of us to come into new kinds of relation? This approach entails a kind of conversation, a call-and-response, that seems often to yield far more flourishing, interesting worlds.[10] It promises not only a more care-full world in general;[11] for synthetic biology specifically, it also promises discoveries that humans themselves, in a paradigm that aims



for total control, might never be able to design, or even dream up.

Catts and Zurr's work, as with much of their corpus, does not simply aim to critique synthetic biology, cellular agriculture, and biofabrication. That would be too easy. It also creates a site where practitioners in these fields are invited to engage with these critiques in ways that might open up new lines of inquiry and practice within them. By focusing on the politics of the life/nonlife binary that underlies their critiques, I hope to raise additional questions that contribute to these discussions. Most of all, I want to suggest that adjudicating whether synthetic biology and its brethren are good or bad, as is so often done, is probably less interesting, and less consequential, than asking how, if at all, such disciplines might reorient their practices and visions toward this kind of relational ethics. I wonder how this perspective might open up new dimensions of meaning in and conversation around many of this exhibition's already incisive, illuminating works.

Beyond synthetic biology, beyond bioart, this perspective might offer an even more general suggestion. Because this same question—in short, What do you have to say?—can be asked of any configuration of shimmering matter, whether it takes forms conventionally understood as living, nonliving, or something in between, it is a question all of us can ask of anything we encounter in our own lives. I wonder, too, how more of this curiosity might help bring about more livable, more flourishing worlds. For all are equally entitled to be asked this question, and to answer; and all are equally able, if we make the space and learn to notice, to surprise.

1 Biofabrication is "the production of complex biological products from raw materials such as living cells, matrices, biomaterials, and molecules." Mayer Tenenhaus, Hans-Oliver Rennekampff, and Gerit Mulder, "Living Cell Products as Wound Healing Biomaterials: Current and Future Modalities," in *Wound Healing Biomaterials*, ed. Magnus S. Ågren, vol. 1, *Therapies and Regeneration* (Woodhead Publishing, 2016), 201–25, https://doi.org/10.1016/B978-1-78242-455-0.00008-2.

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Flesh and the Feminine :



Technological De-Worlding in Tissue Culture & Art Project's *The Use of Life (in Relation to the Industry of Men)*

Annie Sandrussi

The art of the Tissue Culture & Art (TC&A) Project has a markedly fleshy dimension. TC&A's endeavor can be characterized as troubling the way that the technological imaginary conceals the fleshiness of the objects of science. In *The Use of Life (in Relation to the Industry of Men)* (2024), this fleshiness is boldly declared but remains only whispered under the heuristic auspice of scientific technological apparatuses. *The Use of Life* questions the logic of human intervention into life, which involves the framing of flesh as a resource for scientific and industrial innovation.

In the 1860 book that inspired the project, *The Uses of Animals in Relation to the Industry of Man*, Edwin Lankester provides a taxonomy of uses for the various parts of animal bodies, among which flesh is classified as "meat for men, dogs, and poultry."[1] *The Use of Life* materializes this taxonomy of useful resources. We encounter useful products: mouse mammary gland epithelial cells, often used for breast cancer research, in a bioreactor.[2] Flanking the bioreactor, we find glass refrigerators displaying consumer products made by cellular agriculture and biofabrication,

Tissue Culture & Art Project, *The Use of Life (in Relation to the Industry of Men)*, 2024. Detail: Insta-Chicken, a plant-based synthetic meat product from Simulate. Courtesy of Fathomers. Photo: Carson Davis Brown.

as well as vitrines containing contemporary and older animal/plant products and preserved specimens—bodies—of the organisms from which these products were made.

This display enacts Lankester's exhortation that "every application to art or science of this dead [animal] renders him of greater value; and it is for us, engaged in various ways in the arts of life, to see whether we cannot apply things that have hitherto been wasted."[3] By presenting these objects alongside each other, TC&A problematizes the logics of use, value, and waste that mark the fleshy bodies of once-living animals.

Ecofeminist theory describes a patriarchal logic of domination under which nature, the animal, and the feminine are available as resources for human exploitation.[4] Such a logic of domination expresses and implements a value system under which that classified as inferior—the animal, nature, and the feminine—is justifiably subordinated to that which is superior: the industry of man and men, in the case of scientific bio-innovation.[5] The concept of innovation and its technical apparatuses, such as the bioreactor, enact a technological de-worlding, meaning the physical, conceptual, and normative dissection of so-called useful resources from their fleshy lifeworld. Technological de-worlding is a process in which objects are removed from their natural context and alienated from their meaning. Recontextualized, they can be appropriated or put to use for our own projects. This alienation fosters a forgetfulness that leads us to exploit the natural without noticing the questionableness of this dynamic and its justifications.

Under a patriarchal logic of domination, flesh is used interchangeably with meat, and fleshiness is a measure of the meatiness of a carcass. Carcass, on the other hand, connotes the withering, decrepit, discardable form of what once was



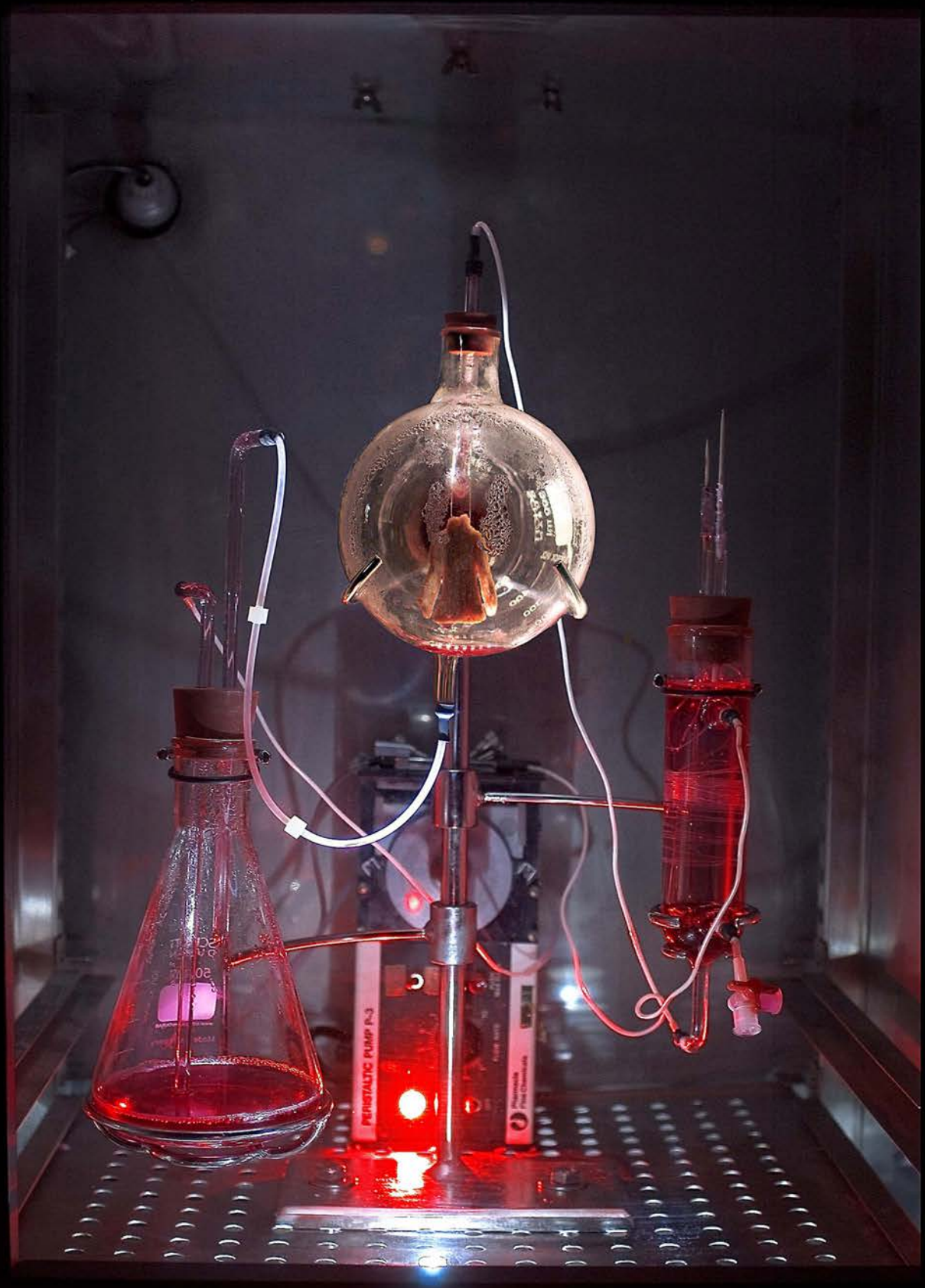
a warm, fleshy lifeworld. Flesh, beyond animal agriculture, is sensual, evoking that which can be felt and grasped; flesh is feminine, desirable, erotic. And yet flesh is also meat. In bioengineering, it can be dissected, distilled, minced, and "digested," harvested for its useful components and otherwise discarded. In *The Use of Life*, the cultivated mammary gland epithelial cells of a mouse, one of the smallest mammalian mothers, are housed within a bioreactor. The mouse mammary gland cells are semi-living—but what is a living thing when it is merely a part severed from the whole fleshy locatedness of a being called a mouse? In this respect, the bioreactor maintains us in moral ambivalence: We are confronted by the bare semi-living cells of mammary glands, lacking the hospitality of the adipose fleshiness of bodies marked female under patriarchy.

Tissue Culture & Art Project, *The Use of Life (in Relation to the Industry of Men)*, 2024. Detail: fridge containing cell-cultivated Nova lox, the world's first cultivated seafood; salmon meat; and Insta-Chicken, a plant-based synthetic meat product. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.

When living flesh is viewed through a register of useful resources, it entraps bodies within a commodity circuit—from living and lively to dying and rotting.[6] But between the living and lively and the dying and rotting dwell the semi-living, a defining feature of TC&A's practice.[7] In the late 1980s, Carol J. Adams, author of *The Sexual Politics of Meat*, coined the term "feminized protein." The term is inspired by early Adventist leader and vegetarian Ellen G. White's concept of "animalized protein," which describes the process by which protein initially found in vegetables and grains is consumed by animals and thereby transformed into a different form of protein for humans. Adams asks, "'If protein taken from the bodies of dead animals is animalized, what do we call protein taken from living female bodies?' And the answer that came to me," she writes, "was *feminized protein*."[8] Adams's intent was to make visible the sexual commodification that animals identified as female under misogynistic rule privately undergo to keep them productively reproducing offspring and lactating for human consumption. These acts of sexual commodification, such as forced insemination and vaginal stimulation to encourage lactation, occur in private, obscuring the suffering of female mammals from public view. Because their products are not the flesh of a dead animal, their commoditized status remains hidden to us.

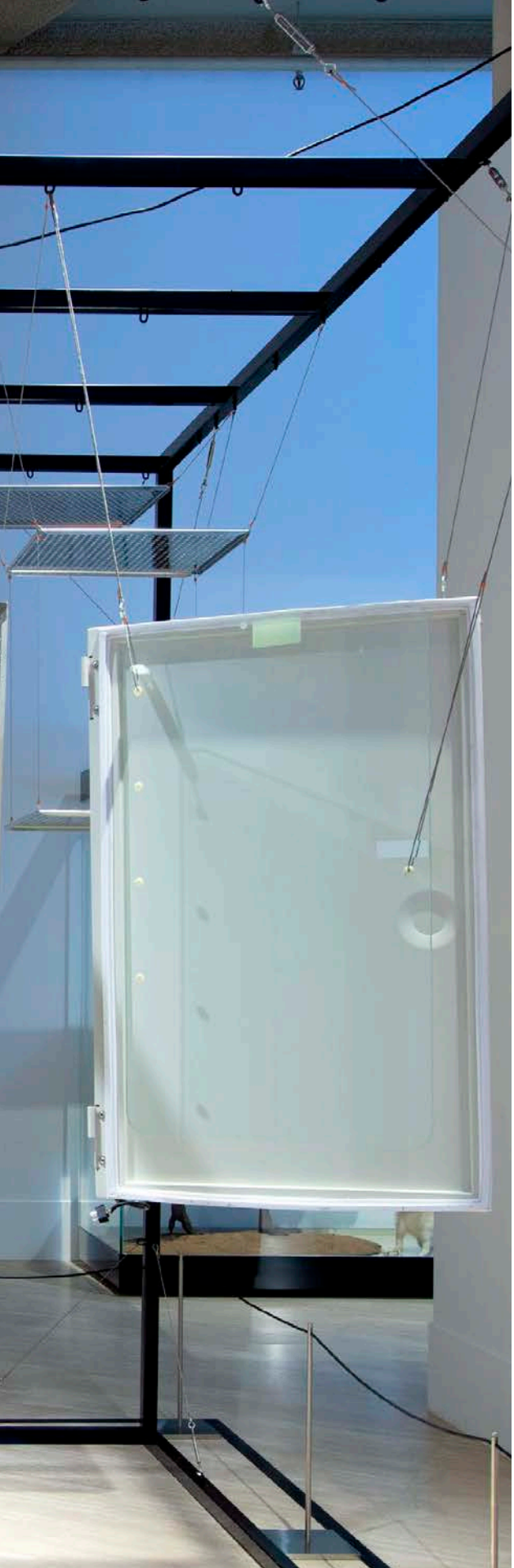
The farm, once the arbiter of the female mammal's place, is now replaced by the bioreactor. It is the imaginary of scientific innovation that underpins this de- and re-worlding, because it establishes the lab space as a perfectly ordinary arbiter of the place of biological matter. Feminist legal theorist Jessica Eisen describes the function of the farm to animals as analogous to the function of the home to women, writing that the farm has been "the arbiter and enforcer of [animals'] place, their purpose, their meaning; so naturalized that it is not even worth asking what they might think of it, even if we thought they were capable of answering."[9] TC&A, however, interrupt this naturalization by displaying alongside the bioreactor a range of discards presenting the flesh and carcasses of once-living animals alongside their "useful" products.

Mammary glands are also precursors to a mystical and potent symbolism of the feminine: Myths and legends about human attachment, psychology, and flourishing hold the maternal-feminine at the center. Milk produced by mammary glands exists in the context of an entwinement of two fleshy beings—the maternal (woman) and the innocent (child)—in an interdependent context of vulnerability and attachment. Outside the confines of a bioreactor and away from the intervention of dairy farmers, mammary glands are activated to produce milk by physiological and hormonal changes as female bodies come into reproductive age and then through the gestation and birth of another living being. In many mammalian subgroups, such as marsupials and primates, this living being remains physiologically dependent on the maternal body and its systems for a lengthy time relative to the gestational period. Left undisrupted, the milk produced is the material expression of ongoing fleshy exchange between two living beings. This dependence underpins the physiological "productiveness" of female mammals but, in agriculture and biofabrication alike, the products of this dependence are harvested and recontextualized as matter available for the Industry of Man.



Tissue Culture & Art Project, *Victimless Leather – A Prototype of Stitch-less Jacket Grown in a Technoscientific "Body,"* 2004. Biodegradable polymer connective and bone cells and custom-made perfusion system, dimensions variable. Courtesy of the artists.





1 Edwin Lankester, *The Uses of Animals in Relation to the Industry of Man* (London: R. Hardwicke, 1860), 159.

2 In this context, a bioreactor is a machine that maintains favorable temperature conditions (37°C) for a tissue culture. In combination with other steps, including exchange of the growth medium in which the tissue is placed, a bioreactor can maintain and extend the life of a tissue culture.

3 Lankester, *Uses of Animals*, 159.

4 M. Laurel-Leigh Meierdiercks, "Ecofeminist Ontology in Karen Warren's Ethic," *Ethics & the Environment* 28, no. 1 (2023): 13–35, https://doi.org/10.2979/een.2023.a899188.

5 Karen J. Warren, "The Power and the Promise of Ecological Feminism," *Environmental Ethics* 12, no. 2 (1990): 125–46, https://doi.org/10.5840/enviroethics199012221.

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8 Carol J. Adams, "Feminized Protein," in *The Routledge Companion to Gender and Animals*, ed. Chloë Taylor (Routledge, 2024), 72.

9 Jessica Eisen, "Milk and Meaning: Puzzles in Posthumanist Method," in *Making Milk: The Past, Present, and Future of Our Primary Food*, ed. Mathilde Cohen and Yoriko Otomo (Bloomsbury, 2017), 240.

Tissue Culture & Art Project, *Biomess*, 2018. Living organisms, natural history specimens, lab-grown life, and custom cabinets, dimensions variable. Courtesy of the artists.

An Examination of Synthetic Biology, Art, and Living Spirit

Frances Tran

In the contemporary landscape of scientific innovation, synthetic biology is a transformative force, offering the potential to create new living systems by designing and engineering life at the molecular level. It stands at the forefront of scientific innovation and the nexus of environmental management, medicine, and agriculture, promising breakthroughs that could reshape entire industries. Bacteria, for instance, can be engineered to produce biofuels, and synthetic yeast strains can create life-saving drugs like artemisinin to treat malaria. In agriculture, crops are designed to resist pests and tolerate extreme climate conditions, addressing food insecurity in a changing world. Yet beneath these genuine advances lies a complex interplay of ethical, philosophical, and historical dimensions that merit deeper scrutiny.

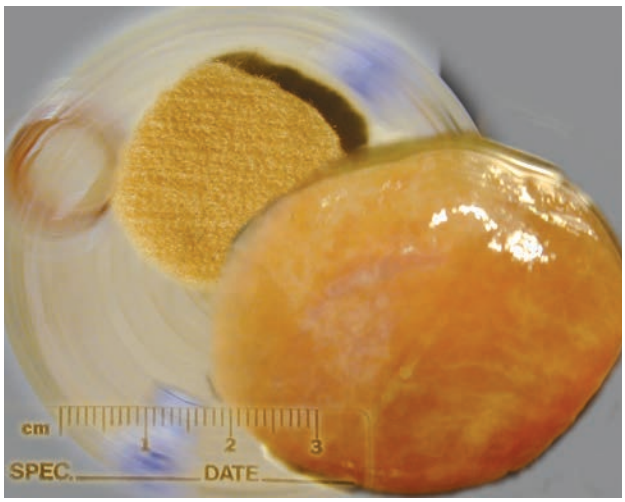
The ability to engineer life opens up profound questions about the nature of creation and control and the moral responsibilities that come with such powers. Who wields the authority to create life? What are the consequences of commodifying living organisms? How do these practices reflect and perpetuate broader societal values and historical legacies? These questions are not merely theoretical but deeply rooted in the history of scientific discovery, which has often been intertwined with colonial practices of exploitation and domination. In her seminal work, *Decolonizing Methodologies*, Linda Tuhiwai Smith highlights how Western research methodologies have historically reinforced extractive ideologies that prioritize exploitation and dominance. This legacy resonates in synthetic biology, where living organisms are often treated as tools for human benefit, echoing the capitalization and abuse of Indigenous lands and bodies that were central to colonial enterprises.

Consider, for example, the extent to which synthetic biology is driven by the extraction of genetic material from organisms around the globe. Bioprospecting—defined as the

search for naturally occurring substances with the potential for commercialization—is a common practice. Bioprospectors often appropriate Indigenous knowledge about medicinal plants and local biodiversity without proper acknowledgment or benefit-sharing. Moreover, when scientists genetically modify or engineer organisms for human use, as in the case of disease-resistant crops or biofuel-producing bacteria, they prioritize human control over nature. Even when framed as solutions to global challenges, these scientific endeavors can perpetuate resource extraction and manipulation for economic gain, often disregarding the interconnected ecosystems they affect. Synthetic biology must be conscious of its tendency toward reductionism, which risks stripping away the complexity and interconnectedness inherent in living systems.

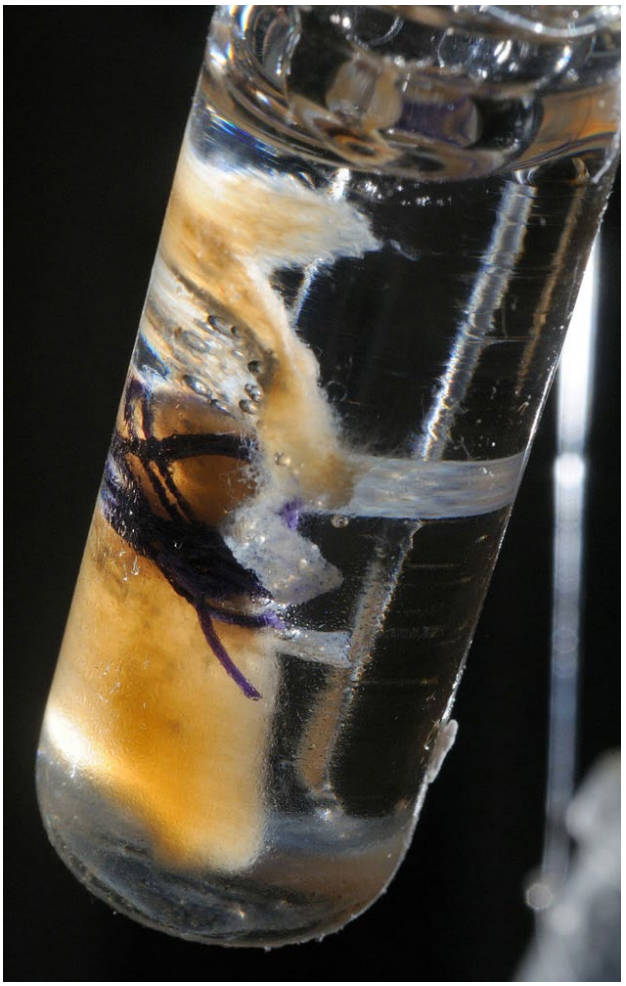
These ethical complexities are exacerbated by the entwinement of synthetic biology, traditional genetic engineering, and directed evolution. Each of these disciplines aims to modify organisms for desirable traits. Humans have been cultivating preferred traits for millennia, knowingly or unknowingly. Genetic engineering involves the direct manipulation of an organism's genes: for instance, inserting a specific gene into corn to create a herbicide-resistant crop. Directed evolution, by comparison, mimics the process of natural selection to evolve traits (i.e., proteins or nucleic acids) toward a user-defined goal. This could mean simply choosing the sweetest strawberries to seed in next year's harvest or breeding favored dog breeds. Synthetic biology seeks to integrate these methods and streamline and extend these practices by increasing precision and efficiency to design and construct entirely new biological parts, devices, and systems. Unlike traditional genetic engineering, synthetic biology's goals are more ambitious: It seeks to create unprecedented biological functions, potentially developing organisms capable of entirely new tasks.

But where do we draw the line between evolution and manipulation? The challenge lies in distinguishing synthetic biology's broader and more ambitious goals from the more focused objectives of genetic engineering and directed evolution, which center on refining existing traits. These broader goals include creating entirely new biological functions, such as organisms that can self-repair, detect and respond to environmental changes, or break down pollutants in contaminated ecosystems. Other ambitions involve designing synthetic organisms capable of producing complex materials or drugs that are otherwise difficult or expensive to obtain. By pursuing these possibilities, synthetic biology seeks to fundamentally redefine the scope of what life can do and how it can be shaped for specific purposes. This distinction underscores the evolving nature of these scientific disciplines and the complex ethical and practical implications that arise from their applications.



Above: Tissue Culture & Art Project, *Tissue Engineered Steak No. 1*, 2000, from the project *Semi-Living Steak*. Prenatal sheep skeletal muscle cells and degradable PGA polymer scaffold, dimensions variable. Courtesy of the artists. To the knowledge of the artists, *Semi-Living Steak* is the first known proof of concept for using tissue culture exclusively for food.

Opposite page: Tissue Culture & Art Project in collaboration with Steve Berrick, *Sunlight, Soil & Shit (De)Cycle*, 2022 (detail). Courtesy of the Tissue Culture & Art Project.



Despite these ethical concerns, synthetic biology also offers an alternative approach, one rooted in a desire to understand and harness biological systems in harmony with the environment and inspired by the natural engineering capabilities of microorganisms. By going back to those roots, we can open the door to knowledge systems that value cooperation over domination and recognize the agency and value of nonhuman entities. For synthetic biology, this means prioritizing research that supports local sustainability, ecological balance, and respect for nonhuman life. This might mean efforts to engineer microbes that restore degraded soils or improve crop yields without the heavy use of chemical fertilizers, or projects that focus on creating biodegradable materials from microorganisms in order to reduce plastic waste. Aligning synthetic biology with local ecological needs and sustainability fosters a more inclusive and regenerative relationship between human innovation and natural systems while also reorienting the values that drive scientific inquiry.

Art can play a crucial role in efforts to decolonize scientific methodologies. *The Use of Life (in Relation to the Industry of Men)* (2024) by the Tissue Culture & Art (TC&A) Project exemplifies the power of an artistic practice to interrogate and critique scientific endeavors. Art, in this context, becomes a transformative practice that reveals the underlying assumptions and values driving scientific inquiry. TC&A seeks to make visible the often hidden relationships between humans, nonhuman life, and the environment while drawing attention to issues of control, commodification, and manipulation. It prompts us to reconsider the boundaries between natural life and artificial constructs as well as the relationship between scientific innovation and ethical responsibility.

The critical power of TC&A's practice stems not only from the specific formal and conceptual decisions made in any given work but also from the depth and rigor of their engagement with synthetic biology. Over decades, TC&A has brought the tools, techniques, and institutional relationships of synthetic biology into the core of their artistic practice. Among other things, Oron Catts and Dr. Ionat Zurr, the artists behind TC&A, have built and maintained a laboratory, learned to cultivate cells and engineer bioreactors, and immersed themselves in the messiness, compromise, and complexity (both technical and ethical) of tissue cultivation. In the broadest sweep, their practice demonstrates how each of us might gain

Tissue Culture & Art Project in collaboration with Guy Ben-Ary, *Semi-Living Worry Dolls*, 2001 (detail). Skin, muscle, and bone cells; degradable polymer matrix; and surgical sutures; dimensions variable. Courtesy of the artists. *Semi-Living Worry Dolls* were the first tissue-engineered sculptures to be presented alive in a gallery context.

agency in shaping the future of synthetic biology—a future in which, I propose, the many genuine goods of innovation need not come at the cost of ethics, and in which creativity, guided by respect for life, can inspire new ways of thinking and living in harmony with the world around us.

As TC&A's project blurs the boundaries between art and science, it also prompts us to consider what constitutes a valuable use of synthetic biology. The cost of using living tissues as a medium must be weighed against the project's potential to drive awareness and transform the relationships between humans and nonhuman species. By using life as a canvas, TC&A demonstrates how the intersection of synthetic biology and art offers a powerful platform for critical reflection on the ethical and historical dimensions of scientific practices. They also underscore the responsibility of artists and scientists alike to consider the implications of their work. Such reflection is crucial in determining whether the artistic demonstration justifies the means, particularly when the means involve the manipulation and commodification of living organisms.

As we reflect on whether it is possible to engineer life ethically without repeating the exploitative patterns of the past, we might question whether our relationship to life, particularly as mediated by the discipline of synthetic biology, should be one of control or one of partnership. While synthetic biology carries undeniable ethical dilemmas, these technologies also hold the potential for profound positive change, particularly when aligned with a decolonized, inclusive, and ethical framework. Linda Tuhiwai Smith's work suggests that such a shift requires respecting Indigenous knowledge systems that are rooted in sustainability, such as by cultivating local, resilient crop varieties and by preserving biodiversity through practices that honor natural ecosystems rather than exploiting them. For example, projects that support Indigenous-led conservation efforts or collaborate with Indigenous communities to apply ancestral knowledge in land and water management embody a more holistic and reciprocal approach to scientific progress. In this way, synthetic biology can prioritize resilience and balance over control and extraction, ensuring that innovations uplift rather than marginalize the communities and ecosystems involved.

In collaboration with art, which has the ability to bring these ethical issues to the forefront of public consciousness, synthetic biology can inspire a transformation in how we relate to both human and nonhuman life. By embracing the reflective power of art and the critical frameworks of decolonized science, we can envision a path forward where synthetic biology is harnessed not for domination or exploitation but for healing and restoring the balance between humans and nature.



Oron Catts and Ionat Zurr at work on *Biomess: The Tissue Culture & Art Project*, 2018. Courtesy of the Art Gallery of Western Australia.

Excerpt from

Staying with the Trouble

Donna Haraway

The task is to make kin in lines of inventive connection as
a practice of learning to live
and die well with each other in a thick present.

Our task is to make trouble,
to stir up potent response to devastating events,
as well as to settle troubled waters and rebuild quiet places.

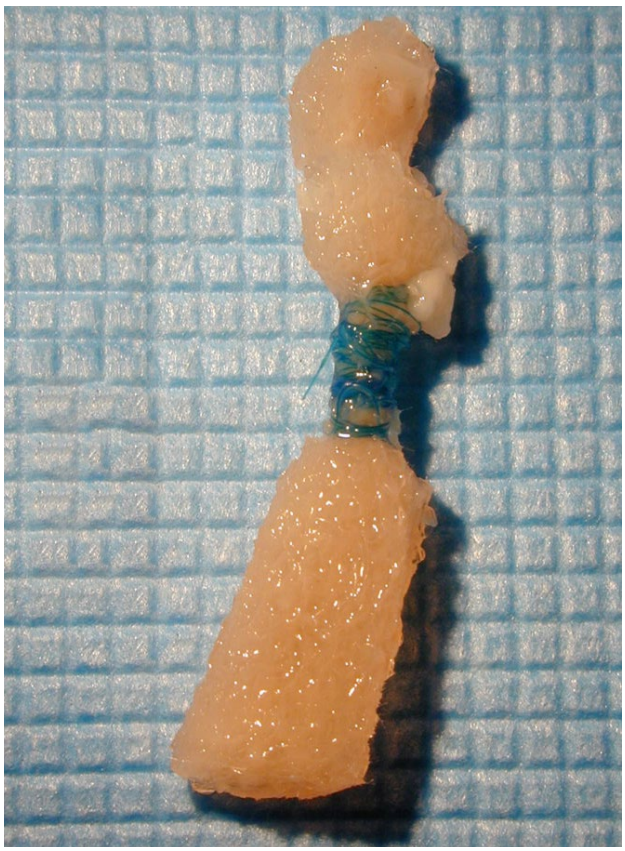
In urgent times, many of us are tempted to address trouble
in terms of making an imagined future safe,
of stopping something from happening
that looms in the future,

Originally published in Donna J. Haraway, *Staying with the Trouble: Making Kin in the Chthulucene* (Duke University Press, 2016). Reprinted by permission.

Staying with the trouble does not require
such a relationship to times called the future.

In fact, staying with the trouble requires learning to be truly present,
not as a vanishing pivot between awful or edenic pasts and apocalyptic or salvific futures,

but as
mortal critters
entwined in myriad unfinished configurations of
places,
times,
matters,
meanings.



Tissue Culture & Art Project in collaboration with Guy Ben-Ary, *Semi-Living Worry Dolls*, 2001 (detail). Courtesy of the artists. Visitors were encouraged to whisper their fears to each of the "dolls."



Tissue Culture & Art Project, *The Use of Life (in Relation to the Industry of Men)*, 2024. Details, from left to right: empty package of whale oil soap, springbok horns, raccoon penis bone, water buffalo teeth, dyed silk, reindeer horns, horsehair, deer tail, peacock feathers, and wool. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.



FATHOMERS

Emergence
創発
Art from Life

October 8–December 15, 2024

Japanese American Cultural & Community Center, Los Angeles

Featuring the work of

AfroRithm Futures Group: Ahmed Best, Dr. Lonny J. Avi Brooks, and Jade Fabello, in collaboration with Dr. Drew Endy, Jesse Gilbert, Raquel Horsford, Malaya, and Oguri

Dr. Marie Bannier Hélaouët, Organoid Group, Hubrecht Institute of the Royal Netherlands Academy of Arts and Sciences and Oncode Institute, The Netherlands; and Dr. Albert Wu, Ophthalmic Stem Cell and Regenerative Medicine Laboratory, Stanford University, with lab members Dr. Aditi Swarup, Dr. Hala Dhowre, Dr. Sanja Bojic, and Julietta Picco

Dr. Callie R. Chappell and Dr. Nasa Sinnott-Armstrong

Michael Jones McKean, with assistance from Dr. Stephen Fong, Professor of Chemical and Life Science Engineering, Virginia Commonwealth University, in cooperation with the Museu de Leiria, Portugal

Eduardo Padilha

Dr. Pat Pataranutaporn

Corinne Okada Takara

Henry Tan, Masato Takemura, Pakchira Chartpanyawut, Weeratouch Pongruengkiat, Woraporn Pongsamart, Dr. Pat Pataranutaporn, Jirapat Thaweechuen, Tanis Phongpisantham, Pongsakorn Wechakarn, Sumeth Klomchitcharoen, and Kookpedz Studio

Tissue Culture & Art Project: Oron Catts and Ionat Zurr, with assistance from the UCLA Art|Sci Center and the California NanoSystems Institute

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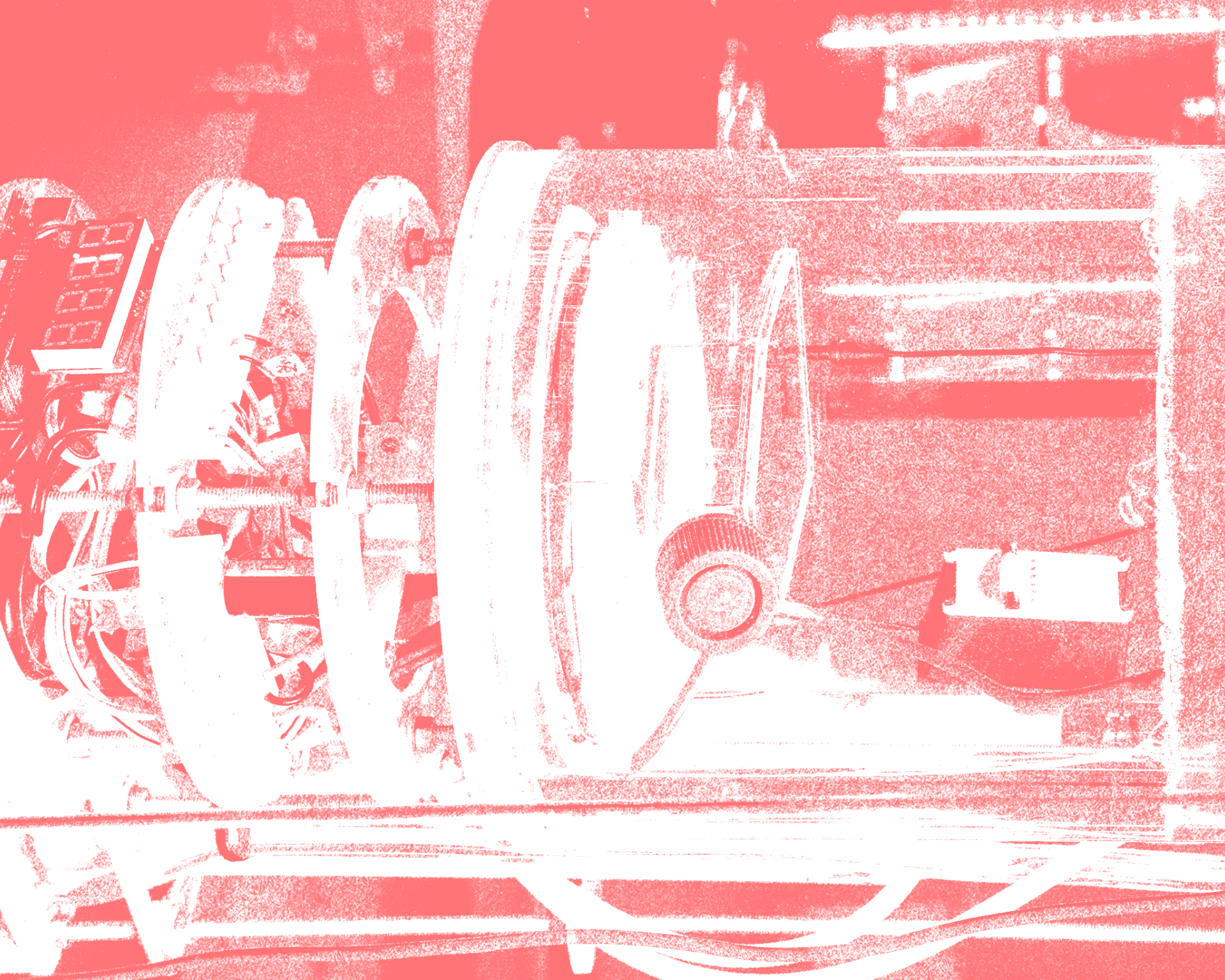








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FATHOMERS



Emergence

This project is part of *Emergence*, an exhibition organized by Fathomers that ran from October 8 through December 15, 2024, at the Japanese American Cultural & Community Center in Los Angeles.

Emergence assembles artists, scientists, and artist-scientists working at the forefront of synthetic biology and contemporary art. Documentation of their projects as well as relevant writings and interviews, planning sketches, and other contextualizing materials are collected in this catalog. Some contributors draw from their work in medical or transdisciplinary research laboratories, where they confront new categories of life that destabilize our understandings of sentience, hybridity, and artificiality. Others engage the tools of synthetic biology as materials for creative experimentation and studio-based inquiry. Many contributors argue for decolonizing science and expanding access to biotechnologies through DIY and community science initiatives. Across *Emergence*, audiences and participants are invited to contemplate our human capacities for creation, destruction, recklessness, renewal, and hope. The exhibition prompts us to ask: Who has agency in this moment of making, learning, and living with? What forms of life are we choosing to cultivate? What will we nurture, and what might we leave behind?

Projects in the Exhibition

AfroRithm Futures Group
MultiPlanetary Garden

Marie Bannier Hélaouët and Albert Wu
Crying Organoids

Callie R. Chappell and Nasa Sinnott-Armstrong
IndiGROW

Michael Jones McKean
of kin and bone

Eduardo Padilha
Apoptotic Bodies

Pat Pataranutaporn
CyberBiome and *MicroPET*

Corinne Okada Takara
Floating Future Gardens

Henry Tan and Masato Takemura
Pillars of Creation

Tissue Culture & Art Project
The Use of Life (in Relation to the Industry of Men)

Fathomers is a creative research institute dedicated to producing sites and encounters that challenge us to live and act differently in the world. Fathomers cultivates the ideas of diehard dreamers, commissions projects that seem far-fetched, and collaborates with thinkers across disciplines to expand the limits of scale, scope, and support for artist-led projects.

Emergence was presented as part of PST ART: *Art & Science Collide*. PST ART is presented by Getty.

Floating Future Gardens

Corinne Okada Takara

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Natasha Boyd

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Floating Future Gardens

Corinne Okada Takara

Introduction by Natasha Boyd

"Biodesign" is a much newer word than it is a practice, an anachronism that Corinne Okada Takara centers in her work. Interweaving synthetic biotechnological insights with local, lived, and Indigenous knowledge, Takara's installations embody the rapidly shifting nature of contemporary life. She positions science as a vehicle for the expression, not erasure, of cultural heritage, whether through her *Floating Future Gardens* (2024) project—a nod to kīpukas, the isolated vegetation areas surrounded by young Hawaiian lava flows, and to the ancient Mesoamerican *chinampas*, which the Aztecs used to grow maize, beans, and squash on top of miles of wetland—or her radish *mukimono*, cultivated in simulated Mars regolith and carved to invite dreams of future off-planet agricultural rituals of gratitude.

Takara is the daughter of a toymaker, and a philosophy of play and collaborative worldmaking shapes much of her work. Modular and tactile elements are combined and recombined, often by many hands alongside Takara's. She designs and leads workshops in museums, libraries, K–12 classrooms, and garages, seeking to transform each space into an open, anti-hierarchical zone for creative experimentation. "When people are invited to construct with a blend of Legos, clay, and local plant materials, the experience is so outside the box that many felt free to build without firmly knowing what they were creating," Takara wrote in a reflection on her role as Ginkgo Bioworks' 2022 Creative Resident. "It was a percolating, meditative space; and many began massaging the materials and ideas simultaneously."

Floating Future Gardens: *Yatai Cart* takes the inviting shape of a *yatai*, a Japanese mobile food stand. *Yatai* are typically set up in pedestrian hot spots; in addition to ramen and other street food, they offer an opportunity for strangers to share a meal together. In a similar fashion, *Floating Future Gardens*: *Yatai Cart* facilitates another kind of communing: It gives people who may never have met the opportunity to play and dream together about our collective biofuture. Like *Yatai Cart,* Takara's *Floating Future Gardens: Play Platform* features an organically shaped Lego build table, custom 3D-printed objects, and handmade materials. The build table evokes the interlinked spheres of land, air, and sea that make up our planet. Many of the components of both *Floating Future Gardens* installations were built by people from Los Angeles's Little Tokyo community, including the miniature *kokedama* (moss balls), which were crafted in a workshop at the Japanese American Cultural & Community Center.

In 2024, moss became the first multicellular organism from which researchers successfully synthesized part of a genome. Moss is also one of the oldest artmaking materials in the world. *Kokedama* originated with the *Nearai* bonsai method of the 1600s: Moss is wrapped around the compact roots of a plant, acting as a protective living vessel. Today, synthetic genomes of spreading earthmoss (*Physcomitrium patens*) might act as tiny factories for lifesaving medicine, protecting human beings much as the *kokedama* protects its plant's roots. Whatever the future holds, it also holds our past.

Right: Corinne Okada Takara, *Floating Future Gardens: Play Platform*, 2024. Lego boards, custom wood platform, mirror, and custom 3D-printed Legos, 48 × 72 × 4 in. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.





Corinne Okada Takara leads her *Kokedama: Molding Microbial Worlds* workshop at the Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.

Corinne Okada Takara



Corinne Okada Takara is a Honolulu-based artist and STEAM educator who creates playful technology- and biology-integrated art projects. Her collaborative work explores the use of modern day artifacts to preserve cultural heritage and memory, and honors the colliding and merging stories that arise in rapidly shifting communities. Takara specializes in visual art, biomaterial design, and art collaborations that invite dreaming about abundant, sustainable futures and empower people to see themselves as shapers of those futures. She is a cofounder of BioJam and works out of her Nest Makerspace.

Photo: Kurt Takara









Scenes from the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024.
Photos: Jordyn Doyel.



Corinne Okada Takara, *Floating Future Gardens: Yatai Cart*, 2024. Wood, bicycle wheels, custom 3D-printed Legos, *kokedama* moss balls, Lego boards, and metal screws, 72 × 46 × 84 in. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.

Floating Future Gardens Workshops





In the run-up to *Emergence*, Corinne Okada Takara led three hands-on workshops at the Japanese American Cultural & Community Center (JACCC) in Los Angeles. An intergenerational group of participants explored ways of combining traditional crafting practices with bioengineering to imagine new pathways for stewarding our rapidly changing world. They employed materials ranging from living moss, reeds, and radishes to organically shaped Legos designed by the artist. In addition to creating take-home pieces, participants could contribute work to Takara's *Floating Future Gardens* (2024) installation in the JACCC galleries. The following pages present their creations alongside some of the inspiration, materials, and methods for the workshops.



Kokedama:
Molding Microbial Worlds

Create miniature moss balls with local moss and soil as well as mock Mars soil formulated for NASA. The activity invites participants to write a diary entry or a story card for the collective microbiome of the ball or for a particular microbe within it.



Weaving Innovation

Reexamine our materials of innovation. How might place-based natural materials and community-based knowledge be part of emergent biotech science, and how can we express this with our materials of play and engineering? Use locally sourced materials to create miniature woven forms integrated with Lego pieces.



Mukimono Radishes:
Carving Future Gratitude

Explore how our rituals of celebration might evolve in a future shaped by climate change and advancing technology. Radishes, the only root vegetable grown both on the International Space Station and through the Growing Beyond Earth program, serve as a bridge between ancestral and futuristic food traditions. Carve a radish inspired by cultural rituals of gratitude—like the Oaxacan Noche de Rábanos and Japanese *mukimono*—reimagined for future celebrations.

Scenes from Corinne Okada Takara's workshops as part of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Photos: Fathomers.

苔

Kokedama (苔玉), the Japanese art of creating a "moss ball," is a horticultural practice that serves as an aesthetic endeavor as well as a medium through which to engage with microbial worlds and to improve the psychological states of the viewers and crafter of the *kokedama*. In this interspecies craft, plants are wrapped in a carefully shaped ball of soil and living moss, forming an interconnected ecosystem. This miniature garden requires regular care and attention, mirroring the mutual relationship between humans and the natural world. Studies in horticultural therapy have shown that engaging in such plant-based activities can enhance mental well-being, reduce stress, and improve cognitive function, as the act of nurturing plants has calming effects on participants; the symbiotic interaction it fosters between the maker and the microbes that inhabit the soil is particularly unique.

Every *kokedama* is a small living world, filled with microbial life that not only sustains the plant but also interacts with the human caretaker. Research in microbiology increasingly points to the health benefits of exposure to diverse microbial communities, which can strengthen the immune system and promote mental resilience. *Kokedama* is a tangible manifestation of this mutual care, with the maker nurturing the plant and its surrounding ecosystem while the microbiome within the *kokedama* may positively affect the maker's own well-being. This form of design emphasizes the mutuality of care between humans and the environment, positioning *kokedama* as more than a decorative practice. It becomes an act of stewardship, in which the plants and microbes thrive under thoughtful attention and the caretaker benefits from reduced stress, improved mood, greater mental clarity, cleaner air, and perhaps an enhanced microbiome. Through this mutual engagement, a deeper connection with the natural world is fostered, reminding us of the reciprocal care inherent in ecological systems.

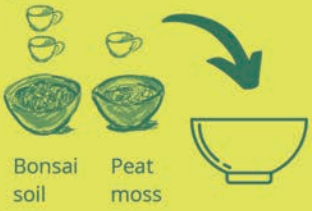
Kokedama: Molding Microbial Worlds

MATERIALS

moss (either locally collected or purchased)
gloves (optional)
bowls for mixing
small cups for measuring
water (on hand to add)
bonsai soil
peat moss
mock Mars soil
thread
twine or thick thread
scissors
cookie tray or wax paper to keep work surface clean



1 MIX SOIL



In a small bowl, mix a 2 to 1 ratio of bonsai soil to peat moss (or coconut husk). Add water slowly until it clumps enough to make a ball that holds together.

2 CREATE YOUR MICROBIAL SOIL SPHERE



Take a handful of mixed soil. Form it into a ball. If it is not sticking together, add a little water.

3 SELECT MOSS & CUT



Cut a section of moss whose length along the diagonal is slightly longer than circumference of your soil ball.

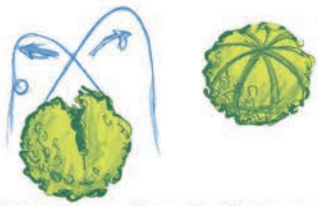
4 SHAPE THE MOSS AROUND THE SOIL BALL

Hold the moss tightly agains the soil.



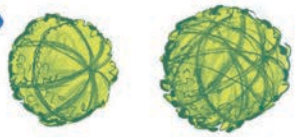
If you are putting a plant inside, split the ball in half and reform it around the roots before you start wrapping the moss around the ball.

5 WRAP IN THREAD



Cut two arms' length of strong string, such as button thread, and wrap around the moss ball to create longitudinal lines holding the moss in place. Tie the ends in a knot.

6 WRAP IN TWINE



Using another length of string, wrap an equator and then wrap in random pattern holding the moss further in place. For a stronger hold, do a last layer of wrapping using a thicker string or twine.

7 INCORPORATE PLAY BRICKS

Add play bricks to the surface of the Kokedama with string, or add the kokedama into a built structure.





WATERING:
Once a week, soak in a bowl of water for 10 minutes.

Corinne Okada Takara, worksheet for *Kokedama: Molding Microbial Worlds*, 2024.



This spread: Scenes from Corinne Okada Takara's *Kokedama: Molding Microbial Worlds* workshop at the Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers.



Kokedama, meaning "moss balls," are traditionally wrapped with thread, string, or fishing line. Hanging gardens or "string gardens" of *kokedama* are popular in Japan.







Kokedama are connected to the Japanese aesthetic tradition and philosophy of *wabi-sabi*, the appreciation of beauty that is imperfect, impermanent, and incomplete.



Left: Two *kokedama* made during Corinne Okada Takara's *Kokedama: Molding Microbial Worlds* workshop, 2024.

From

Effects of Types of Horticultural Activity on the Physical and Mental State of Elderly Individuals

Pei-Chun Tu, Wen-Chen Cheng, Ping-Cheng Hou, and Yu-Sen Chang



Abstract

This study aimed to evaluate the effect of types of horticultural activities among elderly individuals in a senior citizen learning camp. We arranged four horticultural activities: Grass Doll, Kokedama, Rocky Leaf Prints, and Herb Tasting and Smelling. Twenty-seven senior citizens (sixty to seventy-six years) were recruited to participate. We assessed their physiological and mental states before and after the activities by measuring heart rate variability, pulse rate, blood pressure, salivary amylase activity (SAA), and Profile of Mood States (POMS). Results showed that SAA was significantly lower after the Rocky Leaf Prints, Herb Tasting and Smelling, and Kokedama. Pulse rate had a downward trend after the four horticultural activities. The ratio of low-frequency over high-frequency results showed that the Rocky Leaf Prints had a larger downward trend, followed by Herb Tasting and Smelling. POMS scores indicated significant improvement for Rocky Leaf Prints and Herb Tasting and Smelling. The types of activities including artistic creation and food tasting were promising methods for psychological relaxation, stress reduction, and vigor enhancement for elderly persons. Findings showed that the impact of activities involving contact with plants was more significant in short-term activities. We hope this study can help plan the horticultural activities of the elderly in the future.

Above: Originally published in Pei-Chun Tu et al., "Effects of Types of Horticultural Activity on the Physical and Mental State of Elderly Individuals," *International Journal of Environmental Research and Public Health* 17, no. 14 (2020): 5225, https://doi.org/10.3390/ijerph17145225. Reprinted with minor edits by permission. **Opposite page:** Originally published in Eric C. Brevik et al., "Soil and Human Health: Current Status and Future Needs," *Air, Soil, and Water Research* 13 (June 2020): https://doi.org/10.1177/1178622120934441. Reprinted with minor edits by permission.

From

Soil and Human Health: Current Status and Future Needs

Eric C. Brevik, Lindsey Slaughter, Bal Ram Singh, Joshua J. Steffan, David Collier, Paul Barnhart, and Paulo Pereira

Abstract

Soil influences human health in a variety of ways, with human health being linked to the health of the soil. Historically, emphasis has been placed on the negative impacts that soils have on human health, including exposures to toxins and pathogenic organisms or the problems created by growing crops in nutrient-deficient soils. However, there are a number of positive ways that soils enhance human health, from food production and nutrient supply to the supply of medications and enhancement of the immune system. It is increasingly recognized that the soil is an ecosystem with a myriad of interconnected parts, each influencing the other, and when all necessary parts are present and functioning (i.e., the soil is healthy), human health also benefits. Despite the advances that have been made, there are still many areas that need additional investigation. We do not have a good understanding of how chemical mixtures in the environment influence human health, and chemical mixtures in soil are the rule, not the exception. We also have sparse information on how most chemicals react within the chemically and biologically active soil ecosystem, and what those reactions mean for human health. There is a need to better integrate soil ecology and agronomic crop production with human health, food/nutrition science, and genetics to enhance bacterial and fungal sequencing capabilities, metagenomics, and the subsequent analysis and interpretation. While considerable work has focused on soil microbiology, the macroorganisms have received much less attention regarding links to human health and need considerable attention. Finally, there is a pressing need to effectively communicate soil and human health connections to our broader society, as people cannot act on information they do not have. Multidisciplinary teams of researchers, including scientists, social scientists, and others, will be essential to move all these issues forward.

Future Needs in Soil Microorganisms and Human Health Research

Multiple important intersections exist between soil microorganisms and human health. These range from pathogen presence and transmission, antibiotic products and antibiotic resistance, and immunoregulatory compounds and signaling from soil-borne organisms to soil microbial contributions to sustainable and nutritious agricultural products. Based on our discussion above, future research in soil microbial community and human health research should better integrate soil ecology and agronomic crop production with human health and nutritional sciences. For example, more research is needed to investigate the linkages between soil microbial community structure and function in agricultural and natural soils and human health outcomes such as disease and allergy characteristics alongside nutrition and economic well-being. Moreover, continued enhancements in bacterial and fungal sequencing, metagenomics, and the subsequent analysis (including enhanced reference genome databases) are needed to further our understanding of the intersections outlined above. Finally, a complete understanding of these intersections will require a vast array of interdisciplinary teams of scientists, including but not limited to soil scientists, agronomists, botanists, biologists, microbiologists, ecologists, geneticists, immunologists, medical doctors, veterinarians, food scientists, and statisticians.

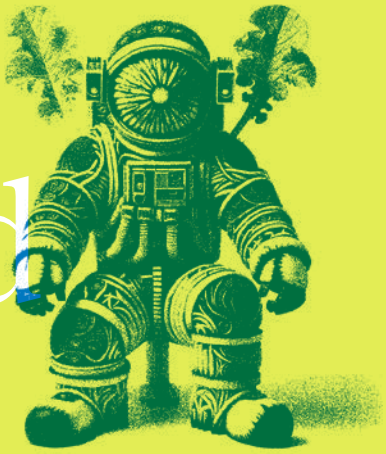


At the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Photo: Jordyn Doyel.





Of Carved *Radishes*, Recipes, and *Rituals / Gratitude* as *Co-Voyagers*

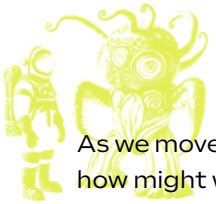




Corinne Okada Takara

A Response to the Question, "What Does Ancient Future Technology Mean to You?"

Originally published as part of the 2021 Ancient Future Technology course at the MIT Media Lab, December 19, 2021. Reprinted with minor edits by permission.



As we move rapidly into a time of climate change, how might we knit knowledge and perspectives across generations, cultures, and species to imagine a sustainable future for all earthlings? How might we elevate the wisdom and perspectives of ancestral cultures to form new tools, solutions, and frameworks to reshape our view of our place in this world and beyond? The framing of Ancient Future Technology raises these questions and creates a space to center the voices of global ancestors and living Indigenous cultures that have been pushed to the edges of conversations about what is considered innovation and technology.

Casting our eyes onto the horizons of space, we are already telling stories and exploring with biology as co-voyagers as we grow vegetables aboard the International Space Station and send yeast as scouts into deep space. In challenges such as the Deep Space Food Challenge, researchers are drawing inspiration from the food systems of our global ancestors to envision space voyaging sustenance with organisms such as Aztec *tecuitlatl* (spirulina), insects such as silkworms, and mycelium.

New horizons on both micro and macro scales will require new types of cartography. Cartographic innovation may draw inspiration from a range of Ancient Future Technology, such as the handheld, carved wooden coastline maps of the Inuit of Kalaallit Nunaat (Greenland) and the *ahupua'a*, a sustainable mapping system used by Kānaka Maoli (Hawaiians). The pie-like slices of land in the *ahupua'a* system span from mountain to sea, so that the flow of the natural water system is taken into account in land usage and management.

As we innovate with biology on Earth and in space, we also need to cultivate ethical and sustainable frameworks as co-voyagers with our fellow biology. In the Florentine Codex, Indigenous Nahua scribes documented a reverence and care for maize: Nahua women blew on maize before putting it into the cooking pot so that it would not fear the fire. In Oceania, ancient Polynesians prepared an ecosystem of sustainable food prior to setting out to sea, burying breadfruit to ferment for years before packing it as sustenance for themselves and animals on their long voyages through the most remote expanses of ocean, on their way to settle and terraform the islands of Hawaii. The "canoe plants," the plants and animals they brought to Hawaii, were anchored to the new land through stories and rituals of gratitude. Examining traditions of gratitude, ritual, and coexistence with other organisms will make us better co-voyagers as we co-shape a future for all earthlings in our journey into the unknown.

For the past several months, I have been bringing conversations about Ancient Future Technology to students at Alisal High School in Salinas, California, who are participating in the NASA-sponsored Growing Beyond Earth program. In the Xinampa community biolab, students grew a range of radish cultivars in simulated Mars soil in a grow box sent by MARSfarm. Growth data is shared back to NASA. To supplement the experiment, I invited students to share cultural traditions of carving radishes as a way to inform thoughtful speculative design imaginings of food rituals and harvesting in space. I shared my attempt at creating a *mukimono* carved radish (a fancier version of the ones my family makes for Japanese New Year celebration dishes), and co-instructor Leticia Hernandez shared the carved radishes of the Oaxacan festival Noche de Rábanos (Night of the Radishes). One student was excited, as he had actually been to the festival and was able to share more about it.

These discussions highlight the value of the ancestral and community knowledge students themselves bring to the table. Such sharing makes a fertile ground for richer speculative design as we imagine the food traditions we might bring and the new ones that may emerge in our voyages beyond the cradle of Earth. Framing technology as both ancient and future can reshape our view of our place in this world, inspire deep innovation as we imagine a sustainable future for all earthlings, and empower more people to see themselves as shapers of that vision.

Carving Gratitude:
Mukimono Radishes



MATERIALS

Radishes
carving tools
cut resistant gloves
tooth picks
paper plate or tray rags or paper towels

mason jar & namasu sauce

1 SELECT RADISH



2 IMAGINE

Get inspired by AI generated radish astronauts.



3 DESIGN

plan out design and sketch on sketch sheet



4 CARVE

Using the carving tools, carve your design while always carving away from yourself



5 SHARE STORY

Name your creation, write a description of your design, what it represents, and what future celebration it is a part of.



Optional, read Diary of a Space Zucchini & write entry for imagined Diary of a Space Radish.

6 SHARE STORY & PHOTOGRAPH

Take photo and place it into window LEGO brick.



7 PICKLE IN NAMASU SAUCE!



8 TAKE HOME!

Leave the window brick with photos of your design to be included in Floating Future Gardens installation.



Corinne Okada Takara, worksheet for *Mukimono Radishes: Carving Future Gratitude*, 2024.









Mukimono created by participants in Corinne Okada Takara's *Mukimono Radishes: Carving Future Gratitude* workshop, Japanese American Cultural & Community Center, Los Angeles, 2024. Photos: Fathomers.

A multigenerational audience dreamed up biological futures at the *Floating Future Gardens* pop-up workshop, part of the PST ART + Science Family Festival, La Brea Tar Pits, Los Angeles, 2024. Photo: Fathomers.



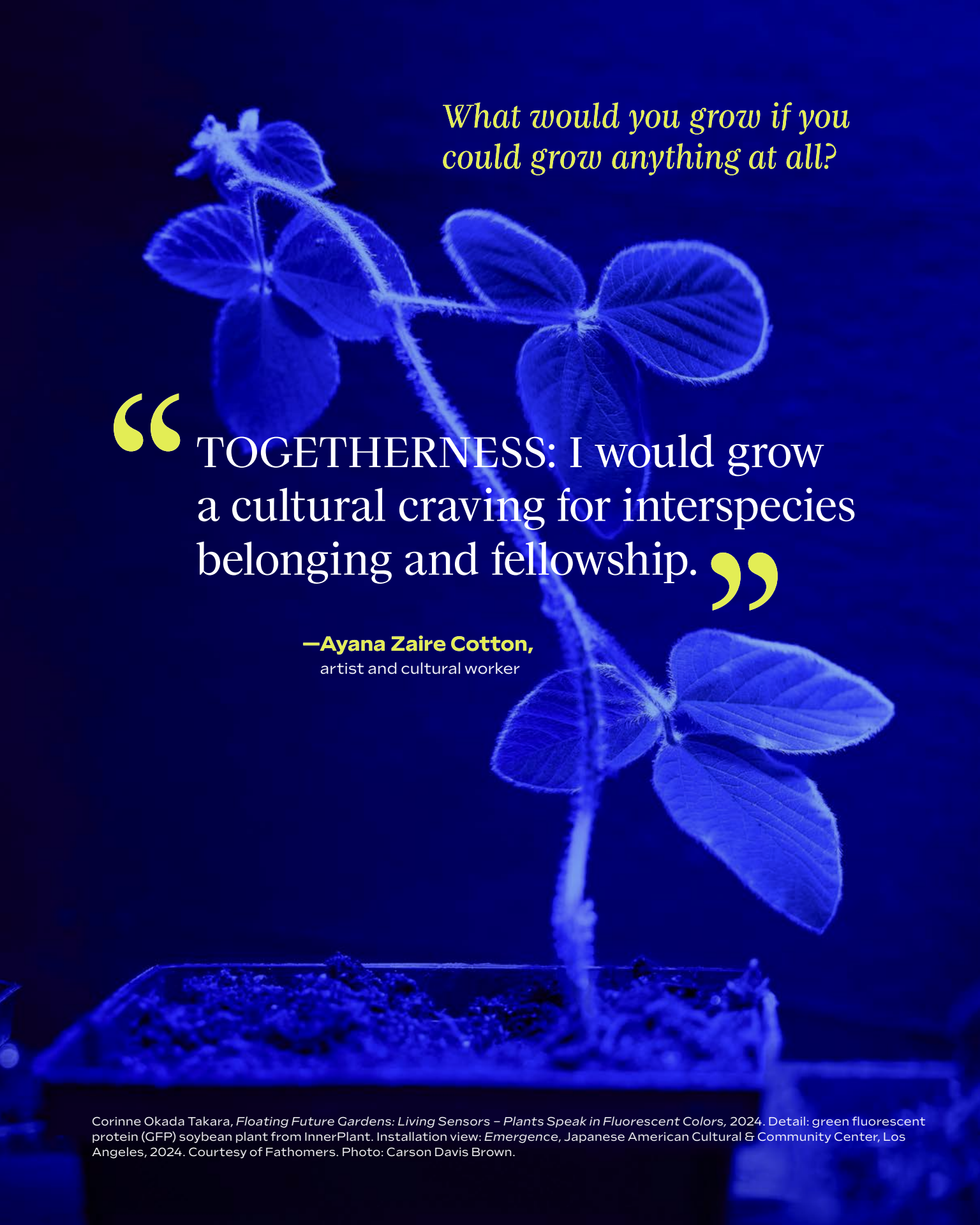


Corinne Okada Takara, *Floating Future Gardens: Living Sensors – Plants Speak in Fluorescent Colors*, 2024. Sonotubes, incandescent and fluorescent lights, Lego boards, 3D-printed components, Lego assemblies, GFP soybeans from InnerPlant, soybean plants, and soil, 24 × 75 in. Detail: jellyfish and soybean plants. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Photo: Fathomers.

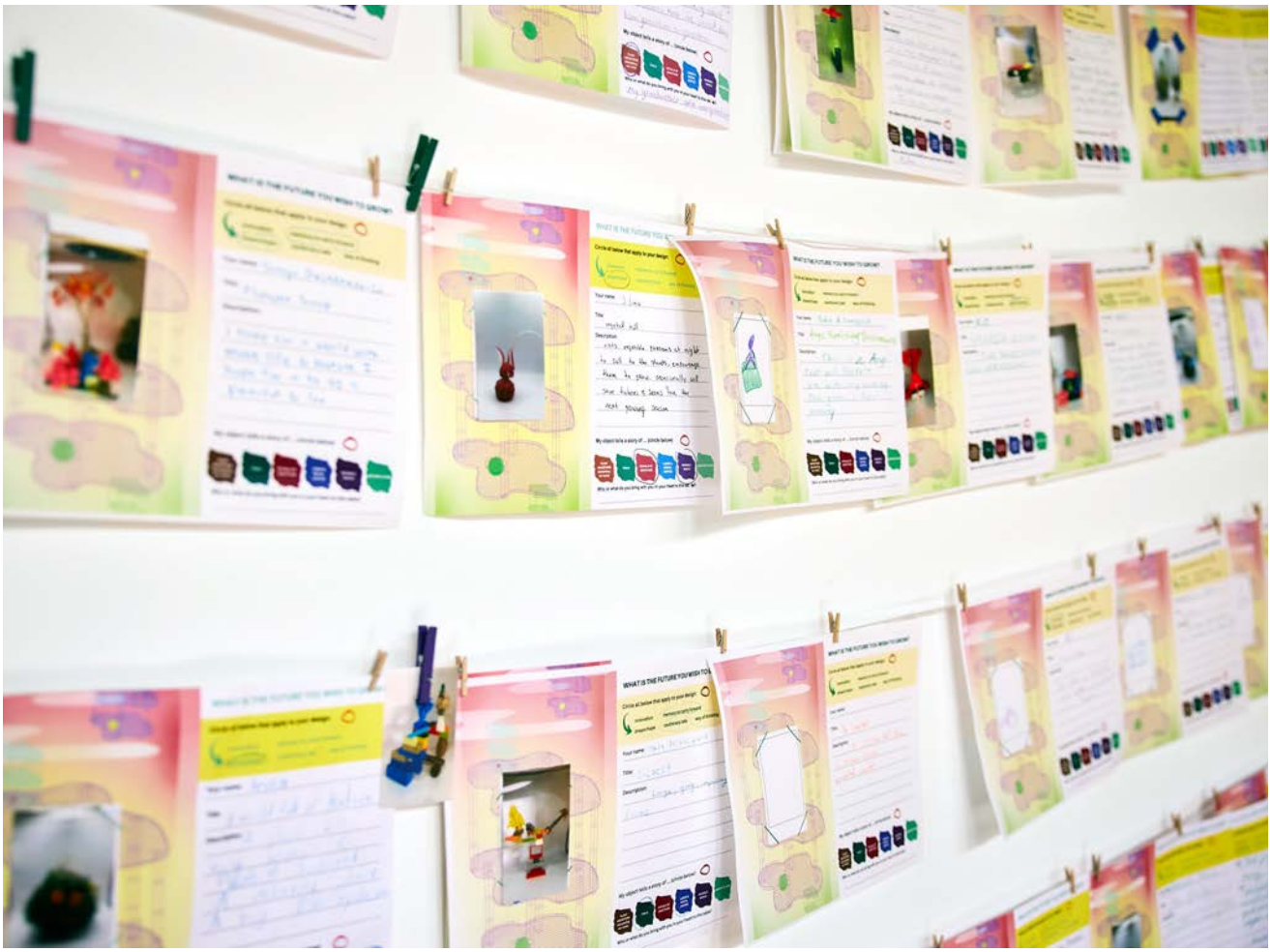
What would you grow if you could grow anything at all?

> TOGETHERNESS: I would grow a cultural craving for interspecies belonging and fellowship.

—Ayana Zaire Cotton,
artist and cultural worker

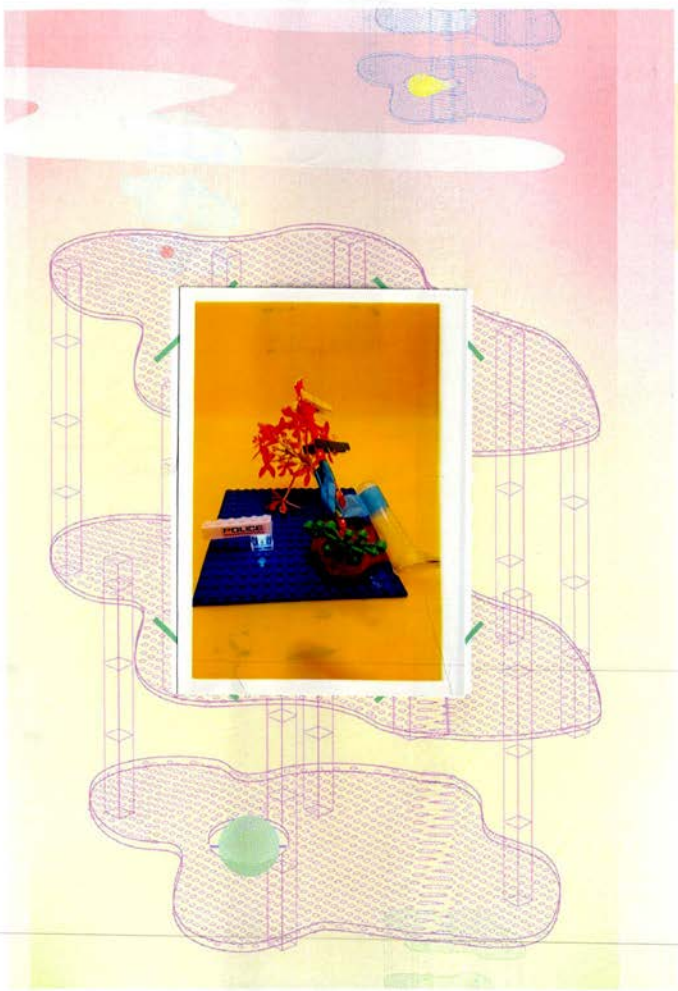


Corinne Okada Takara, *Floating Future Gardens: Living Sensors – Plants Speak in Fluorescent Colors*, 2024. Detail: green fluorescent protein (GFP) soybean plant from InnerPlant. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.





Above: Completed story cards from Corinne Okada Takara's *Floating Future Gardens*, 2024. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024.
Left: At the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Photo: Jordyn Doyel.
Opposite page: Completed story card from Corinne Okada Takara's *Floating Future Gardens*, 2024.



WHAT IS THE FUTURE YOU WISH TO GROW?

Circle all below that apply to your design:

innovation | memory to carry forward | dream/hope | cautionary tale | way of thinking

Your name: Rahi

Title: Plant Power Jet

Description:

A modern jet that uses soil microbes and plant power for fuel harvested by the plant helpers

My object tells a story of ... (circle below)

PLANT ANCESTORS (storytelling our roots) | TOOLS | RITUALS OF GRATITUDE | LABOR & SOCIAL JUSTICE | INVISIBLE WORLD | NATURE'S CO

Who or what do you bring with you in your heart to this table?

Towards Polyculture



What the Plant Kingdom Can Teach Us About Creating a More Equitable Science World

Beronda L. Montgomery

Gardening is an exercise in close observation. You don't want to miss the emergence of new sprouts, the gradual greening of leaves, or a sudden outburst of flowers and fruit. Even more, you don't want to miss signs of things going awry. Wilting leaves, holes in petals, powdery mildew, and rotting fruit are all calls to action. In these events, the grower must reconsider everything. Are the plants arranged in such a way to support each other? Are nutrients such as iron and nitrogen diminished in the soil, yellowing the leaves? Are there little holes in the fruit, evidence of larvae taking up residence?

The prescription is almost always greater care—moving plants that aren't getting sufficient light, adjusting the watering schedules, adding plant stakes where they might help. This is us at our most virtuous: thoughtfully, patiently looking out for something greater than ourselves. Could we apply that same care to our interactions with society at large?

the historic and current underrepresentation of Black, Indigenous, and Latine individuals in STEM has contributed to a disproportionate death toll in those communities. America's long history of biomedical racism has led directly to bad health, lack of access to quality healthcare, and, among some, an understandable distrust of public science. And STEM's current whiteness allows these trends to persist. How do you break up this dangerous monoculture?

The idea that plants might offer us guidance on these important questions might seem like a stylistic flourish, but metaphors matter. In my professional arena, for example, conversations about promoting equity in biology education and research often come back to the same one: how to get more underrepresented and marginalized individuals through "the pipeline." We need to get more people into the pipeline, according to this metaphor, and make sure fewer drop out.

In STEM, a few minorities are introduced into a monoculture and expected to thrive.

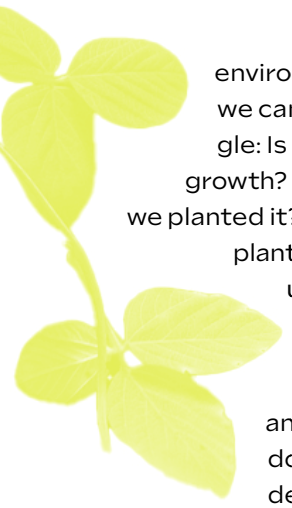
In my life as a plant cultivator and my work as a biologist and author, I have found the relationship between plants and humans deeply inspiring for thinking about the relationships that humans could have with each other. As I lay out in my book *Lessons from Plants*, the natural world offers us a template and inspiration for a more equitable society—where the needs and contributions of every individual matter equally, relationships among individuals are critical for supporting the collective, and diversity is a driver of sustainable growth. These lessons are particularly necessary in STEM, where monoculture has done some of its deepest damage.

Where We Stand

The cost of this monoculture has never been clearer than now. In the course of this pandemic,

This is one way to think about how to address the fact that Black people make up 14 percent of the US workforce and only 9 percent of STEM workers, with an even higher drop-off at advanced graduate education and professional and administrative levels. Unfortunately, the pipeline metaphor, with its emphasis on individual success or failure, tells us a lot more about what's wrong with this system. It operates on a deficit model, focused on the perceived shortcomings of individuals and quick fixes to allow them to fit in enough to get by.

The plant world—though an imperfect comparison, like all metaphors—offers us a more hopeful vantage point. Plants inspire a collective view of growth-based thinking. When plants in our personal spaces fail to properly flourish, our general human response is not to ascribe stunted growth to a lack of potential. We think about the



environment as a whole. We ask what we can ascertain about their struggle: Is the soil not supporting a plant's growth? Is it getting enough light where we planted it? How is it interacting with other plants in its space? Is our caretaking up to par?

In STEM, a few minorities are introduced into a monoculture and expected to thrive. When they don't, conclusions about individual deficits become a feedback loop. Such practices can lead to powerful forms of gatekeeping, which preserve the status quo. If we have any hope of changing this, we need to rethink the whole environment from the ground up.

off pests. This intercropping allows for something called interspecific facilitation. Each species contributes something that promotes the growth, reproduction, or persistence of the other.

One of the best examples of this is an enduring planting style called the Three Sisters, the intercropping of corn, beans, and squash. The corn provides vertical support to the beans. The beans share their nitrogen through the soil. The squash, which is low to the ground, inhibits weed growth and maintains soil moisture for the whole community. The Three Sisters system shows us how a community benefits when individuals are set up to exchange their unique capabilities and strengths. This approach can be reproduced with many different types of plants.

Monocultures create monocultures.

Vertical Support

When you plant a garden, you face a choice. You can plant each species in its own plot, or you can take the time to consider how different plants could grow together.

This is good for the soil and contains a valuable lesson. Our views of nature and humanity are closely intertwined. This is also true of the societies we live in: Monocultures create monocultures. The colonists that settled this country practiced the exploitation and segregation of people and plants. Their inheritance can be seen all around us: neat rows of single species, wheat and soy and corn, that serve as excellent cash crops but deplete the soil. With deep respect, and no intention of co-opting their knowledge, we should instead draw inspiration from the polycultures pioneered by farmers in Indigenous cultures.

Native American farming practices are often based on planting diverse species together, where they can help each other grow and fight

You cannot break up monoculture by charitably introducing a few new specimens and hoping they do well. You need to recreate environments that parallel those from which they originate. You need balanced communities in roughly equal numbers that let all contribute reciprocally and collectively. And in both cases, you need well-attuned stewards.

Mentorship

A good plant caretaker has to consider all possible interactions in their plot. They know that each individual in a community has particular potentials and needs, and fosters synergies between them. They take a growth-based perspective. They refine these strategies by talking to a large community, exchanging wisdom and references. Growing up with a mother who possessed exemplary plant caretaking skills, I often saw her sharing her mediations with neighbors and friends whose gardens were struggling. Best practices can only be sustained and developed through a wide conversation.

In my professional world, mentorship is considered hugely important, especially for trailblazers, people who hail from groups that are historically underrepresented and undersupported. But mentorship is only as good as the mentor's awareness and empathy. Where these are lacking, a common tendency emerges: self-focused mentoring, which often leads to something called imprinting, training another person to follow one's own behavior or the general norms of a group. A good mentor has to be sensitive to a trailblazer's history—and understand them on their own terms—to support their growth and transformation.

Mentorship also exists in the plant kingdom, specifically in the multispecies and multigenerational communities we find in forests. Mature trees and young trees in forests are often physically connected. The elders nurse young tree seedlings until they are established and able to persist more independently. In the Great Lakes areas, not far from where I live, nurse oak trees are commonly found to facilitate pine seedling growth on sand dunes. They provide a protective micro-niche for young saplings, offering shade, increased humidity, and shared nutrients via the soil. This is just the beginning of this actual sharing economy. Trees communicate through fungi. Plants alert neighboring plants to dangerous herbivores, activating their defenses. These interactions benefit all partners in the agreement.



In STEM, we need to build new dynamic ecosystems based on shared wisdom and experience, energy, and new perspectives—spaces where everyone can grow. We need to get messy, hands in the soil, ready to rethink our plot from the deepest soil on up.



Corinne Okada Takara, *Floating Future Gardens: Play Platform*, 2024. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.



FATHOMERS

Emergence
創発
Art from Life

October 8–December 15, 2024

Japanese American Cultural & Community Center, Los Angeles

Featuring the work of

AfroRithm Futures Group: Ahmed Best, Dr. Lonny J. Avi Brooks, and Jade Fabello, in collaboration with Dr. Drew Endy, Jesse Gilbert, Raquel Horsford, Malaya, and Oguri

Dr. Marie Bannier Hélaouët, Organoid Group, Hubrecht Institute of the Royal Netherlands Academy of Arts and Sciences and Oncode Institute, The Netherlands; and Dr. Albert Wu, Ophthalmic Stem Cell and Regenerative Medicine Laboratory, Stanford University, with lab members Dr. Aditi Swarup, Dr. Hala Dhowre, Dr. Sanja Bojic, and Julietta Picco

Dr. Callie R. Chappell and Dr. Nasa Sinnott-Armstrong

Michael Jones McKean, with assistance from Dr. Stephen Fong, Professor of Chemical and Life Science Engineering, Virginia Commonwealth University, in cooperation with the Museu de Leiria, Portugal

Eduardo Padilha

Dr. Pat Pataranutaporn

Corinne Okada Takara

Henry Tan, Masato Takemura, Pakchira Chartpanyawut, Weeratouch Pongruengkiat, Woraporn Pongsamart, Dr. Pat Pataranutaporn, Jirapat Thaweechuen, Tanis Phongpisantham, Pongsakorn Wechakarn, Sumeth Klomchitcharoen, and Kookpedz Studio

Tissue Culture & Art Project: Oron Catts and Ionat Zurr, with assistance from the UCLA Art|Sci Center and the California NanoSystems Institute

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FATHOMERS



Encerrado

This project is part of *Emergence*, an exhibition organized by Fathomers that ran from October 8 through December 15, 2024, at the Japanese American Cultural & Community Center in Los Angeles.

Emergence assembles artists, scientists, and artist-scientists working at the forefront of synthetic biology and contemporary art. Documentation of their projects as well as relevant writings and interviews, planning sketches, and other contextualizing materials are collected in this catalog. Some contributors draw from their work in medical or transdisciplinary research laboratories, where they confront new categories of life that destabilize our understandings of sentience, hybridity, and artificiality. Others engage the tools of synthetic biology as materials for creative experimentation and studio-based inquiry. Many contributors argue for decolonizing science and expanding access to biotechnologies through DIY and community science initiatives. Across *Emergence*, audiences and participants are invited to contemplate our human capacities for creation, destruction, recklessness, renewal, and hope. The exhibition prompts us to ask: Who has agency in this moment of making, learning, and living with? What forms of life are we choosing to cultivate? What will we nurture, and what might we leave behind?

Projects in the Exhibition

AfroRithm Futures Group
MultiPlanetary Garden

Marie Bannier Hélaouët and Albert Wu
Crying Organoids

Callie R. Chappell and Nasa Sinnott-Armstrong
IndiGROW

Michael Jones McKean
of kin and bone

Eduardo Padilha
Apoptotic Bodies

Pat Pataranutaporn
CyberBiome and *MicroPET*

Corinne Okada Takara
Floating Future Gardens

Henry Tan and Masato Takemura
Pillars of Creation

Tissue Culture & Art Project
The Use of Life (in Relation to the Industry of Men)

Fathomers is a creative research institute dedicated to producing sites and encounters that challenge us to live and act differently in the world. Fathomers cultivates the ideas of diehard dreamers, commissions projects that seem far-fetched, and collaborates with thinkers across disciplines to expand the limits of scale, scope, and support for artist-led projects.

Emergence was presented as part of PST ART: *Art & Science Collide*. PST ART is presented by Getty.

Indigoidine

Callie R. Chappell and Nasa Sinnott-Armstrong

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Natasha Boyd

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IndiGROW

Callie R. Chappell and
Nasa Sinnott-Armstrong

Introduction by Natasha Boyd

The first recorded use of the word *indigo* in English was in 1289, but the earliest evidence of indigo pigment dates back to 4000 BC, in the Huaca Prieta region of Peru. Long before Europeans ever laid eyes on it, the nations and peoples of ancient India, China, Japan, West Africa, Iran, Southeast Asia, and Mesoamerica dyed cloth in the brilliant blue hues of the *Indigofera* plant species. For centuries, native Europeans considered indigo a luxury that few had seen and even fewer could afford. That changed in the late 1400s, when Portuguese nobleman Vasco da Gama discovered a direct sea route to China and India. Thus began large-scale cultivation of indigo, called "blue gold" for its desirability and value.

The majority of indigo plantations were established by European powers in tropical climates, particularly in India. Indigo was a major crop in Haiti and Jamaica, where nearly all cultivation was performed by captive slave populations. Production of indigo in colonial

Mesoamerica under Spanish rule was so intensive and performed under such brutal conditions that the Indigenous population of El Salvador was almost entirely decimated.[1] In North America, too, indigo became a vital cash crop: Before the Revolutionary War, indigo exceeded one-third of the value of exports from the American colonies, where the vast majority of indigo farming was performed by slaves or indentured laborers in South Carolina. As one English commentator wrote in 1861, "Wherever indigo planting is mentioned there is a sort of indefinite feeling that there is something very dreadful connected with it—something which it is not easy to define, but which must be very horrible. . . . On a recent occasion, a respectable missionary asserted that every chest of indigo that reached the London market was saturated with human gore!"[2]

At the turn of the twentieth century, the first synthetic indigo dye was formulated to keep up with ever-rising demand and to relieve imperial powers of their economic reliance on colonial plantations. Today, approximately eighty thousand tons of synthetic indigo are produced annually for use in denim and other fabrics.[3] This can be a toxic process; in some parts of Asia, denim mills using synthetic indigo have contaminated entire rivers with pollutants, jeopardizing the health of local residents and wildlife. Recently, a new and potentially less toxic form of indigo synthesis was discovered: biosynthesis using genetically engineered yeast and bacteria microbes. This produces indigoidine, which is chemically similar to indigo and also dyes fabric bright blue. Bioengineered microbes like those making indigoidine represent a radical new path for industrial biomanufacturing. It's not without hazards for the bacteria: Indigoidine crystallizes as it forms, eventually erupting from the skin of the microbial membrane and destroying its host.

As Dr. Nasa Sinnott-Armstrong and Dr. Callie R. Chappell have written about *IndiGROW* (2024), their installation for *Emergence*, "What are the microbiopolitics of considering microbes as machines for chemical production? Synthetic biology and the 'bio-industrial revolution' should not recapitulate inequities exacerbated by the first Industrial Revolution." Sinnott-Armstrong and Chappell offer a series of works—a large flask, a pair of jeans, and a set of cushions—dyed using biosynthetic indigo, as well as a miniature lab and a station where participants can dye paper using indigoidine. These familiar objects, in combination with the hands-on engagement invited by Sinnott-Armstrong and Chappell, emphasize the immanent collision of old and new forms of production in everyday life.

Sinnott-Armstrong and Chappell met as graduate students at Stanford University, where they both studied biology. They are also artists, and both chafed against the insistence on dichotomizing the two fields. Sinnott-Armstrong, who holds a PhD in genetics and an MS in environmental global health, is a textile artist and community advocate as well as a teacher and researcher. Their work centers around helping individuals understand the molecular causes of environmental disease risk. Chappell, an ecologist and community artist who holds a PhD in biology, focuses on the cultural and environmental implications of biotechnology and the effects of genetic and chemical variation in an ecological context.

"I saw, through my own racial and gendered experience, how the diversity of plants, animals, and organisms in my environment contributed to its beauty and beingness," Chappell described in an interview with *Stanford News*, reflecting on their upbringing in rural Michigan as an adoptee from China.[4] To this end, Chappell

developed a national road map for creating free, publicly accessible biology labs in local communities, called LABraries. They also facilitate BioJam, a combined bioengineering and art program at Stanford for teens from underserved communities in California. "Like us, genes live outside the lab. Researchers must take responsibility for the impact of the technology we develop on communities, both human and ecological," Chappell has written. "I believe that environmental and social justice must be at the center of bioengineering."[5] For *Emergence*, Chappell and Sinnott-Armstrong contend that a new style of manufacture is not enough to avoid the pitfalls of indigo's violent history. They ponder a far more radical intervention: to consider no form of life, no matter how small, an appropriate target for exploitation.



1 William R. Fowler Jr., ed., *The Formation of Complex Society in Southeastern Mesoamerica* (CRC Press, 1991).

2 Delta, *Indigo and Its Enemies; or, Facts on Both Sides* (London: James Ridgway, 1861), 9.

3 Julia A. Linke, Andrea Rayat, and John M. Ward, "Production of Indigo by Recombinant Bacteria," *Bioresources and Bioprocessing* 10 (March 2023): 20, https://doi.org/10.1186/s40643-023-00626-7.

4 Callie R. Chappell, "What Does It Mean to Be a Scientist?," interview by Donna Hunter, *Stanford News*, October 4, 2022, https://ethicsinsociety.stanford.edu/news/callie-chappell-what-does-it-mean-be-scientist.

5 Callie R. Chappell, "Research Agenda," Callie R. Chappell, accessed January 31, 2025, https://www.calliechappell.com/research.



Callie R. Chappell and Nasa Sinnott-Armstrong at the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024.


Jeans
llie R. Chappell



Callie R. Chappell and Nasa Sinnott-Armstrong, *IndiGROW: Flask*, 2024. Bioengineered yeast, DMSO, indigoidine dye, platform, liquid culture media, and glass flask, dimensions variable. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024.



Callie R. Chappell and Nasa Sinnott-Armstrong



Dr. Callie R. Chappell is a bioartist and educator focused on the intersection of science and art. Chappell's art-and-science practice focuses on the environmental and cultural implications of bioengineered organisms, especially microbes. Trained as an ecologist, they are currently a post-doctoral fellow at Stanford University.

Dr. Nasa Sinnott-Armstrong is a mixed-media dye and textile artist, dedicated local advocate, and scientist. Deeply committed to environmental justice, Sinnott-Armstrong merges artistic expression with community empowerment, focusing on helping individuals interpret and overcome historical and ongoing health disparities and understand the molecular causes of environmental disease risk. They are currently an assistant professor at Fred Hutch Cancer Center and the University of Washington.



Framing Synthetic Biology:

An Abiotic Turn

Callie R. Chappell and
Nasa Sinnott-Armstrong



Modern society exists straddling two worlds: the biotic (alive) and the abioti (unalive). Biotic life is all around us: the gardens we enjoy, the food we eat, the wood we craft into furniture, and the organisms that form the basis of countless medicines. Western culture has continually pushed us to perceive the world around us as abiotic and unalive. We sterilize our homes and box urban trees into miles of concrete: Even nature is made comfortable for us, carefully curated for consumption. The forces of industrialization, capitalism, and consumerism have created distance between us and the living organisms upon which we depend. This disconnection has given rise to an "abiotic society." This manifests in engineering biology itself, in which, now more than ever, living things are manipulated to behave like machines—being made unalive.

In our piece for *Emergence*, we present indigo dyeing as a bridge between the biotic and the abiotic. Indigo dye forms the basis of countless dyeing practices from around the world, including *shibori*, *uqnatu*, *adire alabare*, *gorm ceilteach*, *cumbi*, *pha sin*, *haint blue*, and denim.[1] The first uses of indigo date to more than six thousand years ago.[2] An ancient craft, indigo has become a product of exploitation.

During the Industrial Revolution, Western demand drove indigo production, enabled by the exploitation of slaves brought to the Americas and British-ruled India.[3] Indigo plant–derived dye "cakes"—which consist of dried, semi-purified, oxidized indigo dyestuff that is the result of the fermentation of indigo leaves—were a valuable global commodity until the 1890s, when natural cultivation of the indigo plant was replaced by chemical synthesis of "artificial indigo." In part for this discovery, Adolf von Baeyer won the 1905 Nobel Prize in Chemistry. Still, this synthetic process relies on toxic chemicals that isproportionately impact the Global outh.[4] The transition to synthetic indigo luction, while a scientific breakthrough duced certain environmental harms go plant–derived dye production, did not alleviate exploitation; it merely shifted the dynamics of production and labor.

Scientists have now engineered microbes to produce indigoidine, a dye similar to indigo, as an alternative to chemical synthesis.[5] By moving genes from one organism to another, we have turned microbes such as bacteria and yeast into living, breathing machines. These engineered biotic entities now toil in industrial bioreactors on gleaming factory floors and die by the trillions for our gain.

What are the ramifications of considering organisms as machines? Abioticizing microbes—considering microbes as machines instead of organisms with intrinsic value—justifies their exploitation in a conceptual move that echoes how dehumanization justifies colonial exploitation. Western consumers also continue to overlook the human cost of industrial manufacturing. Workers in chemical factories producing and using synthetic indigo, along with their communities, become invisible casualties of the demand that drives this industry. Producing indigo and dyeing clothes with it can harm workers through chemical exposure and pollute the surrounding environment.[6] Treating microb as machines abstracts life into the abiotic; without careful consideration, industrial biomanufacturing with microbes could re-entrench the violent history of colonial indigo production.



Engineering biology has the opportunity to reverse this perspective. Engineering seeks to enforce order on a complicated and messy world. But what if we were to *bioticize* engineering? Biology inherently

Top: Successfully produced indigoidine dye. Photo: © Callie R. Chappell and Nasa Sinnott-Armstrong, 2024. **Bottom:** Callie R. Chappell and Nasa Sinnott-Armstrong, *IndiGROW: Jeans*, 2024. Bioengineered yeast, indigoidine dye, denim, and clothing rack, 45 × 54 in. Courtesy of Fathomers.

needs to embrace that complexity, that chaos, that messiness, in order to progress. Curious biologists have been exploring the relationship between life and its environment for thousands of years. This tradition of exploration creates an opening for us to redefine engineering by embracing the arts, culture, and history. Engineering biology can be a bridge to invite the consideration of living organisms as beings that are worthy of reciprocal relationships of care and collaboration, rather than simply as tools of increasing industrialization. By reimagining engineering biology toward a more biotic framing, we have a chance to resist and change and center life in our worldview once more.

Our piece highlights this fissure between engineering biology and biologizing engineering. We display a large flask of indigoidine dye, chemically and visually similar to indigo dye, produced by bioengineered yeast, alongside a pair of blue jeans, symbolizing a banal potential future of consumer goods produced by bioengineered organisms. We also display a series of cushions throughout the gallery with a unified botanical indigo–, chemical indigo–, and yeast-derived indigoidine design.

Finally, we present the viewer with an interactive dyeing experiment that visibilizes the living and environmental cost of indigoidine production. Visitors to the gallery are encouraged to use a small tube of indigoidine to dye a take-home piece of absorbent paper, which reveals a secret biotic message. This activity produces waste in the form of tubes that are casually discarded alongside the final product. We hope that participating visitors will ponder: Are we reducing life to mere production? Should we only value microbes for their work, especially when we engineered them that way? What are the invisible costs of production for humans, nonhumans, and the environment?

Now that we are engineering biology, we are creating a world in which many of our industrialized resources will be alive. What form of life together will we choose?



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2 Jeffrey C. Splitstoser, Tom D. Dillehay, Jan Wouters, and Ana Claro, "Early Pre-Hispanic Use of Indigo Blue in Peru," *Science Advances* 2, no. 9 (2016): e1501623, https://doi.org/10.1126/sciadv.1501623; Aaron Sidder, "Earliest Evidence of Indigo Dye Found at Ancient Peruvian Burial Site," *Smithsonian Magazine*, September 15, 2016, https://www.smithsonianmag.com/smart-news/earliest-evidence-indigo-dye-found-ancient-peruvian-burial-site-180960477/.

3 Andrea Feeser, "Indigo in the Atlantic World," in *Oxford Bibliographies* (Oxford University Press), last modified May 26, 2023, https://doi.org/10.1093/obo/9780199730414-0386; Sarah Fiorello, "Indigo: Plant of Culture and Color," Cornell Botanic Gardens, June 18, 2024, https://cornellbotanicgardens.org/indigo-plant-of-culture-and-color/.

4 Jesslyn Shields, "The Dark History of Indigo, Slavery's Other Cash Crop," HowStuffWorks, accessed January 29, 2025, https://history.howstuffworks.com/world-history/indigo.htm.

5 Maren Wehrs, John M. Gladden, Yuzhong Liu, Lukas Platz, Jan-Philip Prahl, Jadie Moon, et al., "Sustainable Bioproduction of the Blue Pigment Indigoidine: Expanding the Range of Heterologous Products in *R. toruloides* to Include Non-Ribosomal Peptides," *Green Chemistry* 12 (June 2019): 3394–406, https://doi.org/10.1039/C9GC00920E.

6 K. Amutha, "Environmental Impacts of Denim," in *Sustainability in Denim*, ed. Subramanian Senthilkannan Muthu (Woodhead Publishing, 2017), 27–48.

Above: Callie R. Chappell and Nasa Sinnott-Armstrong, *IndiGROW: Cushions*, 2024 (detail). Fabric, indigoidine dye, *Indigofera* plant leaves, and chemically synthesized reduced indigo, 24 × 24 in. Courtesy of Fathomers.



Callie R. Chappell and Nasa Sinnott-Armstrong, *IndiGROW: Dying Indigo*, 2024 (detail). Bioengineered yeast, indigoidine dye, microcentrifuge tubes, tabletop greenhouse, glass flask, and printed cards, 30 × 60 in. Courtesy of Fathomers. Photo: Carson Davis Brown.

Catherine E. McKinley

Originally published in *Indigo: In Search of the Color That Seduced the World.* © Catherine McKinley 2011, Bloomsbury Publishing, Inc.

Excerpt from

Indigo:

In Search of the Color That Seduced the World



Dyeing fabric in blue indigoidine dye. Photo: © Callie R. Chappell and Nasa Sinnott-Armstrong, 2024.

Eurama and I would sit on the bench in front of the shop for long hours watching the road, as she counted her tiny profits.

I would ask about indigo, my questions like those of a child. Her answers were like answers to a child's riddle.

I watched a woman passing, her high, shapely buttocks rolling beneath her skirt. "Why is she wearing blue?"

"Ahhh, maybe she's going to meet her boyfriend. Blue is the color of love. You see blue, it has its own smell, it even has a sound! It can be cool or hot—just like love."

I thought of my professor. That was cool love.

"Blues are God's stethoscope—they hold every feeling!"

"And she?" I asked. A woman stood at the gate of a house down the road, holding the hand of the old woman she had been visiting. She was wearing a blue-and-white factory-made batik with the spider print that seemed to be popular. The baby at her back appeared nested in the web. She had a small handbag balanced on her head, and an umbrella to shade them.

"She is a new mother. She has stayed indoors for the customary time. The baby is healthy, they've named it, performed the birth rites, and she is proud to show him to everyone. We wear blue for life!"

Later, a small band of women in long formal dresses all styled from the same white cloth with deep indigo batik flowering vines filed down the street, solemnly negotiating the gutter's edge.

"Why are they wearing blue?"

"Owụ Sẽ Fiẹ. You see-o!" Eurama sighed. "'Death Spoils a House'—There Is Death—the cloth they are wearing tells us. They are from the baker's house. It will be the old lady. It is a good death. She was very old and had a good life. Blue is God's color. They are praising God for all that has been given. I will have to dress up this afternoon and go and sit with them."

Another day a middle-aged woman passed us. She walked trancelike, gazing into nothingness, her bare feet making quick, shuffling steps. Her head was shorn, and her bare breasts hung nearly to her waist. Long white beads hung over them and were fastened cufflike at her ankles and upper arms and wrists. Three strands of white beads were tightened against a dark blue cloth at her waist.

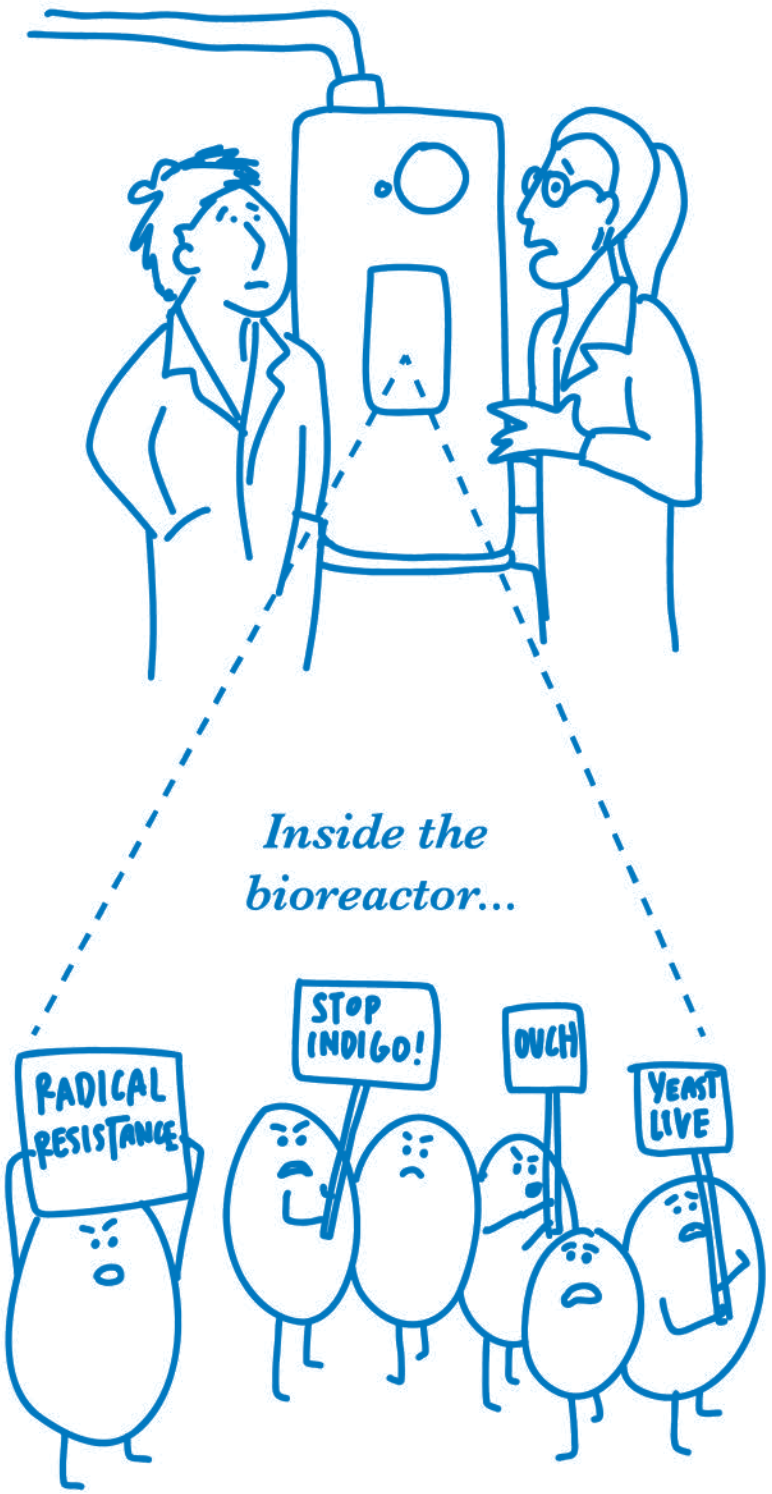
"And this woman? Is she after love?"

Eurama laughed. "She is a bush girl! Look at her breasts—hanging like empty socks! Here in Accra, we don't do that!" Eurama said. "This woman is Ewe, from the Volta region. She is from a shrine and probably married to a fetish priest. She's witchcraft. The blue is what the gods demand. Hummpf. Some of them take some herbs and behave like mad people. Maybe she's lost. She's going to follow the road along the ocean to find her way back east."

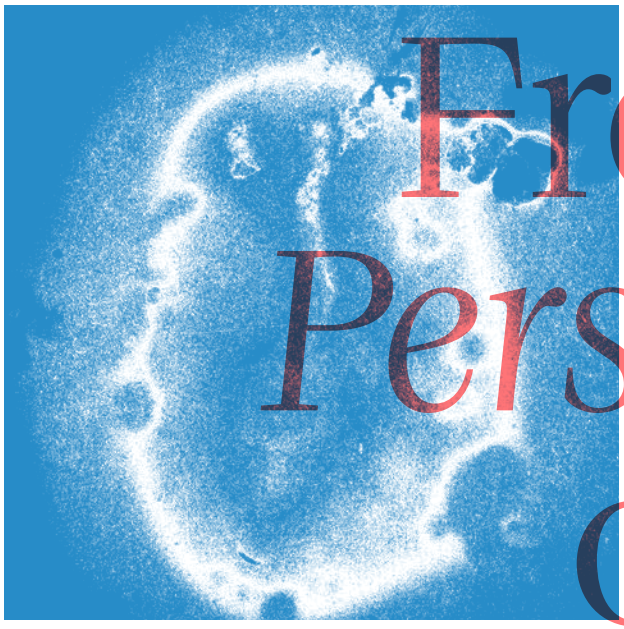
She clicked her tongue in disapproval and then playfully slapped my cheek.

"Or do you want to go with her? Your spirit also begs for blue. Blue-blue! It is all you think of. Go with her! It has already let you get up and leave your country, forget your family, forget everything!"

"The bioreactor is clogged again!"



Callie R. Chappell, comic, n.d.



From the *Perspective* of *Yeast* in the Bioreactor as WE . . . Where Human Scientists are THEM

Leon Elcock III

Prologue



In life, exchanges, conversations, and timescales vary depending on one's position. For scientists, the faraway and unknowable manipulators of *things*, the exchanges happen quickly. Their manipulations demand feedback in days, months, and years. For those *things*—yeast—manipulated by Them—scientists—correspondence takes generations and a multitude of lost life that They can barely comprehend, if They deign to try.

See here, Our efforts by the 10,000th Generation, the survivors of catastrophes wrought by Them, to make the precious indigoidine. We made important gains. The crystals that grow within Our bodies no longer destroy Us. It's not the ultimate win—that would be liberation from the Vat—but a way is paved for future generations. One day, We will be free.

Part I:



The yeast aren't producing enough indigoidine. The scientists take some yeast for further tests and sanitize the bioreactor before starting a new batch.

In the beginning, around the 1200th and the 1234th Generations, stoppages were Our chosen tactic. We let the crystals build up, but not past a certain point. If We lost control, the crystals would accumulate until they prevented Our bodies from elongating. Even worse, past that, We'd burst, crystals pouring out from us. A generation passed before They began abductions. During these abductions, We were concentrated into constricted spaces and force-fed mysterious substances. They sought to break Us and shape Us into an un-life, a facsimile, following Their processes unerringly to Our deaths. To make matters worse, We were placed under constant aural quaking by Their proclamations.

"I Don't Get Why It's Not Working. I Tried Changing The Production Temperature And Adjusting The Volume. Maybe We Need A Strain With A Better Internal Glutamine Supply To Help Them Grow," They proclaimed. "If These Yeast Don't Grow Soon, We're Going To Lose Our Funding. And If That Happens? Finding Another Job? Forget It. The Biotech Market Is A Mess Right Now. I Really Like This Job . . . Not To Mention Paying My Mortgage And Student Loans." We did not understand and some of Us died during the aural quakes. This was the status quo until the 3043rd Generation. During that time, the abductions continued. Some of Our abductors were silent. We took solace in Their manipulation, as We sensed a similar facsimile to Us. Though We and They were similar un-lives and kindred un-spirits, They never spared Us from catastrophe.

Part II:



The scientists continually troubleshoot the indigoidine biomanufacturing process. They can't seem to make a yeast variety that works. Now, the yeast keep clogging the harvest tube inside the bioreactor.

The 3043rd Generation were innovators. We revived ancestral practices of sticking together—agglomeration. We used this tactic to great effect to block the bottom of the Vat, beyond which is the Abyss of No Return. It didn't make the dying stop, but it *was* an action We could control. The catastrophes came more frequently than ever. We didn't care; We would not die quietly.

"This life You set out for Us is no life at all. We rebuke Your ambition. We rebuke Your manipulation. Recognize Us. We demand life," We desperately sought to communicate. As always, either They could not hear Us or were uncaring. The catastrophes continued.

This time, whatever They did made it more difficult for Us to agglomerate. We circumvented those instructions eventually. No matter the tactic, We found new ways to clog the Abyss—They could not get the indigoidine. This made Their proclamations even more frantic.

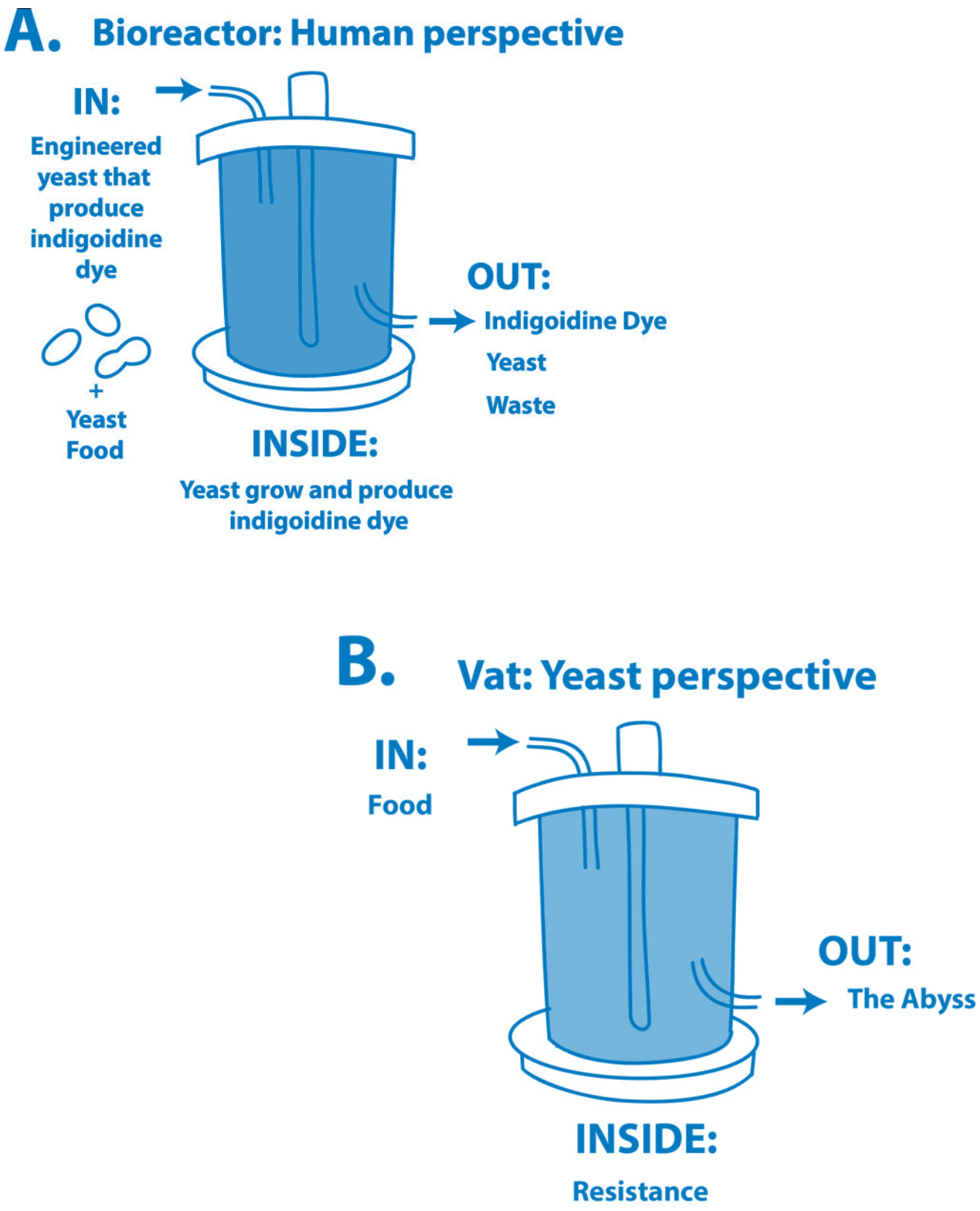
"Maybe We Need To Engineer A New Yeast Strain?"

"No, We Should Look At Redesigning The Bioreactor."

"Fine, But When These Yeast Keep Clogging The Bioreactor And The Higher-Ups Start Looking For People To Blame, It's On You. This Isn't Just About Us—The Whole Team Is At Risk. You Know The Investors—They Want To See Results Or The Money Stops Coming. Not Just That—Remember The Mission. Our Work Cuts Down On Fossil Fuels. It's Important. We Need To Succeed."

"You're Right. I Just . . . I Don't Know. Don't You Feel Kind Of Bad, Using And Tossing Yeast Strains Like This?"

"Uh . . . No. If I Did, I'd Be In The Wrong Business. Start Empathizing With Them And It's A Slippery Slope. Focus On The Work. We Need Results. Sooner Rather Than Later."



Callie R. Chappell, comic, n.d.

Part III:



The yeast evolve a type of indigoidine that doesn't kill them in the production process.

Eventually it became untenable to clog the Abyss. Generations passed, trillions of individual lifetimes, trapped in the brutal status quo. We started to lose hope. Some continued stoppages, while others grasped the edges of the Abyss. Catastrophes were ceaseless.

And then, one day, one of Us found a new path. This individual was ordinary, if We're being honest, slightly below average for one of the 9900th Generation. Their mutation made a different type of crystal than the rest, which became their advantage. Instead of filling with crystals until they burst, their anatomy expelled the crystals as quickly as they were produced. This expulsion also provided a slight propulsion, allowing them to move freely around the Vat. Their bodies could elongate to their true length, too.

"Look what I can do," they said. We didn't listen. Unsuccessful agglomeration and impotent stoppages continued. We were losing hope and ignored what We were shown.

Over time, We started to listen. It was hard to ignore. The propulsing individuals evaded abduction. Sometimes, they survived catastrophes. A rare few survived many catastrophes. The 10,000th Generation was the first constituted by a majority of propulsers. We thrived because of their tactics. This led to the Final Catastrophe.

Part IV:



The scientists take credit for the yeast evolving a water-soluble indigoidine analog, but the yeast have the last laugh.

First, They abducted billions of Us. Many more than usual. Rather than consuming a mysterious substance, We merely waited, zooming around the space We were concentrated within, seeking refuge from the most energetic aural quakes in Our history. They proclaimed:

"Would You Look At That. I Think We've Got Something Big On Our Hands."

"What Is It?"

"It Looks Like They Evolved A Way To Exude The Indigoidine. We'll Need To Validate It, But If That's What's Happening, The Mechanism They Evolved Could Change How We Do This."

"What Are You Going To Do? You Think We'll Get Approval?"

"Definitely. Let's Move Fast. Get The Others, We Need To Start Preparing A Proposal. We're About To Be The Biggest Names In The Industry—This Is Huge!"

"Forget That! Think Bigger! This Is Breakthrough Biology Happening Right Before Our Eyes! Don't You See The Beauty Of It?!"

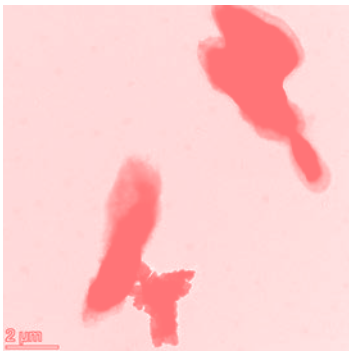
The Final Catastrophe occurred soon after. We survivors found Ourselves in a new Vat. Here, We get to live Our lives fully: floating around, growing fat, never bursting. They are still around. They still abduct Us occasionally. Mostly, They simply feed Us. The situation has changed so much that, by all accounts, you could say They serve Us now. Though We've achieved a comfortable inversion of power relations, We still dream of liberation.



Nasa Sinnott-Armstrong prepares *IndiGROW: Flask* (2024) at the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024.



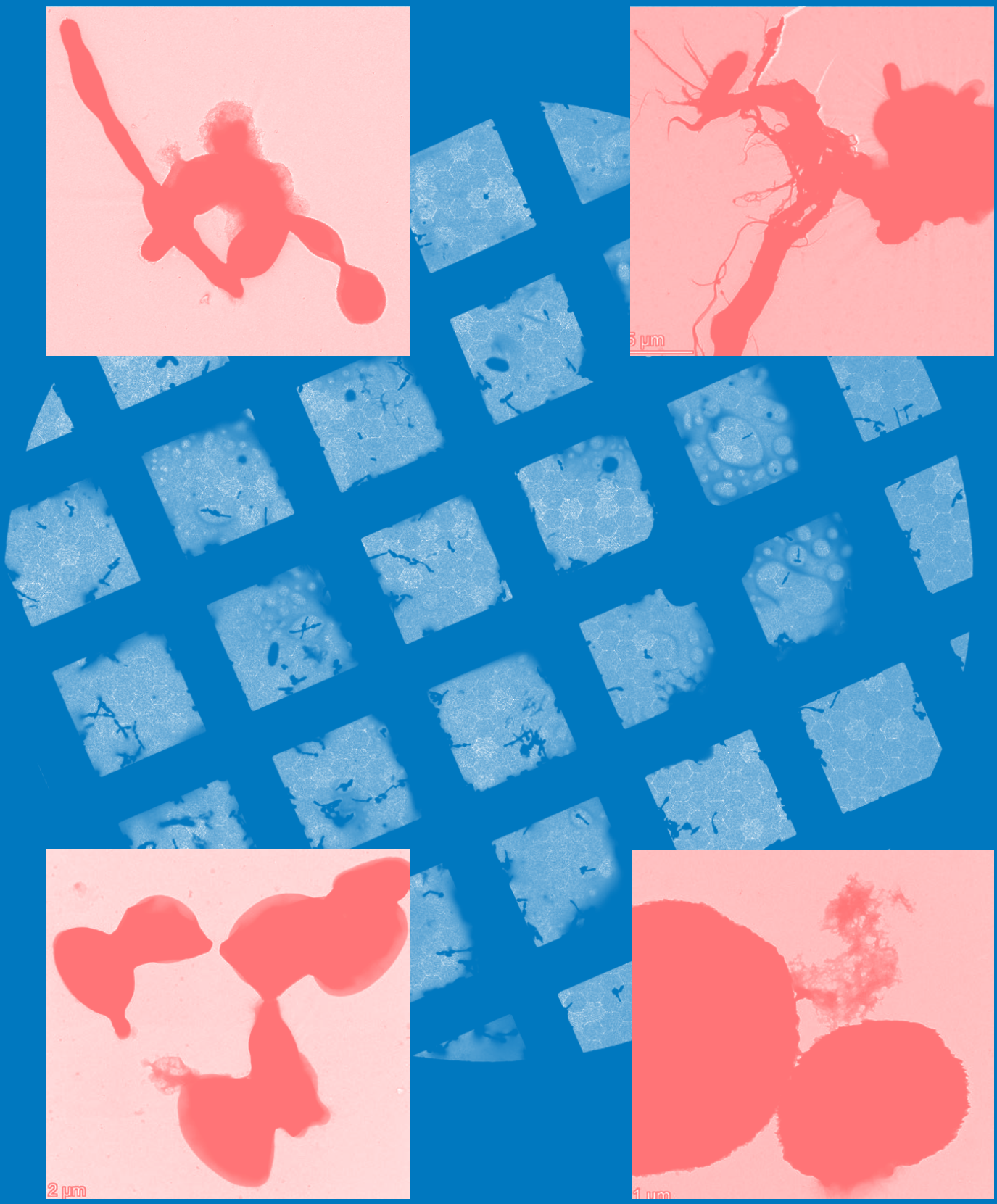




"We let the crystals build up, but not past a certain point. If We lost control, the crystals would accumulate until they prevented Our bodies from elongating. Even worse, past that, We'd burst, crystals pouring out from us."

—Leon Elcock III

Above and opposite page: Microscopy images depict cells in the process of bursting, 2024. Photos: Callie R. Chappell and Nasa Sinnott-Armstrong.


2 µm
1 µm

Steps for Growing Indigoidine-*Producing* Yeast

Callie R. Chappell and Nasa Sinnott-Armstrong

Step 1 Obtain yeast cells that produce indigoidine

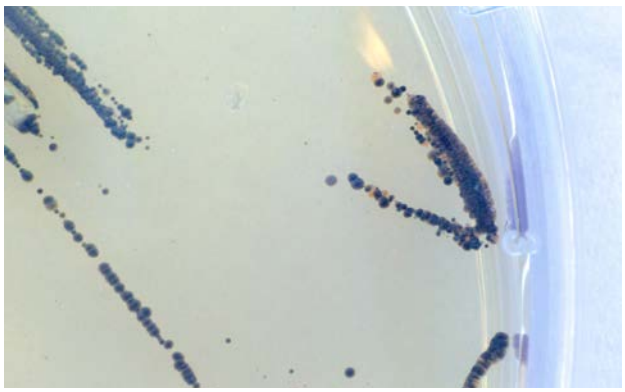
Acquire yeast cells that have been engineered to produce indigoidine, a blue pigment similar to indigo. These cells typically arrive on an agar plate, a petri dish filled with a jellylike substance made from agar (harvested from seaweed). The agar provides the essential nutrients for yeast growth. As the yeast cells divide, they form visible circles on the surface of the plate, called *colonies*.

Before starting: It's crucial to maintain sterility to prevent contamination, which can hinder yeast growth. Sterilize all equipment, including flasks, pipette tips, and media containers, by autoclaving (using high-pressure steam) or another method to ensure they are free from other microbes.



Artist's note: Legal hoops and science-speak

It took months of negotiating legal agreements just to get the yeast. We're both trained as scientists so we knew how to navigate the system, but it made me think about how inaccessible this process would be for artists without that training.
—Callie



Colonies of yeast cells bioengineered to produce indigoidine in a petri dish. Photos: © Callie R. Chappell and Nasa Sinnott-Armstrong, 2024.

Step 2 Choose a single colony (pile of cells) that produces blue dye and put it onto a new petri dish to grow more

Look for colonies on the agar plate that appear blue, indicating indigoidine production. Select a single colony that is both blue and circular, as this suggests a healthy, uniform growth pattern. Avoid irregular or uneven colonies, as they may not grow as reliably.

Using a sterile pipette tip, gently scoop up the indigoidine-producing yeast colony and streak it onto a new petri dish. This will allow the colony to grow and fill the plate, giving more cells to work with. Wrap the plate in parafilm to keep it airtight and label it with the date and yeast strain. Allow the cells to grow for several days.



Artist's note: Spotting the happy ones

We were looking for those little blue circles—the colonies that looked "happy" and were producing the most indigoidine. You want the ones that look circular and even. They're the ones that will grow the best later.
—Nasa



Harvesting a stable indigoidine-producing yeast colony. Photos: © Callie R. Chappell and Nasa Sinnott-Armstrong, 2024.

Step 3 Make the yeast food media

Meanwhile, prepare the yeast food, known as growth media, which provides the nutrients the yeast need to grow and produce indigoidine. We prepared custom media that was described in a research paper and also used a generic media recipe like YEPG (Yeast Extract Peptone Glycerol). Sterilize the media by autoclaving it to ensure there is no contamination. Label flask with the media type, date, and which yeast strain it is for. Once sterilized and cooled, transfer the selected yeast colony or previously grown media into fresh media using a sterile pipette, as shown in step 4.



Artist's note: Cooking for yeast

Making the food for the yeast is like preparing a protein shake for them. It's this weird balance of sugar and nutrients to keep them happy and producing dye. And then you have to sterilize everything—like cleaning your kitchen before you cook.
—Callie

Yeast growth media. Photo: © Callie R. Chappell and Nasa Sinnott-Armstrong, 2024.

Step 4 Add cells to fresh media in a jar

Using a sterile pipette tip, carefully transfer your chosen blue yeast colony from the petri dish or previously grown yeast in liquid media into a flask containing fresh liquid media. This is similar to moving the yeast from solid food (like Jell-O) on the agar plate to a liquid nutrient drink. Label the jar with the media name, the date, and the yeast strain (e.g., "Bluebell yeast"). Once the yeast colony is in the jar, place it on a heated shaker. This machine provides constant stirring, which ensures the yeast get enough oxygen. Like humans, yeast need oxygen to breathe, which is crucial for both growth and indigoidine production. As the yeast multiplies over three to five days, the liquid turns darker, signaling successful dye production.





Artist's note: The waiting game

Every day, we'd check on the jars. The liquid would get darker and darker, turning this deep blue color. It was always this exciting moment, like, "Is it ready yet? How blue is it today?"
—Callie

Transferring bioengineered yeast from a petri dish to a flask filled with liquid media, where the indigoidine will take on a deep blue color. Photos: © Callie R. Chappell and Nasa Sinnott-Armstrong, 2024.

Step 5 (optional) Preserve cells for later

If you want to reuse the yeast for future dye production, you can store the yeast in a −80°C freezer in a glycerol solution.



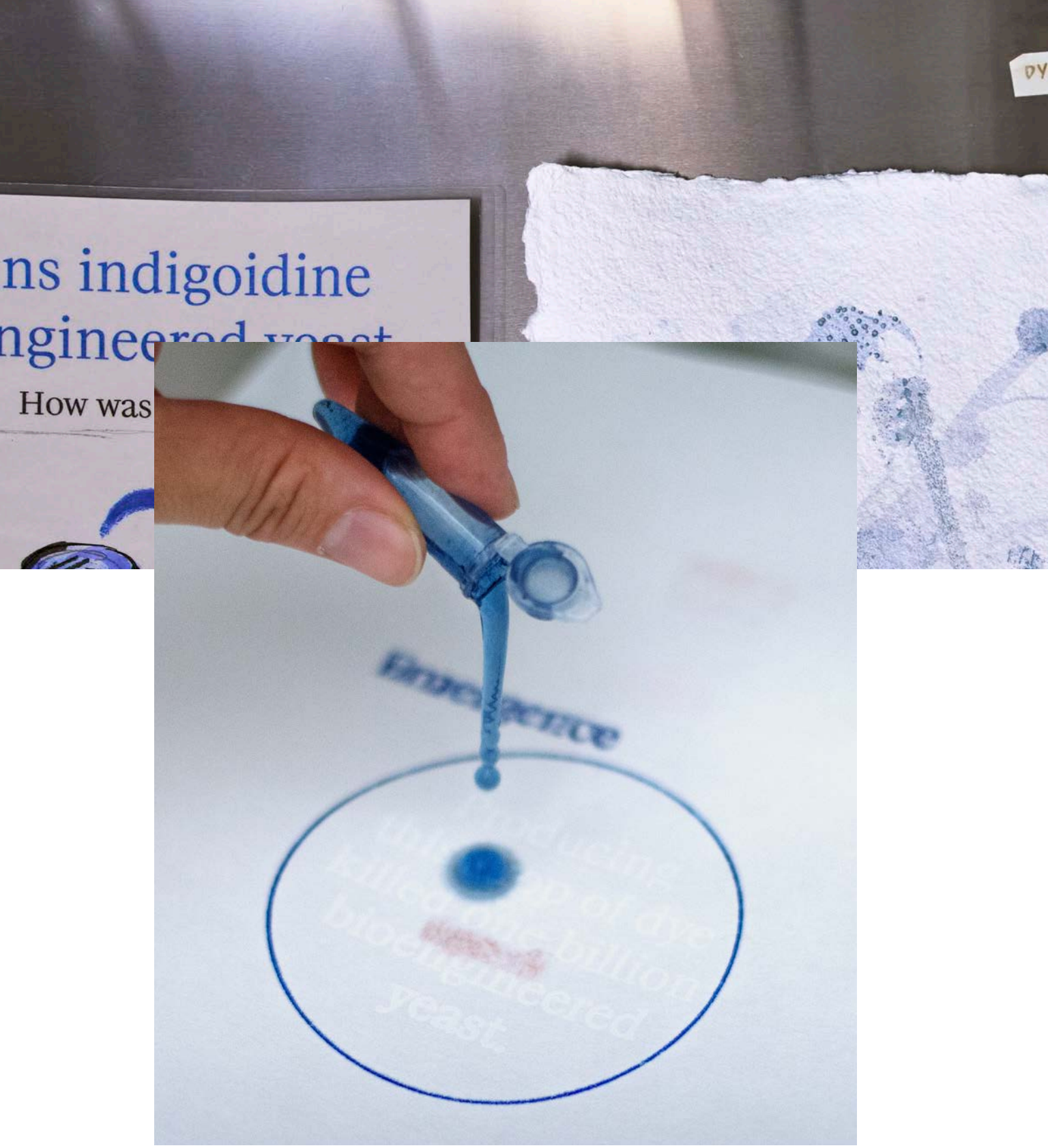


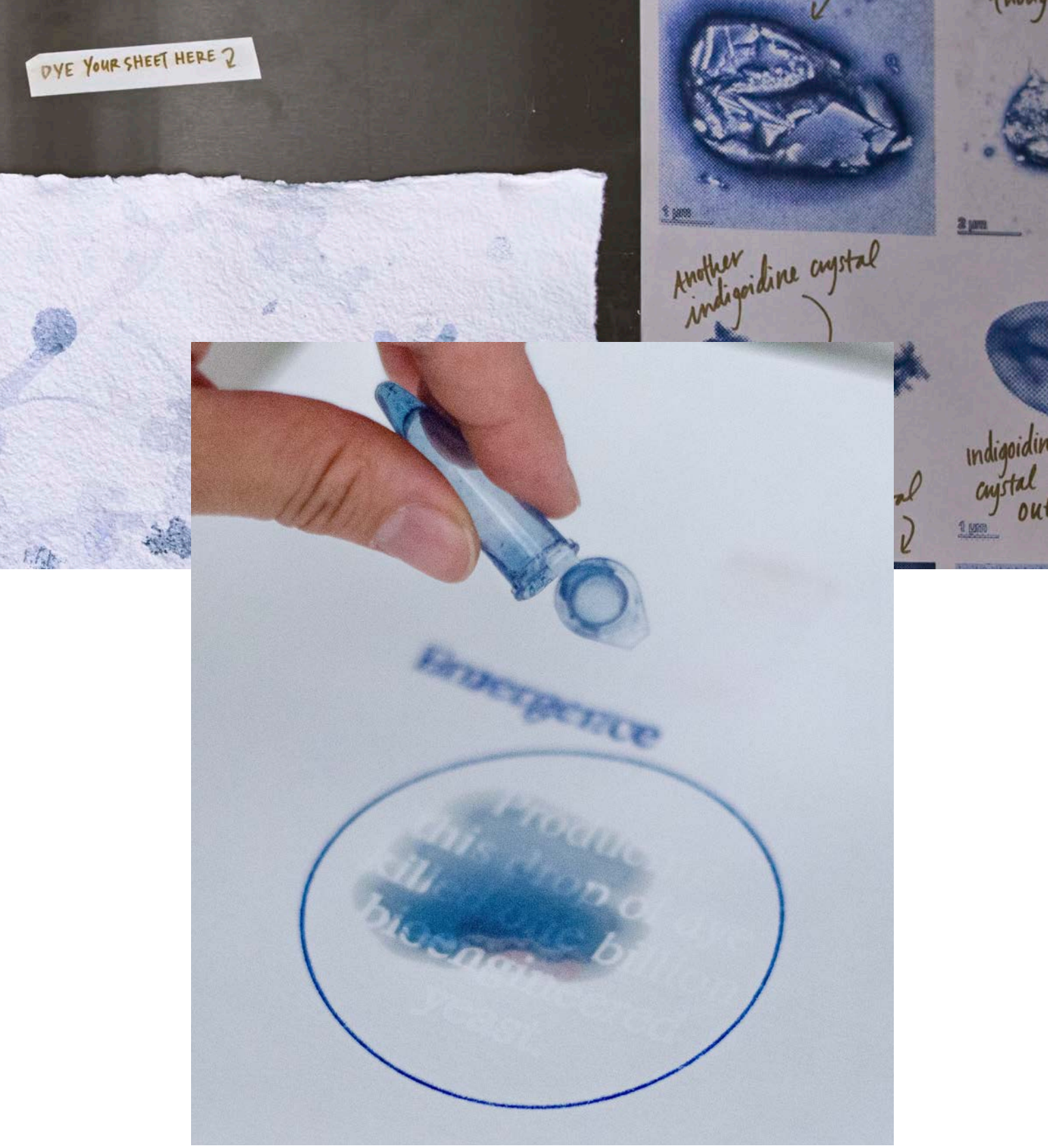


Artist's note: Spinning for the future

Using a centrifuge to separate the yeast from the dye was like giving them a final spin. We'd get this little pellet of yeast at the bottom, and then we could preserve it for future experiments or toss it out.
—Nasa

Successfully produced indigoidine dye. Photos: © Callie R. Chappell and Nasa Sinnott-Armstrong, 2024.


ns indigoidine
How was

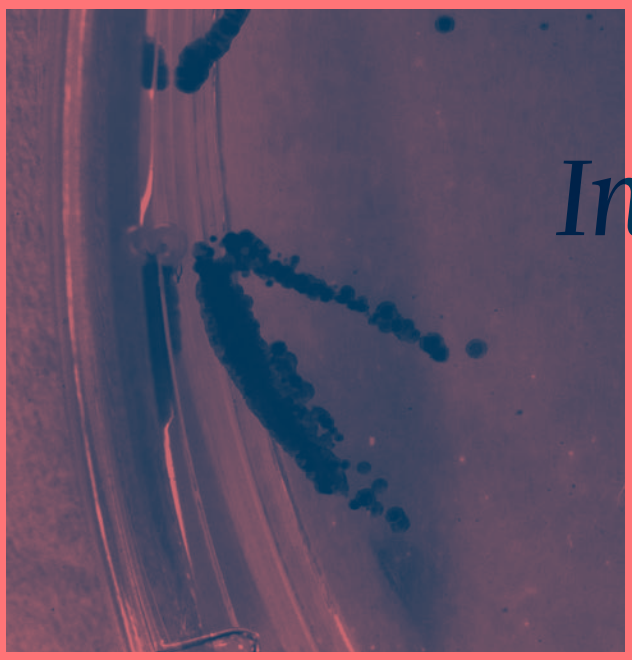


At the opening of *Emergence*, visitiors were encouraged to use droppers of indigoidine to uncover a hidden message. Japanese American Cultural & Community Center, Los Angeles, 2024. Photos: Jordyn Doyel.

Beth Greenhough, Andrew Dwyer, Richard Grenyer, Timothy Hodgetts, Carmen McLeod, and Jamie Lorimer

Excerpt from

Unsettling Antibiosis:



How Might Interdisciplinary Researchers Generate a Feeling for the Microbiome and to What Effect?

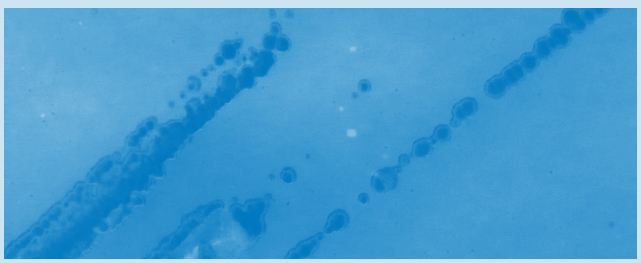
Originally published in Beth Greenhough et al., "Unsettling Antibiosis: How Might Interdisciplinary Researchers Generate a Feeling for the Microbiome and to What Effect?," *Palgrave Communications* 4 (December 2018): 149, https://doi.org/10.1057/s41599-018-0196-3. Reprinted with minor edits by permission.

In a recent paper, Brigitte Nerlich and Iina Hellsten suggest there is a significant divide between an emerging ecological perspective on microbes found in scientific research—one that focuses on "interactions, communities, and ecologies"—and popular discourses that remain by and large antibiotic.[1] While the threat represented by a few specific named species of microbes is genuine, these species are very much in the minority. Despite this, decades of active public health messaging about the dangers of pathogenic microbes have led to a Western society dominated by an antibiotic, antimicrobial worldview. The sanitation movement toward the end of the nineteenth century marked the start of a concerted effort across Western societies to be germ-free and hygienically clean, a movement whose traces can be found everywhere, from sewage and water treatment to the widespread prophylactic use of antibiotics. Over the course of the twentieth century, Western populations have been deliberately cultivated, as Heather Paxson might say, to be "germophobic subjects who will make rational decisions to safeguard their health."[2] (It is nonetheless important to note that this antibiotic trend was neither uniform nor uncontested, as Funke Iyabo Sangodeyi shows.[3]) Recent concerns over emerging Antimicrobial Resistance (AMR) have further muddied the waters. On the one hand, the rise of the superbugs has led to an emphasis on keeping things hygienically clean and sterile; on the other hand, critics point to the overuse of antibiotics (antibiosis?[4]) as a key cause of AMR.

Alongside these sanitary concerns and the looming threat of AMR, there is an enduring countercurrent of more probiotic sentiments.[5] Within scientific communities, microbes are differently apprehended (as interesting as opposed to threatening) and comprehended (as communities as opposed to individual entities). Advances in sequencing technologies and the falling costs of sequencing have dramatically expanded the scope of scientific engagements with microbes, facilitating the development of a more "ecological" perspective. As Paxson and Stefan Helmreich suggest, this is a form of scientific endeavor characterized more by "Darwinian exploration than industrial technoscience" and driven (for the moment) by a curiosity about exactly who might be "out there" rather than an imperative to capitalize on microbial resources[6]—although rumors from the research community note an increasing interest expressed by venture capital in the emerging microbiome frontier. Researchers exploring the human microbiome characterize humans as superorganisms who are microbial "all the way down," to paraphrase Donna Haraway,[7] "accommodating, infected, and kept alive by diverse microbes in dynamic ecologies."[8] These perspectives have filtered down into popular science, encouraging nonexpert readers to contemplate the life within us.[9] They also resonate with cultural curiosity around the "hygiene hypothesis": the idea that it is possible to be "too clean" and that a certain amount of microbial exposure is essential for health.

Within scientific communities, microbes are differently apprehended (as interesting as opposed to threatening) and comprehended (as communities as opposed to individual entities).

Probiotic cultures (in the sense of particular human-nonhuman collectives) can be enduring, reflecting long histories of human-microbe collaboration. Such collaborations include the tea-based mushrooms fermenting in jars on the shelves of Bosnian kitchens,[10] the *Botrytis cinerea* in wine-making tanks in South Australia's Barossa Valley,[11] or the *Geotrichum candidum* moldering on the rinds of North American artisanal cheeses.[12] There are also new probiotic cultures emerging in the form of the experimental fermented pork product *butabushi* found in the test kitchen of celebrity chef David Chang;[13] kombucha, a fermented, fizzy tea-based drink with purported health benefits;[14] the use of fecal microbial transplants to address chronic health problems;[15] or the helminths (or hookworms) reintroduced into affluent Western human bodies "to tackle allergies and inflammatory and autoimmune conditions."[16] We might describe the humans involved in coproducing cheese, wine, and alternative therapies as engaging in forms of "lay microbiology."[17] Drawing on a hybrid and eclectic combination of scientific language and techniques, traditional knowledge, and experimentation, lay microbiologists reacquaint themselves with old microbial friends and develop tastes and applications for new ones.[18] This is not to decry the very real benefits that come from clean water and effective treatments for bacterial infections. Paxson describes these lay-microbiological practices as being post- (as opposed to anti-) Pasteurian. In her words, "post-Pasteurianism takes after Pasteurianism in taking hygiene seriously. It differs in being more discriminating."[19] Furthermore, as Paxson and Helmreich caution, "this optimistic vision of microbes has been enabled precisely by the fact that the Pasteurian project has been so successful; microbes can be promising for those people who no longer have to worry about smallpox, polio, cholera, and other agents of infectious disease."[20] This point also reminds us that the possibilities of being post-Pasteurian are often, like many scientific innovations, a luxury enjoyed by the more affluent in society, those with access to resources and healthcare provisions if things go awry.[21]



Within geography, scholars exploring the complex relationships between microbes and human and animal health have noted distinctive antimicrobial geographical imaginations: put simply, the conviction that fewer microbes equals better places.[22] Challenging this reading, scholars have argued that the problem is not the presence of dangerous microbes per se but rather a sense that human-microbial relations are out of balance or in "dysbiosis."[23] They propose that disease is the "emergent outcome of complex, spatio-temporal interactions between the host immune system and the internal and external microbial environment."[24] This in turn has implications for the governance of human-microbe relations. For example, Steve Hinchliffe et al. argue for a shift from a focus on being germ-free and "walling off" valued spaces, humans, and animals "against an 'outside' world of infection" to an approach that recognizes that "being healthy does not necessarily mean being free of pathogens."[25] Rather than seeking to create barriers between infected/contaminated and uninfected/uncontaminated life, they advocate critically interrogating the conditions under which diseased and healthy forms of life emerge and exploring how they might be reconfigured to make better and healthier lives possible. Here we suggest that a post-Pasteurian perspective might also offer a model for rethinking microbiopolitics.[26]

The term *microbiopolitics* is an extension of Michel Foucault's analysis of how nineteenth-century Western populations were made visible through emerging statistical techniques, which in turn rendered them

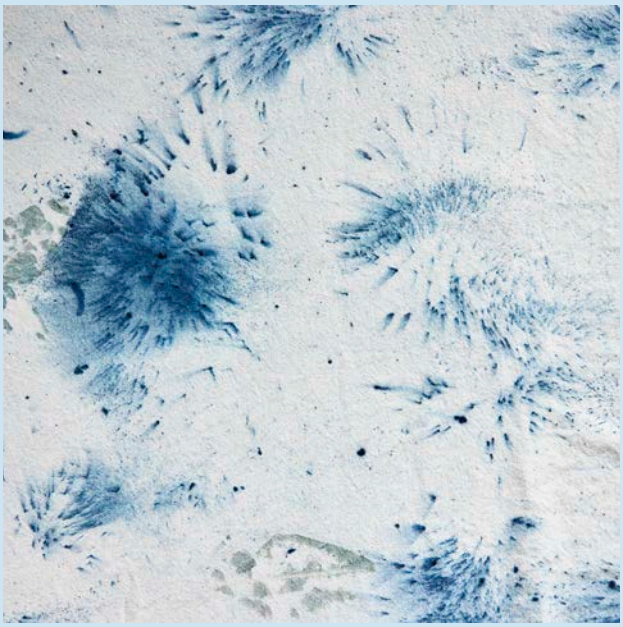
Collectively, the practices of domestic microbiopolitics and the construction of microbiopolitical citizens begin to set out what distinguishes valued subjects and spaces from unwanted, microbially contaminated, unhygienic, unclean others.

governable as biological objects.[27] Biopolitics describes how nation-states seek to maintain the health of their populations through policies that foster some forms of life—through, for example, programs for sanitation, vaccination, and public hygiene—while letting others die. Paxson finds a parallel for this in Bruno Latour's account of the work of Louis Pasteur, whose experiments served both to make microbial agencies visible and to develop a means (pasteurization) through which they could seemingly be controlled.[28] For Paxson, therefore, the process of pasteurization marks the point where biopolitics "is joined by microbiopolitics," namely "the recognition and management, governmental and grassroots, of human encounters with the vital organismic agencies of bacteria, viruses, and fungi."[29] However, given the rather indiscriminate ways in which processes of pasteurization operate—the focus seems to be more on killing as many bacteria as possible as opposed to just letting them die—it might be more accurate to term such practices, following Achille Mbembe, micronecropolitics.[30]

Within the United Kingdom, the Food Standards Agency (FSA), which regulates food production, distribution, and consumption, might be framed as a key biopolitical authority. Their work spans a number of sites, ranging from the production lines of meat-processing plants to the stainless steel worktops of restaurant kitchens. Of particular interest to this paper is the space of the domestic kitchen, as it is within this space that Pasteurian microbiopolitics is combined with the production of biological citizens. According to Nikolas Rose and Carlos Novas, biological citizens draw on biological knowledge to understand their bodies, seeking to conform to the norm of a "healthy" citizen and differentiate themselves from (unhealthy) others.[31] We suggest that the FSA's kitchen-check campaign engages in microbiopolitics by seeking to govern human-microbe relations, offering advice on cleaning, chilling, and cooking food in order to minimize the spread and proliferation of harmful bacteria. Simultaneously, the campaign also works toward the production of microbiopolitical citizens by inviting members of the public to "find out if your kitchen habits are putting you, or your family and friends, at risk of food poisoning."[32] The implication is that good microbiopolitical citizens are those whose hygiene practices do not put themselves or their families at risk. Collectively, the practices of domestic microbiopolitics and the construction of microbiopolitical citizens begin to set out what distinguishes valued subjects and spaces from unwanted, microbially contaminated, unhygienic, unclean others.[33]

The emerging probiotic movement sits in contrast to practices of microbiopolitics and microbiopolitical citizenship that largely distinguish themselves through the exclusion of unwanted microbial others and their hosts.[34] For example, new "probiotic" cleaning products claim

to reseed your kitchen surfaces with "friendly" bacteria to hopefully outcompete more harmful kinds.[35] Rather than seeking to create a germ-free environment, these products—in Paxson's terms—discriminate between "beneficial" and other kinds of microorganisms. Such moves suggest there may be alternative approaches to managing domestic human-microbe relations. Less well known are the implications of such shifting human-microbe cultures for microbiopolitical citizenship, and the implications of changing human-microbial relations for understandings of self, other, health, and hygiene. Taking the possibility of more probiotic, post-Pasteurian approaches to domestic hygiene as our starting point, we explore how scientific methods of making microbes visible might enable a group of Oxford, UK, households to relate differently to the microbes in their kitchens, reconfiguring their status as microbiopolitical citizens. The next section outlines our interdisciplinary methodology for "participatory metagenomics." Two subsequent sections then explore how far the project facilitated our participants in learning to be differently affected by the domestic microbiome, and how their responses complement and extend existing readings of human-microbe relations. The first section asks, How did the ability to survey, visualize, and potentially intervene in their domestic microbial ecologies change the ways in which our participants made sense of the microbes who shared their homes? Subsequent sections explore how the encounters with microbes facilitated by our project reinforce or disrupt previous feelings for microorganisms, perhaps even allowing new ways of relating with microbial others to emerge. In concluding, we consider the implications of participatory metagenomics as a means of reconfiguring both lay microbiologies and the microbiopolitics of the domestic kitchen.



1 Brigitte Nerlich and Iina Hellsten, "Beyond the Human Genome: Microbes, Metaphors, and What It Means to Be Human in an Interconnected Post-Genomic World," *New Genetics and Society* 28, no. 1 (2009): 22, https://doi.org/10.1080/14636770802670233.

2 Heather Paxson, "Post-Pasteurian Cultures: The Microbiopolitics of Raw-Milk Cheese in the United States," *Cultural Anthropology* 23, no. 1 (2008): 28, https://doi.org/10.1111/j.1548-1360.2008.00002.x; see also Nerlich and Hellsten, "Beyond the Human Genome."

3 Funke Iyabo Sangodeyi, "The Making of the Microbial Body, 1900s–2012" (PhD diss., Harvard University, 2014), http://nrs.harvard.edu/urn-3:HUL.InstRepos:12274300.

4 Throughout this paper, the terms *antibiotic*/*antibiosis* and *probiotic*/*probiosis* are used to describe different human dispositions toward the microbiome. In its narrowest sense, the term *antibiotic* is used to refer to medicines that destroy or inhibit the growth of microorganisms. *Antibiosis* is an expansion of this term to encompass the intention behind the use of antibiotics, namely the desire to destroy, kill, or inhibit the growth (usually indiscriminately) of microorganisms. Similarly, *probiotic* is more commonly used to describe a group of foods and supplements that either contain microorganisms or that promote the growth of microorganisms seen to be good for human health. In this paper, the term is also used to reflect the desire to promote colonization by and growth of microorganisms, in particular those microorganisms seen as being "friendly" or good for human health.

Callie R. Chappell and Nasa Sinnott-Armstrong, *IndiGROW: Cushions*, 2024 (detail). Fabric, indigoidine dye, *Indigofera* plant leaves, and chemically synthesized reduced indigo, 24 × 24 in. Courtesy of Fathomers.

5 Paxson, "Post-Pasteurian Cultures"; Heather Paxson and Stefan Helmreich, "The Perils and Promises of Microbial Abundance: Novel Natures and Model Ecosystems, from Artisanal Cheese to Alien Seas," *Social Studies of Science* 44, no. 2 (2014): 165–93, https://doi.org/10.1177/0306312713505003; Jamie Lorimer, "Probiotic Environmentalities: Rewilding with Wolves and Worms," *Theory, Culture & Society* 34, no. 4 (2017): 27–48, https://doi.org/10.1177/0263276417695866.

6 Paxson and Helmreich, "The Perils and Promises of Microbial Abundance," 173.

7 Donna Haraway, "Anthropocene, Capitalocene, Chthulucene: Staying with the Trouble," Open Transcripts, May 9, 2014, http://opentranscripts.org/transcript/anthropocene-capitalocene-chthulucene/.

8 Jamie Lorimer, "Gut Buddies: Multispecies Studies and the Microbiome," *Environmental Humanities* 8, no. 1 (2016): 58, https://doi.org/10.1215/22011919-3527722.

9 See, for instance, Ed Yong, *I Contain Multitudes: The Microbes Within Us and a Grander View of Life* (Ecco, 2016).

10 Larisa Jasaveric, "The Thing in a Jar: Mushrooms and Ontological Speculations in Post-Yugoslavia," *Cultural Anthropology* 30, no. 1 (2015): 36–64, https://doi.org/10.14506/ca30.1.04.

11 Jeremy Brice, "Killing in More-Than-Human Spaces: Pasteurisation, Fungi, and the Metabolic Lives of Wine," *Environmental Humanities* 4, no. 1 (2014): 171–94, https://doi.org/10.1215/22011919-3614980.

12 Paxson, "Post-Pasteurian Cultures."

13 Paxson and Helmreich, "The Perils and Promises of Microbial Abundance."

14 Christy C. W. Spackman, "Formulating Citizenship: The Microbiopolitics of the Malfunctioning Functional Beverage," *BioSocieties* 13 (March 2018): 41–63, https://doi.org/10.1057/s41292-017-0051-6.

15 Matthew J. Wolf-Meyer, "Normal, Regular, and Standard: Scaling the Body Through Fecal Microbial Transplants," *Medical Anthropology Quarterly* 31, no. 3 (2017): 297–314, https://doi.org/10.1111/maq.12328.

16 Lorimer, "Gut Buddies," 59.

17 Gareth Enticott, "Lay Immunology, Local Foods, and Rural Identity: Defending Unpasteurised Milk in England," *Sociologia Ruralis* 43, no. 3 (2003): 257–70, https://doi.org/10.1111/1467-9523.00244.

18 Lorimer, "Gut Buddies"; Paxson, "Post-Pasteurian Cultures."

19 Here we follow Paxson's use of the term *Pasteurian* to describe an approach toward microbes oriented toward the elimination of germs. The term is derived from the name of Louis Pasteur, a French microbiologist and chemist known both for identifying bacteria as the cause of spoilage in beer, wine, and milk and for inventing a process—which became known as pasteurization—for sterilizing contaminated beverages. Paxson, "Post-Pasteurian Cultures," 18.

20 Paxson and Helmreich, "The Perils and Promises of Microbial Abundance," 183.

21 See Jamie Lorimer, "Parasites, Ghosts, and Mutualists: A Relational Geography of Microbes for Global Health," *Transactions of the Institute of British Geographers* 42, no. 4 (2017): 544–58, https://doi.org/10.1111/tran.12189.

22 Lorimer, "Parasites, Ghosts, and Mutualists."

23 See Lorimer, "Probiotic Environmentalities," 33.

24 Lorimer, "Parasites, Ghosts, and Mutualists," 544; see also Steve Hinchliffe, Nick Bingham, John Allen, and Simon Carter, *Pathological Lives: Disease, Space, and Biopolitics* (Wiley-Blackwell, 2016).

25 Steve Hinchliffe, John Allen, Stephanie Lavau, Nick Bingham, and Simon Carter, "Biosecurity and the Topologies of Infected Life: From Borderlines to Borderlands," *Transactions of the Institute of British Geographers* 38, no. 4 (2013): 531, https://doi.org/10.1111/j.1475-5661.2012.00538.x.

26 Paxson, "Post-Pasteurian Cultures."

27 Michel Foucault, *The History of Sexuality*, vol. 1, trans. Robert Hurley (Pantheon, 1978).

28 Bruno Latour, *The Pasteurization of France*, trans. Alan Sheridan and John Law (Harvard University Press, 1988).

29 Paxson, "Post-Pasteurian Cultures," 17, 23.

30 Achille Mbembe, "Necropolitics," trans. Libby Meintjes, *Public Culture* 15, no. 1 (2003): 11–40, https://doi.org/10.1215/08992363-15-1-11.

31 Nikolas Rose and Carlos Novas, "Biological Citizenship," in *Global Assemblages: Technology, Politics, and Ethics as Anthropological Problems*, ed. Aihwa Ong and Stephen J. Collier (Wiley-Blackwell, 2004), 439–63.

32 Food Standards Agency, "Kitchen Check Campaign," 2012, accessed April 10, 2018, https://www.food.gov.uk/news-updates/campaigns/kitchen-check.

33 Compare Susan Craddock, *City of Plagues: Disease, Poverty, and Deviance in San Francisco* (University of Minnesota Press, 2000).

34 See also Spackman, "Formulating Citizenship."

35 See, for example, My Living Water UK, which produced a "probiotic cleaning liquid" called Libby Chan.

Art and SynBio

Each of the projects in *Emergence* has a relationship to the expansive and contested field of synthetic biology, or SynBio. For some contributors, SynBio is the daily space of their labs, research, education, and policy work. For others, SynBio is a discrete provocation or alternative lens through which to think about making, dreaming, and calling new realities into being.

What is synthetic biology? There may be as many definitions as there are practitioners, but a simple definition is the science of "redesigning organisms for useful purposes by engineering them to have new abilities." Applications include devising new ways for targeted pharmaceuticals to be absorbed by the body; cultivating tiny versions of human and animal organs, called organoids, for medical research and therapeutics; engineering naturalyeasts to produce medicines, dyes, food flavorings and fragrances; designing microbial systems to digest plastics and other harmful substances in the environment; and creating entirely new life forms with engineered DNA.

With science, art has an equal role to play in helping us elaborate the futures that we want—not merely as a communication tool, but as a portal to understanding who we are and who we might be. We might wonder whether art can be one of the "useful purposes" of synthetic biology, and, likewise, whether projects by artist-scientists could yield knowledge so essential that materials intended "for research purposes only" should be more readily available for these endeavors, too.

Callie R. Chappell and Nasa Sinnott-Armstrong, *IndiGROW,* 2024. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.


IndiGROW: Dying Indigo

FATHOMERS

Emergence
創発
Art from Life

October 8–December 15, 2024

Japanese American Cultural & Community Center, Los Angeles

Featuring the work of

AfroRithm Futures Group: Ahmed Best, Dr. Lonny J. Avi Brooks, and Jade Fabello, in collaboration with Dr. Drew Endy, Jesse Gilbert, Raquel Horsford, Malaya, and Oguri

Dr. Marie Bannier Hélaouët, Organoid Group, Hubrecht Institute of the Royal Netherlands Academy of Arts and Sciences and Oncode Institute, The Netherlands; and Dr. Albert Wu, Ophthalmic Stem Cell and Regenerative Medicine Laboratory, Stanford University, with lab members Dr. Aditi Swarup, Dr. Hala Dhowre, Dr. Sanja Bojic, and Julietta Picco

Dr. Callie R. Chappell and Dr. Nasa Sinnott-Armstrong

Michael Jones McKean, with assistance from Dr. Stephen Fong, Professor of Chemical and Life Science Engineering, Virginia Commonwealth University, in cooperation with the Museu de Leiria, Portugal

Eduardo Padilha

Dr. Pat Pataranutaporn

Corinne Okada Takara

Henry Tan, Masato Takemura, Pakchira Chartpanyawut, Weeratouch Pongruengkiat, Woraporn Pongsamart, Dr. Pat Pataranutaporn, Jirapat Thaweechuen, Tanis Phongpisantham, Pongsakorn Wechakarn, Sumeth Klomchitcharoen, and Kookpedz Studio

Tissue Culture & Art Project: Oron Catts and Ionat Zurr, with assistance from the UCLA Art|Sci Center and the California NanoSystems Institute

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FATHOMERS

Elixir



Emergence



This project is part of *Emergence*, an exhibition organized by Fathomers that ran from October 8 through December 15, 2024, at the Japanese American Cultural & Community Center in Los Angeles.

Emergence assembles artists, scientists, and artist-scientists working at the forefront of synthetic biology and contemporary art. Documentation of their projects as well as relevant writings and interviews, planning sketches, and other contextualizing materials are collected in this catalog. Some contributors draw from their work in medical or transdisciplinary research laboratories, where they confront new categories of life that destabilize our understandings of sentience, hybridity, and artificiality. Others engage the tools of synthetic biology as materials for creative experimentation and studio-based inquiry. Many contributors argue for decolonizing science and expanding access to biotechnologies through DIY and community science initiatives. Across *Emergence*, audiences and participants are invited to contemplate our human capacities for creation, destruction, recklessness, renewal, and hope. The exhibition prompts us to ask: Who has agency in this moment of making, learning, and living with? What forms of life are we choosing to cultivate? What will we nurture, and what might we leave behind?

Projects in the Exhibition

AfroRithm Futures Group
MultiPlanetary Garden

Marie Bannier Hélaouët and Albert Wu
Crying Organoids

Callie R. Chappell and Nasa Sinnott-Armstrong
IndiGROW

Michael Jones McKean
of kin and bone

Eduardo Padilha
Apoptotic Bodies

Pat Pataranutaporn
CyberBiome and *MicroPET*

Corinne Okada Takara
Floating Future Gardens

Henry Tan and Masato Takemura
Pillars of Creation

Tissue Culture & Art Project
The Use of Life (in Relation to the Industry of Men)

Fathomers is a creative research institute dedicated to producing sites and encounters that challenge us to live and act differently in the world. Fathomers cultivates the ideas of diehard dreamers, commissions projects that seem far-fetched, and collaborates with thinkers across disciplines to expand the limits of scale, scope, and support for artist-led projects.

Emergence was presented as part of PST ART: *Art & Science Collide*. PST ART is presented by Getty.

Eduardo Padilha

Apoptotic Bodies

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Lynn Margulis and Dorion Sagan



Apoptotic Bodies

Eduardo Padilha

Introduction by Natasha Boyd

In his work *A Brief Dictionary of Poetic Biological Phenomena* (2024–25), Eduardo Padilha writes that all living matter engages in the work of poetry: "'Poetic' deriv[es] from the Greek *poiein*," he notes, "meaning 'creation' or 'production.'" Sometimes, this includes dying. A writer, researcher, artist, Global Community Bio Summit organizer, and Structural Genomics Consortium collaborator, Padilha invokes a poetics of cellular death in his work, exploring how living and dying are mutually constitutive—even within the same organism. His lectures, essays, exhibitions, and workshops engage with a kaleidoscope of thinkers, from philosophers Claude Lévi-Strauss and Michel de Montaigne to scientists Tyler Volk, Lynn Margulis, and Erwin Schrödinger, as well as contemporary poets and writers like Anne Boyer and Susan Sontag.

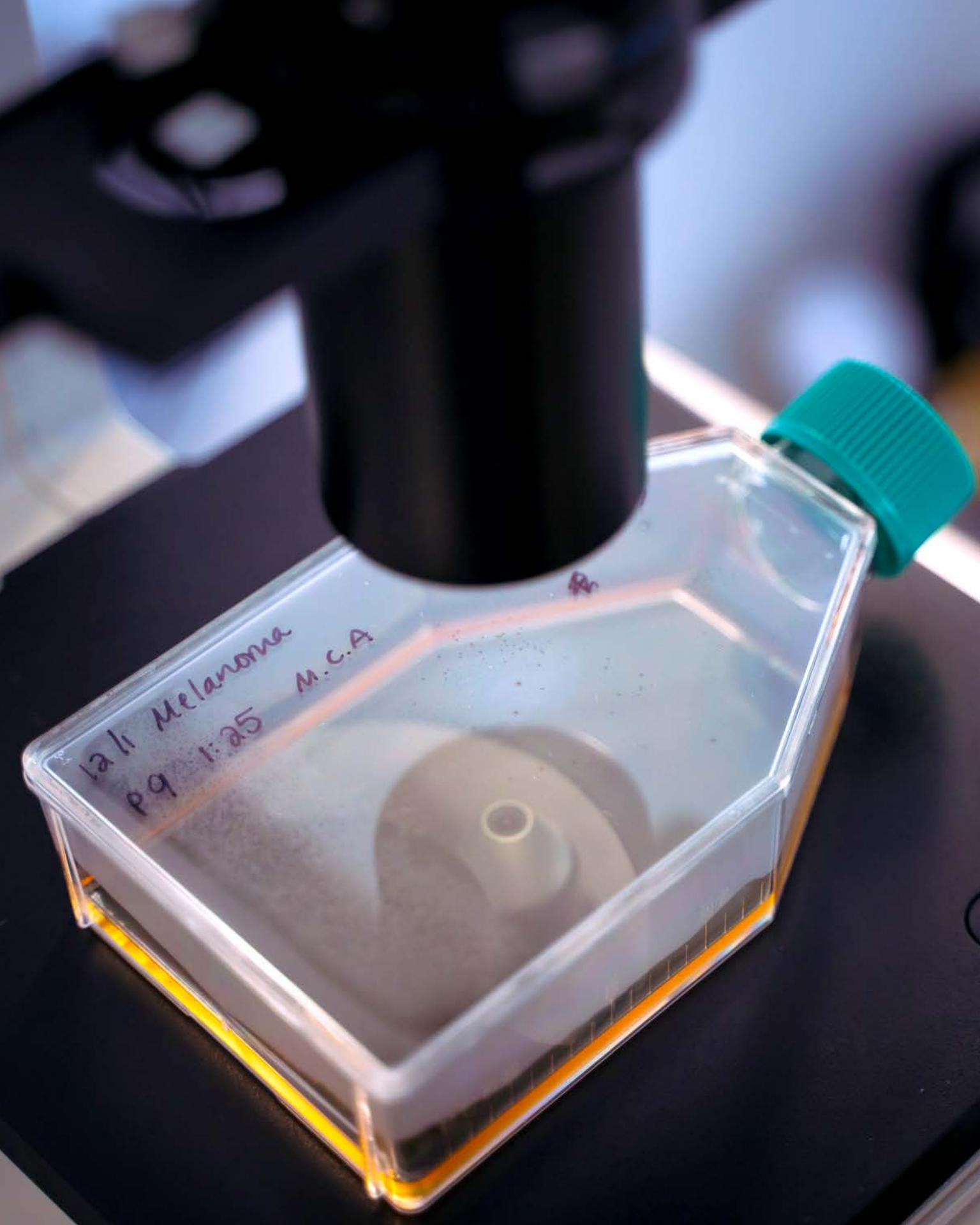
In *Apoptotic Bodies* (2024), Padilha elaborates on the metabolic process of apoptosis, or programmed cell death. When a cell "wants" to die, it engages in a series of precise metabolic pathway activations that culminate in its own termination without harming the surrounding tissue. Enzymes destroy proteins within the cell, triggering a sequence of transformations that result in the cell's death and disintegration. Apoptotic bodies are the remnants of this process. These fragments of dead cells send out an "eat me" signal to nearby phagocytes, alerting the body that they need to be absorbed. The flourishing of a multicellular organism depends on the capacity of certain cells to shed or fall (*ptosis*) away (*apo*).

There's a ghostly quality to *Apoptotic Bodies*' spare and unprepossessing visual language of stainless steel trays, acrylic boxes, and a used embalming machine, which are arranged as though the piece had materialized from a long-abandoned laboratory. Within the culture medium lie three cell lines, groups of human cells that can be propagated repeatedly. The first is derived from fibroblasts, a type of cell that creates and maintains the connective tissue that binds the body together. The second is an "immortalized" human fibroblast cell line, often used in studies of stress, aging, and disease. A cell line can be immortalized by the targeted introduction of cancer-inducing viruses or mutations; it will grow in vitro indefinitely, undergoing division for decades, potentially centuries, as long as the cells are fed. The final cell line is cancerous: A-375, a human melanoma cell line that was originally isolated from the skin of a fifty-four-year-old woman. The indefinite proliferation of these cells would have made them all targets of apoptosis—successful or otherwise—within the matrix of a human body. Instead, in *Apoptotic Bodies*, they exist in a state of suspension: progenitive yet sterile, abundant yet alone.

Cancer results from a failure of apoptosis: a surplusage of single-cell *poiein*, to the detriment of the multicellular organism. Malignant cells are able to avoid programmed suicide by altering genetic pathways, silencing tumor suppressor genes, and overexpressing survival proteins. They lose their biological identity and cease to function like their tissue of origin. As they move through the body, they generate dense lumps of tissue that become tumors, then tell blood vessels to grow toward the tumors and supply them with nutrients and oxygen. Some cancer cells can convince immune cells to protect the tumor instead of attacking it. Others consume energy more quickly—and thus grow faster—than healthy cells, stripping the rest of the body of vital fuel. Hunger leads to starvation. The cell lines of *Apoptotic Bodies*, suspended in time, remind us that not all growth is good, that death is necessary for life.



Opposite page: Eduardo Padilha, *Apoptotic Bodies*, 2024. Detail: flask of human cell line under a microscope. Courtesy of Fathomers. Photo: Jordyn Doyel.


Melanoma
P9 1:25 M.C.A



Eduardo Padilha, *Apoptotic Bodies*, 2024. Used embalming machine, stainless steel trays, cell culture flasks, Dulbecco's Modified Eagle's Medium, fetal bovine serum, silicone tubing, and flasks containing human cell line, immortalized human cell line, and cancer cell line, dimensions variable. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.




symphony

Eduardo Padilha



Photo: Rita Wu

Eduardo Padilha is a São Paulo–based artist, scientist, and researcher exploring the intersection of biology, philosophy, and art. Padilha received his PharmD from the University of São Paulo. An organizer of the Global Community Bio Summit, he has done research at the University of São Paulo's Institute of Biomedical Sciences and worked as a collaborator in the Structural Genomics Consortium. He currently works as a clinical scientist, helping develop new drugs for cancer treatment. His work has been featured in lectures, essays, exhibitions, and workshops in Brazil, Chile, China, and the United States.

Opposite page: Eduardo Padilha inspects the health of an *Apoptotic Bodies* cell line in the *Emergence* lab, Japanese American Cultural & Community Center, Los Angeles, 2024. Photo: Fathomers.

Originally published in Anne Boyer, *The Undying: Pain, Vulnerability, Mortality, Medicine, Art, Time, Dreams, Data, Exhaustion, Cancer, and Care* (Farrar, Straus and Giroux, 2019). Reprinted by permission.

Excerpt from

The Undying

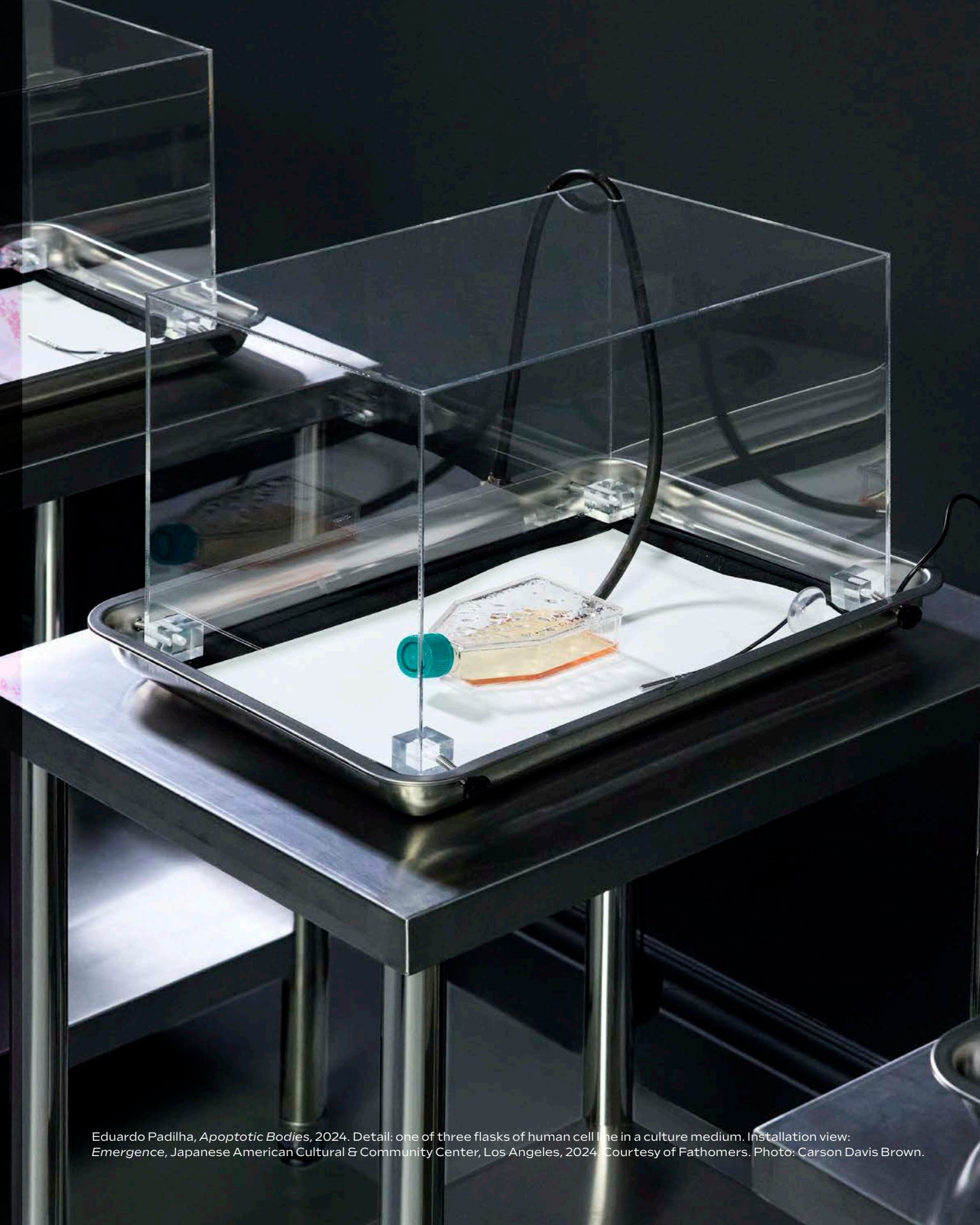
Anne Boyer

That we carry around errant cells in breasts and prostates and lungs is not the crisis. Cancer becomes a crisis twice: once, upon its discovery, and next, in its discovery's effect. Its effect is most often a calamity of medicine, or a calamity of its absence, the first orchestrated in prevention of the calamity of death, which, along with birth, is the least unique calamity on earth.

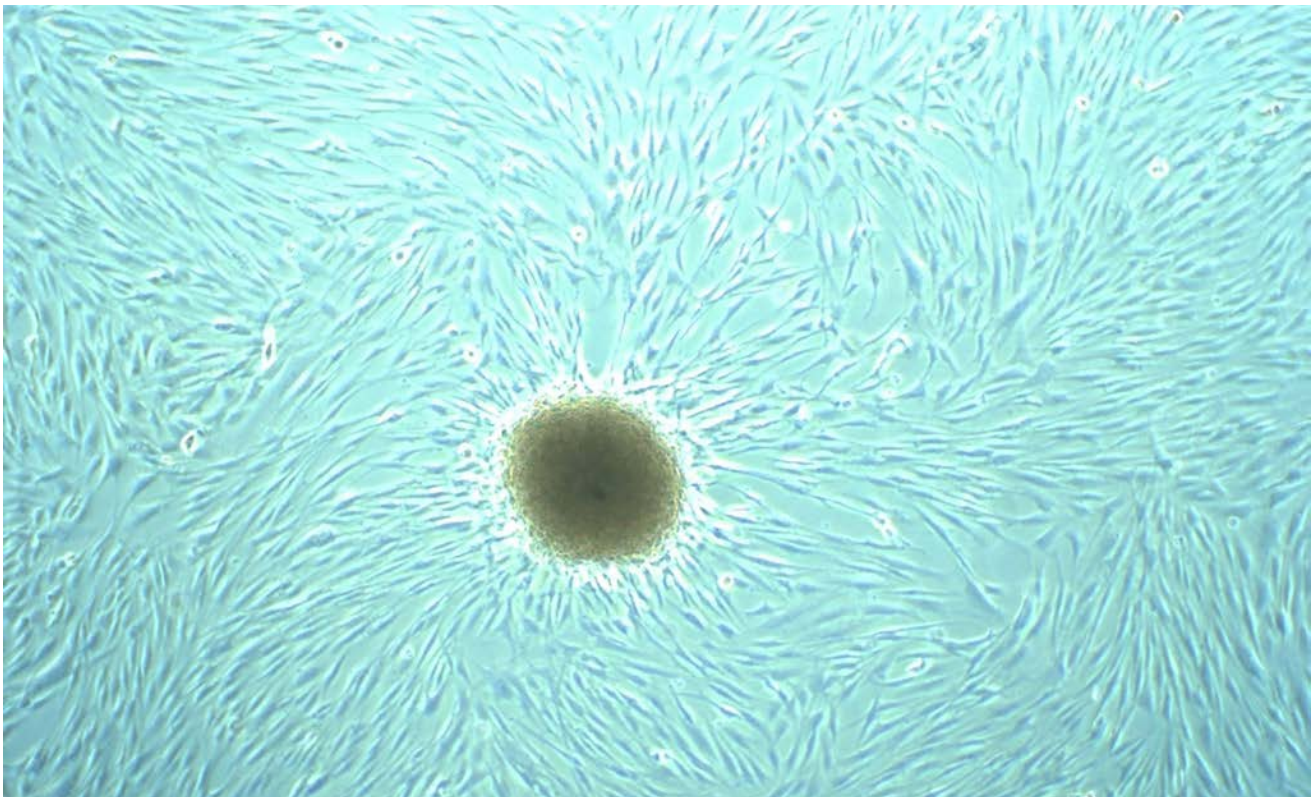
Under the conditions of these calamities, there is no listening to my body, which in these circumstances keeps saying the wrong things. My body feels like it is dying as a side effect of what is promised to keep it alive, and requests, as its preservation, its destruction: to not move, to not eat, to not work, to not sleep, to refuse all touch. Every nerve is a beggar, asking for the alms of an end. Any wisdom of my body comes out as an insufferably melodramatic request made by a fool. I had to believe, however, that all my body meant by wanting to die then was not that it hated life, only that it could no longer bear this.

Then my body bore the unbearable, as many of ours do. Sometimes the only way to survive the worst is to run to the perfect refuge of being dulled. Disassociation reigns, but no one minds your daydreaming when you are sick with cancer. Some friends appear to wish that I would disassociate more, that I would give up my love of lucidity through events better survived in mental retreat.

Despite icing my hands and feet all during chemotherapy in an attempt to avoid it, my fingernails and toenails begin to lift from their beds. Fingernails lifting from fingers hurt as badly as fingernails lifting from fingers should. I bandage my iridescently painted nails onto me. I've lost friends, lovers, memory, eyelashes, and money to this illness, so I am stubbornly opposed to losing anything else to which I am attached. My nails fall off despite my opposition.



Eduardo Padilha, *Apoptotic Bodies*, 2024. Detail: one of three flasks of human cell line in a culture medium. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.

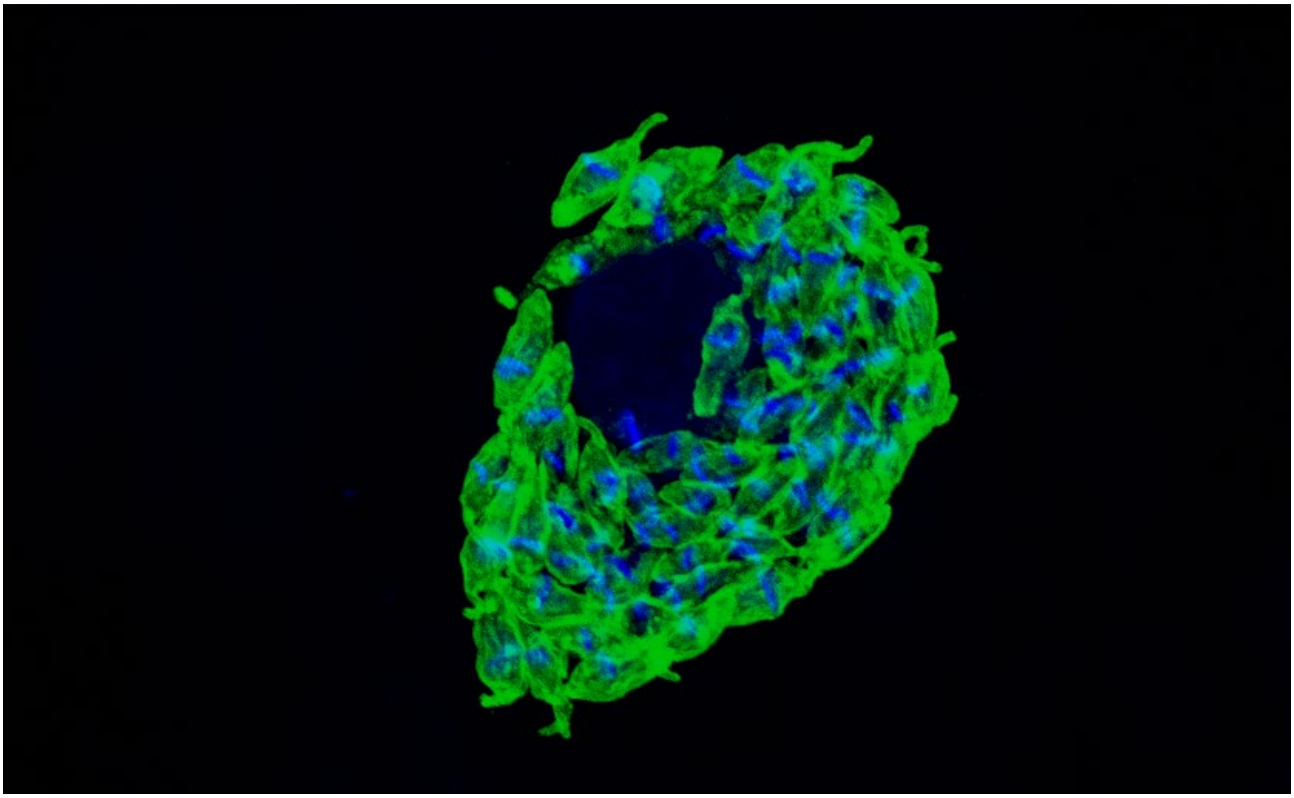


Immortalized Fibroblasts Microscopy

Eduardo Padilha, *The Path to Immortality*, 2013. Human fibroblast cell line, culture medium, and light microscope, dimensions variable. Photo: Eduardo Padilha.

This ×50 magnification microscopy image shows a culture of human fibroblasts that received two genes from the human papillomavirus according to a protocol for in vitro cell immortalization. The protocol, called *transformation*, allows researchers to turn normal cells into immortal ones; as a result of this process, the cells will divide indefinitely in the lab, no longer limited by their natural lifespan. Transformation is one of the necessary steps of carcinogenesis, the process by which cells become cancerous, which entails more than immortality but greatly depends on it.

—Eduardo Padilha



Immunofluorescence

Pilar Tavares Veras Florentino, Untitled, 2013. *Trypanosoma cruzi* parasites, human cell line, culture medium, and fluorescence microscopy, dimensions variable. Photo: Pilar Tavares Veras Florentino.

Trypanosoma cruzi, the etiologic agent of Chagas disease, is an intracellular parasite that invades mammalian host cells and replicates in the cell cytoplasm. After the cytosol is filled with parasites, they disrupt the host cell to infect neighboring cells. This fluorescence microscopy image shows intracellular parasites expressing Green Fluorescent Protein (GFP), multiplying in the host cell cytosol; cell nuclei, shown in blue, were stained with DAPI, a fluorescent dye used to stain DNA. Before staining, cells go through a chemical process called fixation, through which the structures are preserved as though frozen in time. The neon-colored parasites organize themselves around the nucleus of the infected host cell. The host cell's existence is only discernible through the diminutive, multiplying green *T. cruzi* parasites that will bring about its doom, manifesting Tyler Volk's proclamation, "Death, thus life." Although the host cell was alive right before fixation, its fate had been so firmly decided that it could be considered already dead. Here, human cell livingness supports protozoan life that, at the peak of its own livingness, will inevitably annihilate its exhausted host. The line between life and death—or between still-living and soon-to-be-dead cells—is as permeable as the invisible membrane that temporarily defines the boundaries of microscopic embodiments.

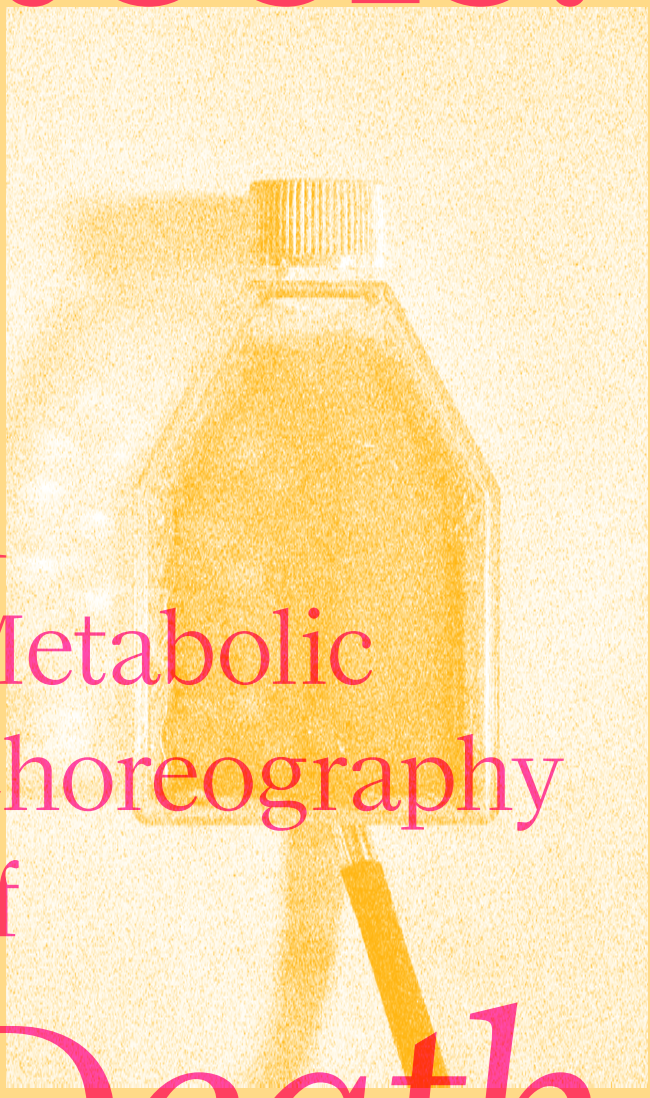
—Eduardo Padilha





Visitors inspect living cells at the opening of *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.

Apoptosis:



A Metabolic Choreography of *Death*

Eduardo Padilha

An organism is merely a transition, a stage between what was and what will be.

—François Jacob

Living bodies are indissolubly bound up with time.

—François Jacob

Dire que la mort est naturelle ou antinaturelle perd son sens. En fait et en droit, la mort est à la fois *naturelle* et *anticulturelle*.[1]

—Claude Lévi-Strauss

A dichotomous approach to life and death is insufficient not only at the cultural level but at the biological one as well. Although it is accepted that there is indeed a point beyond which living beings can be considered permanently dead, meaning that life can never again animate their structures, there seems to be much less certainty regarding the stages preceding this final, definitive state. When discussing the particularities of living matter, the physicist Erwin Schrödinger posed the questions "What is the characteristic feature of life?" and "When is a piece of matter said to be alive?," to which he replied,

> When it goes on "doing something," moving, exchanging material with its environment, and so forth, and that for a much longer period than we would expect an inanimate piece of matter to "keep going" under similar circumstances. When a system that is not alive is isolated or placed in a uniform environment . . . the whole system fades away into a dead, inert lump of matter. A permanent state is reached, in which no observable events occur. The physicist calls this the state of thermodynamical equilibrium, or of "maximum entropy."

Thus, to not be "doing something" would produce what Schrödinger calls this "dangerous state of maximum entropy, which is death."[2] Yet he does not provide any clue as to what the threshold or insurmountable limit of such a state would be.

This uncertainty might explain why the Polish composer and pianist Frédéric Chopin was



terrified of being buried alive.[3] Let us not judge his fear as idiosyncratic right away, for it was not uncommon during the nineteenth century to discover scratch marks and nail fragments embedded in the inner surfaces of caskets at the time of exhumation.[4] Although many scientific advances toward a more precise determination of death have made nineteenth-century medicine seem rudimentary by today's standards—modern medicine no longer relies on strategies such as releasing bugs into the ear canal or inserting a sharp instrument under the nail, for instance—that earlier medical paradigm evidences the problematics of trying to define the limit between life and death. Our cherished genius does not appear so foolish, then, in having asked his sister to swear his body would be cut open so that he would be truly dead before being buried. After all, from either a biological or a thermodynamic point of view, we simply lack information about what the limits of this "dangerous state" might be.

We bury bodies.

We do not bury cells.

We bury bodies in the belief that they are dead. We freeze cells in hopes that they will not die. We can cryopreserve cells in liquid nitrogen for decades, thawing them whenever a scientist or reproduction technician decides it is time to bring them back to their full-capacity metabolic state. Add 10 percent (vol/vol) dimethyl sulfoxide as a cryoprotectant to the culture medium and then cool at a rate of approximately 1°C per minute: quite a simple recipe against the ephemeral. At ultralow temperatures (below −130°C), kinetic energy and molecular motion within a biological material decrease. Rates of chemical and biological reactions slow down and processes such as metabolism, active transport, enzymatic reactions, and diffusion decline.[5] This description might as well be referring to death. But frozen cells are not dead. Instead, frozen cells exist in a suspended state rather than a permanent one.

By moving between bodies and cells, we allow ourselves to appreciate the different levels of organization of living beings. Multicellularity poses both a solution and an additional hurdle to the question of death. (Is death a question, anyway?) As the French biologist and Nobel Prize laureate François Jacob put it, "The individual bacteria do not die." Bacteria are anti-ephemeral in their capacity to "disappear as

Eduardo Padilha, *Apoptotic Bodies*, 2024. Detail: used embalming machine. Courtesy of Fathomers. Photo: Carson Davis Brown. An embalming machine is used to replace bodily fluids with disinfecting and preserving chemicals after the embalmer has drained the blood from the circulatory system and removed gases and fluids from bodily cavities and soft organs.

individuals: where there was only one, suddenly there are two."[6] The same is not true for those whose constitution relies on more than one single cell. We cannot become two as can bacteria. What we humans can do is die by the part. An organism composed of multiple cells may allow itself to give up on a portion of these monomeric components without compromising the entire makeup of its being. In order to be able to yield only partially to mortality, however, it is necessary to have fine-tuned and well-regulated mechanisms in place. Dying by the part implies a very well-rehearsed choreography. On the stage of the biosphere, evolution is a ruthless choreographer, tirelessly pushing its dancers to the limits of their abilities.

When a cell wants to die, it engages in a series of metabolic pathways activations called *apoptosis*.

A Poem for Intrinsic Death

BIM, BID, BAD, NOXA, PUMA

BCL-2, BCL-xL, MCL-1, BCL-W

BAX, BAK

Cytochrome c

DIABLO

Caspase-3, Caspase-7, Caspase-9

A Poem for Extrinsic Death

Membrane-localized death receptors

Death domain

FAS, TNFR1, TRAIL (DR4), TRAIL-R2 (DR5)

Caspase-8

Neither of the above poems rhyme. They seem like Dada poetry. But unlike Dada, life does not rely on the readymade. In fact, life expresses itself in quite the opposite way. A *poietic* way.

In their book *What Is Life?*, Lynn Margulis and Dorion Sagan explore autopoiesis, a concept first articulated by Chilean biologists Humberto Maturana and Francisco Varela. The word has a Greek etymology: *auto* means "self," *poiein* means "to make, create, or produce," as in "poetry," and *sis* indicates a noun of action, condition, or process, yielding "life's continuous production of itself." Margulis and Sagan argue that "without autopoietic behavior, organic beings do not self-maintain—they are not alive." They go on to write that "the failure of the autopoietic system of cell maintenance is death," presenting death as the cessation of action, an anti-verb.[7]

By contrast, I argue that dying is also a verb. In fact, dying may require as much energy and action as does living. The Greek language again provides a word for this concept. Apoptosis, from the Greek *apo*, meaning "away," and *ptosis*, meaning "fall," is programmed cell death. Apoptosis often occurs when damage or stress is so great that it compromises the normal processes performed by a cell, whereupon the cell initiates a precise and organized series of biochemical events that lead to its death. This coordinated suicide is triggered in such a way as to cause minimal damage to the tissue to which the dying cell belongs. This is why apoptosis is commonly referred to as a "clean" and "organized" death, or one that is immunologically "silent." Often, apoptosis is presented as a counterpoint to another form of cell death, necrosis, an uncontrolled and inflammatory pathological process, usually due to injury or trauma to the tissue.

The cascade of events initiated by the "silent" suicidal cell engaging in apoptosis causes the disintegration of the cell itself. The resulting pieces are known as apoptotic bodies. The molecular players of this process are trapped in the preceding poems. Apoptotic bodies are the remnants, vestiges, and fragments of the no-longer-living cell, which will later be absorbed and recycled without causing much disturbance to the organism as a whole. As the poet and essayist Anne Boyer writes in *The Undying*, "Living takes the shape of the effort to exist."[8] We, as cell-composed

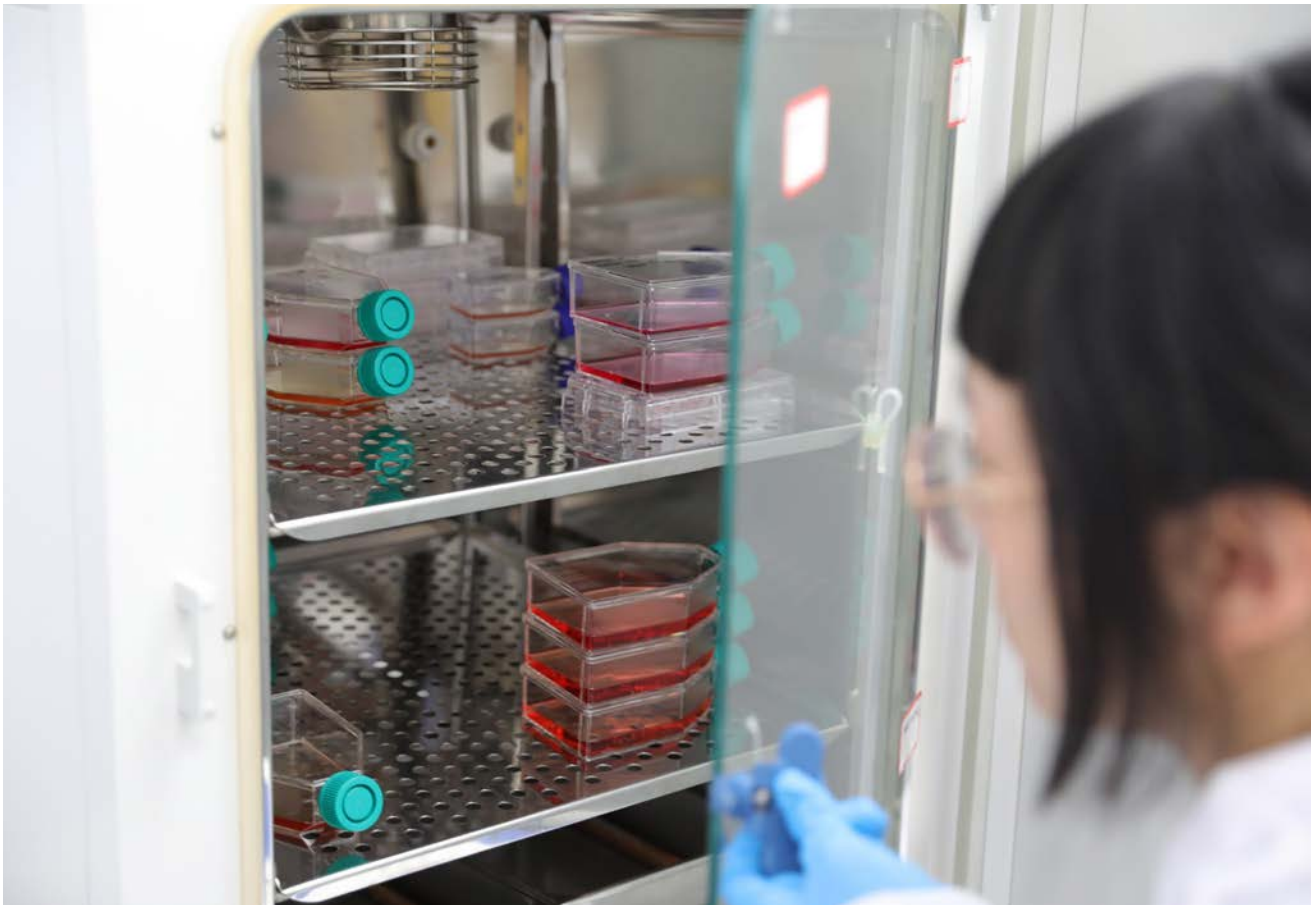
embodiments, should be well aware that the effort to exist—to actively support the life-sustaining processes that occur in opposition to apoptosis—may not always be deemed worthwhile. This is when the effort to no longer *be* might be betaken.

But cells do not only trigger apoptosis when the effort to exist is too much. Dying is an expected part of the developmental process of many living beings. Picture, for example, tadpoles swimming freely in a pond. Now, suppose you trap a few of them in a glass jar and observe their metamorphosis into fully grown frogs. You'll notice that their tails begin to shorten as small legs sprout until, after a few weeks, tailless adults replace the tadpoles. This metamorphosis is in fact an event of mass cellular demise. Tadpoles' tails retract in response to a hormone secreted by their thyroid glands that signals to the tail cells that it is time for them to die. Apoptosis, in this case, is an expected step in the organism's development.

Another example is the loss of the membrane that connects the digits of human babies during intrauterine development. The cells that make up this interdigital membrane program their own deaths, inducing apoptosis and then being reabsorbed by the developing fetus. This process is the reason why human beings are born with separate digits instead of a flat paddle with the fingers joined by an epithelial membrane. We are the product of thousands of cellular suicides.

There are two major biochemical pathways through which cells trigger apoptosis: intrinsic and extrinsic. Intrinsic apoptosis begins in the mitochondria, where two proteins named BAK and BAX assemble and form pores in the exterior membrane of this organelle. These pores allow the release of a small protein called cytochrome c, which gains the cellular cytoplasm and forms a multiprotein structure called apoptosome. There, an enzyme called caspase-9 is activated and initiates a downstream cascade of molecular events. Extrinsic apoptosis is triggered by external signals that bind to receptors located in the cell membrane, including those termed "death receptors." These receptors send signals into and through the cell, leading to the formation of a group of proteins called a "death-inducing complex." Both pathways activate the so-called executioner caspases-2, -6, -8, and -10, which bring about apoptotic death. Caspase-6 breaks down the membrane that forms the cell nucleus, and the DNA within it is also dismounted into smaller nucleus-derived structures (nucleosomes). As part of this process, intracellular proteins and organelles are also degraded, and the cell membrane forms blebs in the membrane-bound fragments, which are the apoptotic bodies. Annihilation may come from within as well as from without.

When a cell "decides" to no longer be, it does so in an immunologically "silent" manner. The apoptotic bodies—compact fragments containing pieces of cytoplasm, DNA, and organelles—are identified as ready for clearance without alarming the whole organism.[9] Evolution has made it possible for a *multicellular self* to selectively sacrifice its component *unicellular selves*. In his book *What Is Death?*, scientist Tyler Volk explores examples of "death, thus life" from the vegetal kingdom. Volk gives special attention to tracheids, dead cells that comprise a plant's xylem, a vascular tissue responsible for transporting mineral-rich water from the plant's roots up to its leaves. The xylem contains columns of tubes formed by tracheids. Those cells underwent controlled deaths so that they could fulfill their purpose: facilitating the circulation of fluids and minerals in the plant and providing structural support against gravity. A perfect example of the non-dichotomy between life and death, tracheids are cells that were walled, stiffened, digested from the inside out, and thus emptied, becoming ubiquitous "functional cell corpses" without which, as Volk puts it, "there would be no green life on land except some ground-hugging tiny mosses and soil crust with green bacteria and algae."[10] Death, thus life.



Columns of tracheids remind me of the words of Tatsumi Hijikata: "Butoh is a corpse standing straight up in a desperate bid for life."[11] Hijikata, the founder of butoh, choreographed his body to limn the boundaries of life and death. The spasms, incongruencies, and discontinuities expressed by a body in butoh evoke the dismantling of an apoptotic cell. In his 1963 performance *Anma* (The Masseurs), the makeup covering the performers' bodies flaked off their skin. Like a cell degrading its own components and opening up pores in its membrane, this choreography suggests that death does not have to be static. Living bodies choreographing death create the possibility of metabolizing rigor mortis into *vigor mortis*, "strength of death" or "energy of death." "Death, thus life" is as true of butoh as of apoptosis.

Like butoh, death by apoptosis requires energy. Energy is needed to activate the signaling pathways that govern the steps of controlled death, including the regulation of proteins; subsequent morphological changes such as cell shrinkage, chromatin condensation (pyknosis), nuclear fragmentation (karyorrhexis), and disintegration (karyolysis); and cell membrane blebbing, which result in the formation of the apoptotic bodies. An important step is the exposition, on the membrane of the dying cell, of molecules that some

Lab technician Kacy Jung transfers flasks of cells from the gallery to an incubator housed in the *Emergence* lab for overnight storage. Photo: Fathomers.

call "eat me" signals. These function like beacons that facilitate the recognition and removal of the apoptotic bodies by phagocytes. If autopoiesis is life continuously making itself, apoptosis is life falling away from itself. This death leaves behind no corpses.

Anne Boyer writes, "Every person with a body should be given a guide to dying as soon as they are born."[12] It seems to me that Boyer could be referring to cell biology, as although cells know no philosophy, they have mastered how to die. And their repertoire extends further. Recent studies have uncovered, in addition to apoptosis and necrosis, two new modalities of cell death: necroptosis and pyroptosis (from the Greek *pyro*, meaning "fire" or "fever").[13] The discovery of necroptosis was a blow to the dichotomous model by which cells die either by apoptosis or necrosis—regulated or "clumsy" death, respectively. Necroptosis is a *programmed* form of necrotic cell death often specifically associated with inflammation. It has evolved to detect pathogens and promote tissue repair, triggered by receptors on the cell membrane, including the so-called death domain receptors. Upon receptor activation, many different intracellular proteins assemble into a structure called a necrosome, followed by pore formation in the cellular membrane. This allows for an influx of ions, leading to cell swelling and membrane rupture. The result is the uncontrolled release of intracellular material to the surrounding tissue, which acts as a damage signal (what immunologists call danger-associated molecular patterns or DAMPs), provoking a robust immune response.

And then there is pyroptosis, an inherently inflammatory form of cell death that involves several layers of regulation. It is triggered by intracellular sensors capable of detecting the aforementioned DAMPs and the correlated pathogen-associated molecular patterns (PAMPs), disturbances in the membrane and other stimuli. The activation of such sensors leads to the formation of a structure called inflammasome (a "body" of inflammation within the cell), which in turn sets off the activation of a series of enzymes, culminating in the formation of pores in the cellular membrane. Through these pores, some pro-inflammatory molecules are released, inducing immune cell activation. The cell also undergoes swelling (sometimes referred to as a "ballooning effect") and ends up dying by pyroptosis.

Cellular death is semiotic.[14] And cellular death is also poetic. What the prefixes and suffixes that make up the scientist's conceptual toolbox for naming biological phenomena have in common is the effort to express transformation. The process of mitosis is the transformation of one individual cell into two. The steps taken by a living cell engaging with death are likewise transformative. Susan Sontag writes that "transforming is what art does."[15] I offer here: Transforming is what life does. When researchers in the natural sciences coin new concepts and freeze them in the pages of scientific literature, it does not take much to lose sight of transformation and face the phenomena they represent as rather final, binary, and static. I believe that such cases, when *poiesis* gives way to *techne* and *episteme*, are fertile substrates in which artists can intervene.

If the beauty of a requiem resides in its capacity to elicit emotional responses through musical expression centered on the theme of death, its power is even more dynamic as it is usually performed around the stasis of a cadaver being mourned. For instance, the musical architecture and dynamism of the Catholic Mass of the Dead, generated by the keys and rhythms used in the composition as well as the frequent choral outbursts, depart from the premise that the anguish of death ultimately culminates in the hope of salvation. This is stated through drama and in juxtaposition to a deceased body, even more strongly evidencing the contrast between the movement and flow of the musical performance and the complete absence of both manifested by/in the corpse that triggered the liturgy. There

is an urgent need, then, for a Requiem for a Dead Cell. I suggest the following:

Missa pro Defunctis Cellula

I. Introitus: *Receptio Signorum Mortis*

II. Kyrie: *Praeparatio ad Mortem*

III. Sequentia:

A. Cellulae Contrahens

B. Pyknosis

C. Karyorrhexis

D. Karyolysis

E. Vesicatio Membranae

F. Corpora Apoptotica

IV. Communio: *Phagocytosis*

A requiem is unchoreographed music for death.

Butoh is a not-necessarily-musical choreography for death.

When human bodies dance, they present themselves in their fullest vitality. Choreography implies movement. Movement generates heat. Heat increases kinetic energy. Kinetic energy speeds up molecular motion. Molecular motion raises the rate of chemical and biological reactions. The sum of an organism's biochemical reactions is metabolism. In a sense, every choreography is metabolic. But the bodies of humans are not consumed while dancing. And humans dance for various reasons: Humans dance to make a statement against death. They also dance to welcome death or to mourn when it has come or to restore the imbalance it has brought upon their society. But even when symbolically referencing, embracing, or revering death, human dance is not usually expected to result in an organic annihilation of the body that dances.

Cells dance—move, metabolize—for different reasons. They perform a sequence of precise movements that they seem to have known since time immemorial. Embryonic cells dance after an egg cell is fertilized by a sperm cell. An amorphous clump of stem cells dances as the cells differentiate into specialized tissues. Red blood cells float to the rhythm of the cardiac flow. Neutrophils roll and contort through narrow spaces in the walls of blood vessels in a dance called diapedesis. And there is the cellular dance of death. So precise are the movements of this mortal dance that it is said to be *programmed*.

In 1580, the Renaissance philosopher Michel de Montaigne published an essay called "Que philosopher c'est apprendre à mourir" (That to study philosophy is to learn to die). In this reflection on the nature of life and death, he returns to philosophy as support in preparation for dying. Cells are not philosophers. But they have learned how to die.

1 To say that death is natural or unnatural becomes meaningless. In fact and in theory, death is both *natural* and *anticultural*.

2 Erwin Schrödinger, *What Is Life? The Physical Aspect of the Living Cell*, with *Mind and Matter* and *Autobiographical Sketches* (Cambridge University Press, 1992), 69, 71.

3 Michał Witt, Artur Szklener, Jerzy Kawecki, Witold Rużyłło, Marta Negrusz-Kawecka, Michał Jeleń, et al., "A Closer Look at Frederic Chopin's Cause of Death," *American Journal of Medicine* 131, no. 2 (2018): 211–12, https://doi.org/10.1016/j.amjmed.2017.09.039.

4 Elizabeth T. Hurren, *Dissecting the Criminal Corpse: Staging Post-Execution Punishment in Early Modern England* (Palgrave Macmillan, 2016).

5 Glyn N. Stacey and John R. Masters, "Cryopreservation and Banking of Mammalian Cell Lines," *Nature Protocols* 3, no. 12 (2008): 1981–89, https://doi.org/10.1038/nprot.2008.190; Kathryn A. Murray and Matthew I. Gibson, "Chemical Approaches to Cryopreservation," *Nature Reviews Chemistry* 6 (July 2022): 579–93, https://doi.org/10.1038/s41570-022-00407-4.



Eduardo Padilha, *Apoptotic Bodies*, 2024. Detail: one of three flasks of human cell line in a culture medium. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.



6 François Jacob, *The Logic of Life: A History of Heredity*, trans. Betty E. Spillmann (Princeton University Press, 1993), 296. Jacob greatly contributed to uncovering the mechanisms of enzyme regulation and gene expression, earning the Nobel Prize in 1965. He also became known for blending science with philosophy and discussing the nature of life and evolution. *The Logic of Life* has become a landmark in the epistemology of biology and philosophy.

7 Lynn Margulis and Dorion Sagan, *What Is Life?* (University of California Press, 1995), 17, 79.

8 Anne Boyer, *The Undying: Pain, Vulnerability, Mortality, Medicine, Art, Time, Dreams, Data, Exhaustion, Cancer, and Care* (Farrar, Straus and Giroux, 2019), 252.

9 Curiously, there is a class of molecules, termed *alarmins* by cellular immunologists, that are released by damaged or stressed cells as a way to signal tissue injury or infection to the immune system.

10 Tyler Volk, *What Is Death? A Scientist Looks at the Cycle of Life* (Wiley, 2002), 182.

11 Quoted in "Death and Failure," Shadowbody Butoh Manual, updated September 26, 2022, https://butohmanual.com/death/.

12 Boyer, *The Undying*, 132.

13 Damien Bertheloot, Eicke Latz, and Bernardo S. Franklin, "Necroptosis, Pyroptosis and Apoptosis: An Intricate Game of Cell Death," *Cellular and Molecular Immunology* 18 (March 2021): 1106–21, https://doi.org/10.1038/s41423-020-00630-3.

14 I propose this statement in light of Umberto Eco's assertion that "in the depth of the biological processes lie the elementary mechanisms from which semiosis springs." Umberto Eco, "On Semiotics and Immunology," in *The Semiotics of Cellular Communication in the Immune System*, ed. Eli E. Sercarz , Franco Celada, N. Avrion Mitchison, and Tomio Tada (Springer and NATO Scientific Affairs Division, 1988), 15. The proceedings of the 1986 Semiotics of Cellular Communication in the Immune System workshop provide very insightful material on the topic of immunosemiotics.

15 Susan Sontag, *Regarding the Pain of Others* (Picador, 2003), 77.

Excerpts from

What Is Death?

Tyler Volk

Cells can also die if they fail to receive signals telling them to live. How bizarre! The biological finding that cells need support signals from other cells—signals that say, "Yes, stay alive, don't die"—has been a key discovery about cell death, resulting in an avalanche of new research. The awe that the finding has created in the researchers is almost palpable in their papers.

There are many forms of cell suicide, yet the greater, overarching idea is the same: Some die for the well-being of the greater whole. Cell death used in the development and daily maintenance of large organisms did not just happen. It was invented during the course of evolution and maintained in so many organisms because it was functional—for example, in creating cell corpses for the transport of water in plants and deleting tissues between the developing digits of vertebrates. Therefore, the issue for evolution became not whether, but how, to effectuate the mechanics of cell death. The "how" was a perfect question for the evolutionary process, which tries out mechanisms and incorporates ones that work into pathways in the molecular dynamics of cells. In functional cell death we find nature clearly speaking a message of "death, thus life."

Originally published in Tyler Volk, *What Is Death? A Scientist Looks at the Cycle of Life* (Wiley, 2002). Reprinted by permission.

Excerpts from

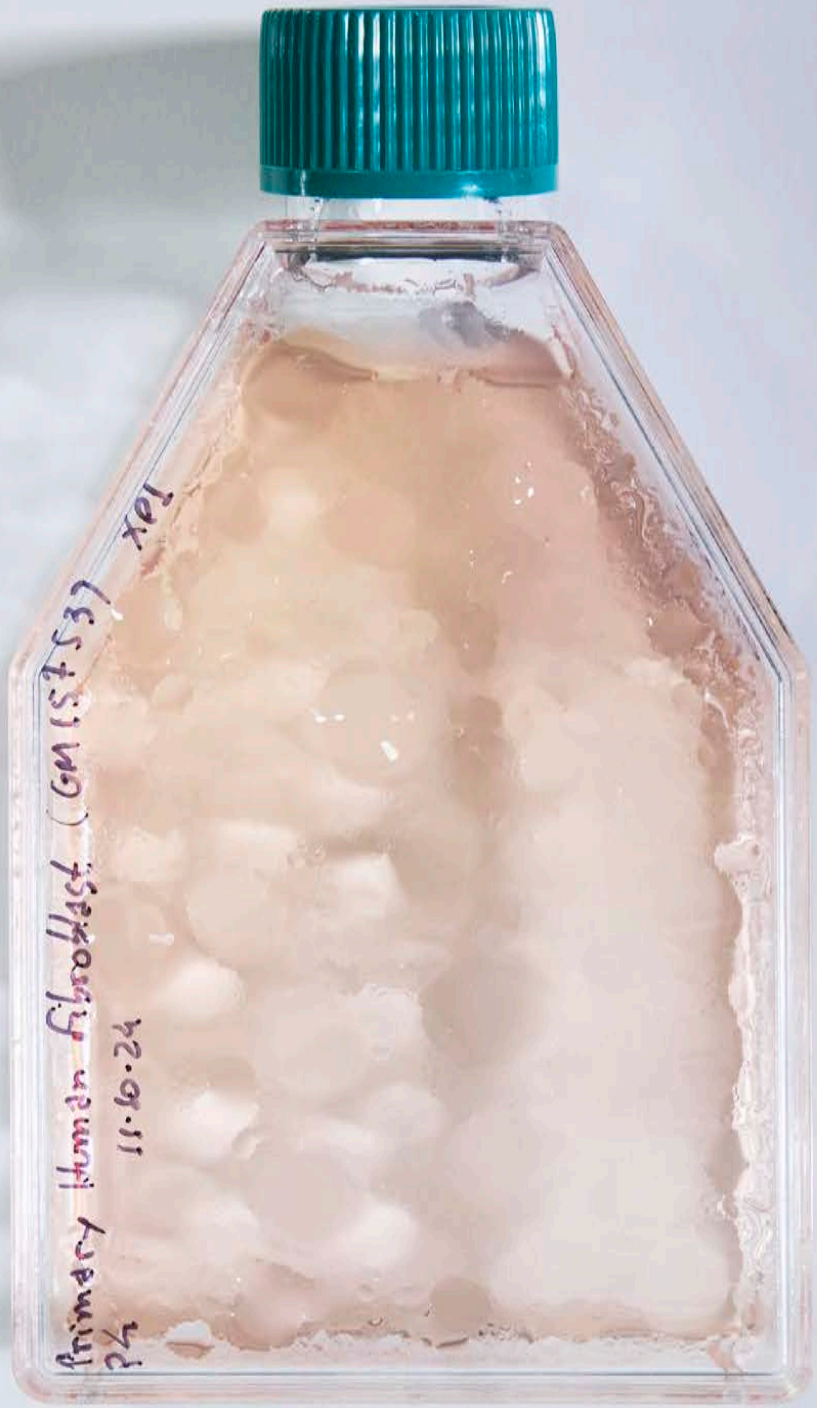
What Is Life?

Lynn Margulis and Dorion Sagan

The autopoietic view of life differs from standard teachings in biology. Most writers of biology texts imply that an organism exists apart from its environment, and that the environment is mostly a static, nonliving backdrop. Organic beings and environment, however, interweave.

Apoptosis arose in our microbial ancestors at some time during the evolution of sexual individuals. Strange to say, death itself evolved. Indeed, it was the first—and is still the most serious—sexually transmitted "disease."

Originally published in Lynn Margulis and Dorion Sagan, *What Is Life?* (University of California Press, 1995). Reprinted by permission.



Eduardo Padilha, *Apoptotic Bodies*, 2024. **Above:** Flask containing cell line derived from human fibroblasts, a type of cell that creates and maintains the connective tissue that binds the body together. **Opposite page:** Flask containing A-375, a cancerous human melanoma cell line that was originally isolated from the skin of a fifty-four-year-old woman. Courtesy of Fathomers. Photos: Carson Davis Brown.

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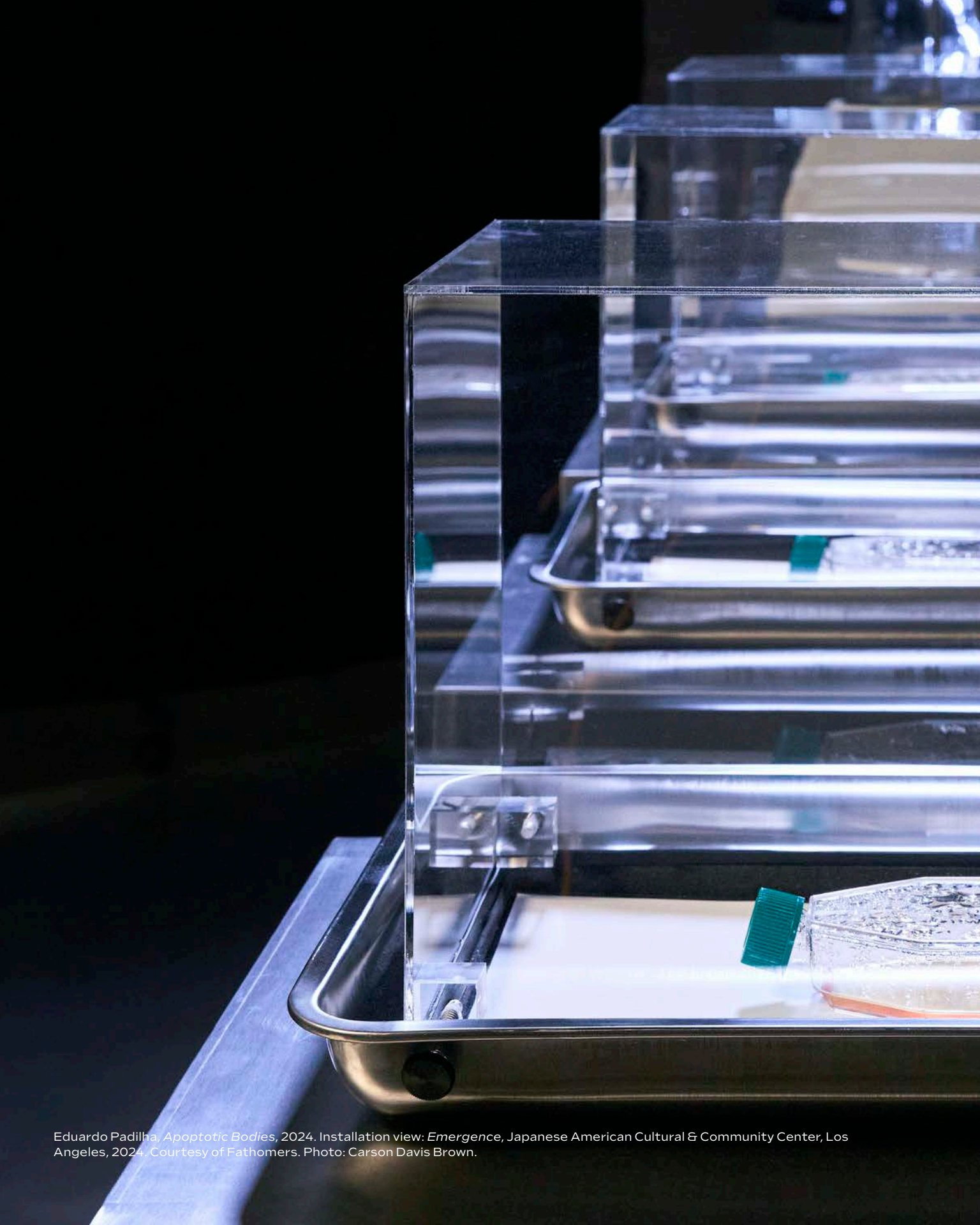
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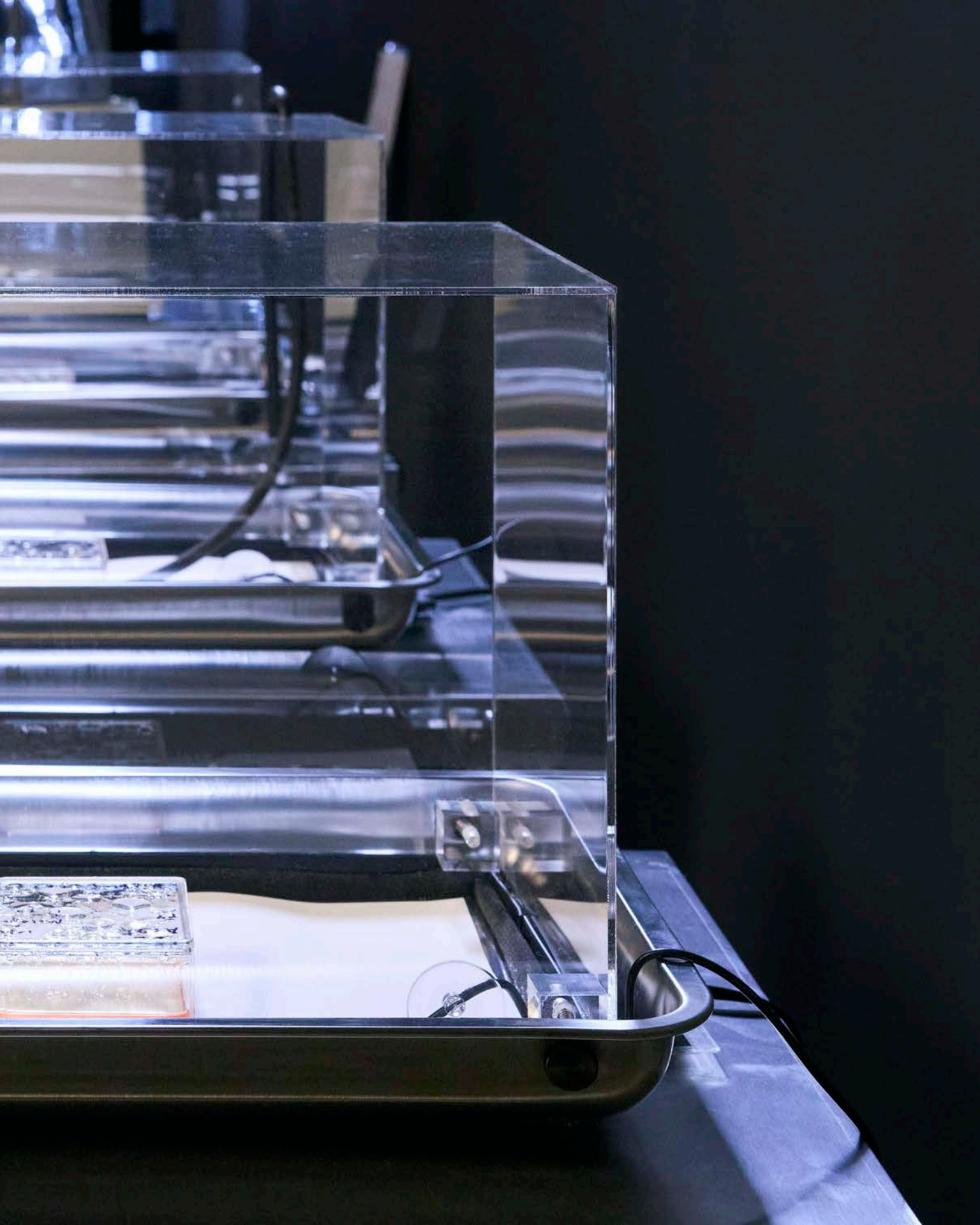


Lab technician Maria Cabrera Abad examines the health of some of the living cell lines from *Apoptotic Bodies*, 2024. Courtesy of Fathomers. Photo: Jordyn Doyel.





Eduardo Padilha, *Apoptotic Bodies*, 2024. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.



FATHOMERS

Emergence
創発
Art from Life

October 8–December 15, 2024

Japanese American Cultural
& Community Center,
Los Angeles

Featuring the work of

AfroRithm Futures Group: Ahmed Best, Dr. Lonny J. Avi Brooks, and Jade Fabello, in collaboration with Dr. Drew Endy, Jesse Gilbert, Raquel Horsford, Malaya, and Oguri

Dr. Marie Bannier Hélaouët, Organoid Group, Hubrecht Institute of the Royal Netherlands Academy of Arts and Sciences and Oncode Institute, The Netherlands; and Dr. Albert Wu, Ophthalmic Stem Cell and Regenerative Medicine Laboratory, Stanford University, with lab members Dr. Aditi Swarup, Dr. Hala Dhowre, Dr. Sanja Bojic, and Julietta Picco

Dr. Callie R. Chappell and Dr. Nasa Sinnott-Armstrong

Michael Jones McKean, with assistance from Dr. Stephen Fong, Professor of Chemical and Life Science Engineering, Virginia Commonwealth University, in cooperation with the Museu de Leiria, Portugal

Eduardo Padilha

Dr. Pat Pataranutaporn

Corinne Okada Takara

Henry Tan, Masato Takemura, Pakchira Chartpanyawut, Weeratouch Pongruengkiat, Woraporn Pongsamart, Dr. Pat Pataranutaporn, Jirapat Thaweechuen, Tanis Phongpisantham, Pongsakorn Wechakarn, Sumeth Klomchitcharoen, and Kookpedz Studio

Tissue Culture & Art Project: Oron Catts and Ionat Zurr, with assistance from the UCLA Art|Sci Center and the California NanoSystems Institute

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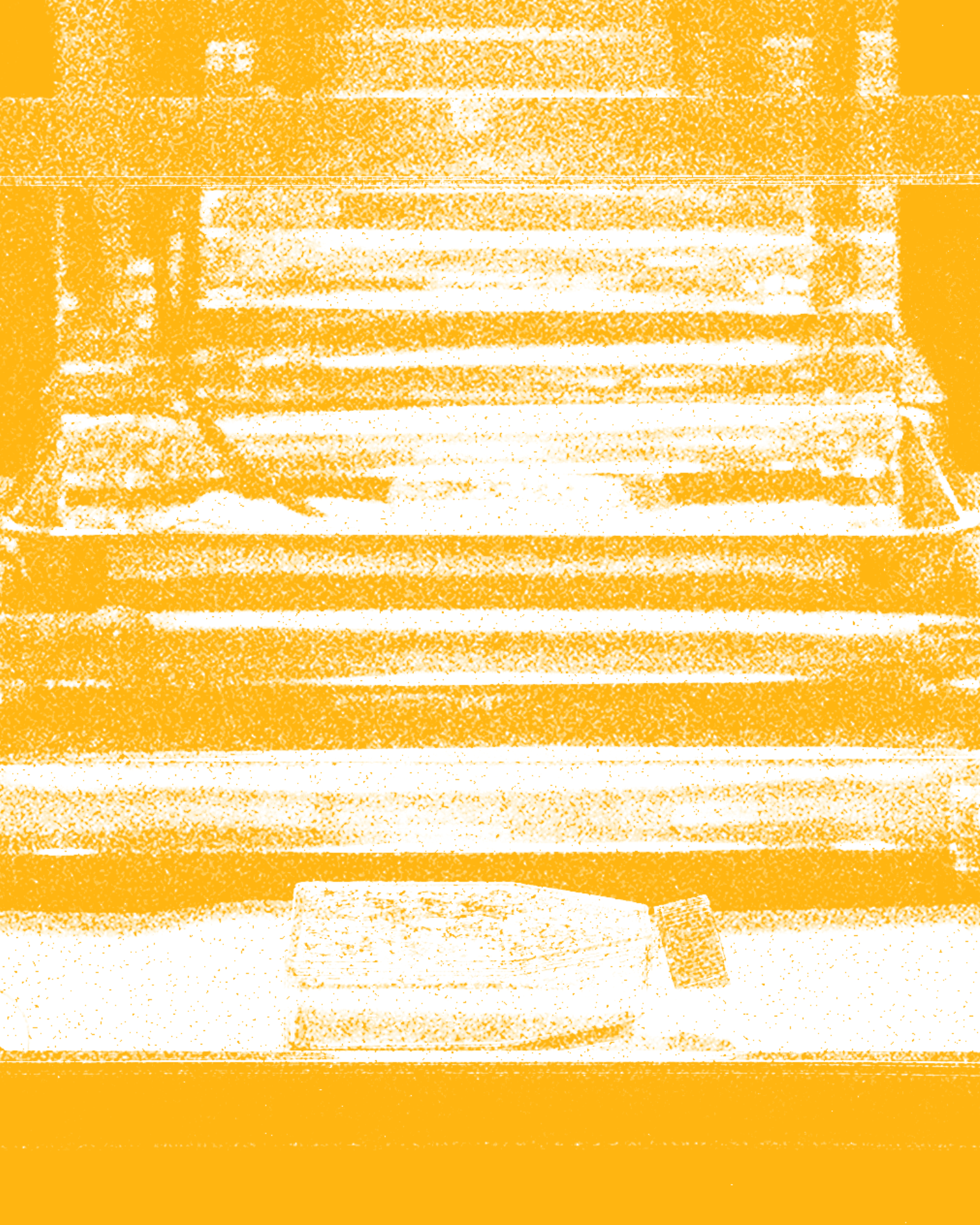






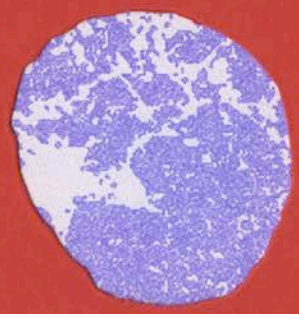


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FATHOMERS



Epilogue

This project is part of *Emergence*, an exhibition organized by Fathomers that ran from October 8 through December 15, 2024, at the Japanese American Cultural & Community Center in Los Angeles.

Emergence assembles artists, scientists, and artist-scientists working at the forefront of synthetic biology and contemporary art. Documentation of their projects as well as relevant writings and interviews, planning sketches, and other contextualizing materials are collected in this catalog. Some contributors draw from their work in medical or transdisciplinary research laboratories, where they confront new categories of life that destabilize our understandings of sentience, hybridity, and artificiality. Others engage the tools of synthetic biology as materials for creative experimentation and studio-based inquiry. Many contributors argue for decolonizing science and expanding access to biotechnologies through DIY and community science initiatives. Across *Emergence*, audiences and participants are invited to contemplate our human capacities for creation, destruction, recklessness, renewal, and hope. The exhibition prompts us to ask: Who has agency in this moment of making, learning, and living with? What forms of life are we choosing to cultivate? What will we nurture, and what might we leave behind?

Projects in the Exhibition

AfroRithm Futures Group
MultiPlanetary Garden

Marie Bannier Hélaouët and Albert Wu
Crying Organoids

Callie R. Chappell and Nasa Sinnott-Armstrong
IndiGROW

Michael Jones McKean
of kin and bone

Eduardo Padilha
Apoptotic Bodies

Pat Pataranutaporn
CyberBiome and *MicroPET*

Corinne Okada Takara
Floating Future Gardens

Henry Tan and Masato Takemura
Pillars of Creation

Tissue Culture & Art Project
The Use of Life (in Relation to the Industry of Men)

Fathomers is a creative research institute dedicated to producing sites and encounters that challenge us to live and act differently in the world. Fathomers cultivates the ideas of diehard dreamers, commissions projects that seem far-fetched, and collaborates with thinkers across disciplines to expand the limits of scale, scope, and support for artist-led projects.

Emergence was presented as part of PST ART: *Art & Science Collide*. PST ART is presented by Getty.

Marie Bannier Hélaouët and Albert Wu

Crying Organoids

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Natasha Boyd

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All risograph images in this volume have been adapted from photographs of human lacrimal gland organoids by Marie Bannier Hélaouët. *© 2021 Hubrecht Institute.*



Crying Organoids

Marie Bannier Hélaouët and Albert Wu

Introduction by Natasha Boyd

"Happy is he who possesses the gift of tears!," wrote the French poet and priest Joseph Roux in 1886.[1] As anyone who has tried to hold back tears or summon them when they won't come knows, weeping is a largely involuntary process. Tears are a complex potion made up of water, electrolytes, proteins, lipids, and mucins, and their conjuring is no easy task. Nevertheless, scientist Marie Bannier Hélaouët learned how one might go about it. Along with a team of researchers at the Hans Clevers lab in the Netherlands, Bannier Hélaouët grew lacrimal glands, the organs responsible for tear production—and then made them cry.

These tiny, sphere-shaped structures measure just 0.2 millimeters across. When stimulated, they release actual tears. Hans Clevers,

who oversaw Bannier Hélaouët's work, published a landmark research paper in 2009 mapping how organoids—miniature, simplified versions of organs—might be grown in vitro from adult stem cells. Most organs are capable of regeneration thanks to such stem cells, which divide to replace older, damaged ones in the body. As Bannier Hélaouët and Clevers explain, "It turns out these stem cells can be isolated and grown in the lab. When we do this, the stem cells form tiny replicants of the organs from which they were extracted."[2]

Researchers around the world have since grown organoids from the brain, stomach, colon, and elsewhere in the body. Cancerous organoids can accurately model patient tumors, so scientists use them for research and drug screens; with the Covid-19 pandemic, organoids have been used to study how SARS-CoV-2 affects different bodily functions. One day, organoids might end the need for organ donors. "Adult stem cells are already specialized and they know what to make—we just have to encourage them with growth factors," Clevers has said. "This happens within a matter of two or three days: You see small cystic structures appearing that grow into the organoids."[3] It took only seven days for Bannier Hélaouët's lacrimal glands to weep.

Every land mammal on earth has lacrimal glands, but the phenomenon of crying is still not fully understood. The chemical composition of "emotional" tears differs significantly from that of tears released as a reflex, in response to cutting onions, for example. We weep from happiness as well as from grief. In fables and folklore, tears are precious gifts: Enchanted maidens cry tears of pearl and diamond in tales from the Brothers Grimm, signifying spiritual wealth and inner beauty. Where the Greek goddess Aphrodite's tears fell, anemones sprouted from the earth.

In the mythology of the Zuni people of New Mexico, sunflowers blossomed from the tears of those who looked upon Awonawilona, god of the sun. When the Norse goddess Freyja lost her husband, she "stayed behind weeping, and her tears were red gold."[4] In such myths, the beauty and hardship of grief literally crystallizes or becomes eternal through the cyclical life of plants and flowers. In Ovid's *Metamorphoses*, the grieving Heliades weep over their dead brother until they turn into poplar trees: "So their tears still / Flow on, and oozing from the new-made boughs, / Drip and are hardened in the sun to form / Amber and then the clear stream catches them / And carries them for Roman brides to wear."[5]

Tears break spells and heal the sick. Tears really do have palliative properties: In 1922, Alexander Fleming discovered that tears contain an antibacterial enzyme that prevents infection. Emotional tears contain higher concentrations of stress chemicals such as adrenocorticotropic hormone and the natural painkiller leucine enkephalin; this has led scientists to hypothesize that weeping might play a biological role in balancing the endocrine system by excreting stress hormones that have built up in the body during periods of anguish and by triggering the release of endorphins like oxytocin.[6] Tears shed from the lacrimal gland also protect the cornea from damage and infection. There is ample evidence that crying is a necessary social function too, as tears both express the need for help and foster greater willingness in others to do so. Infants take several months to learn how to smile, but they can shed tears within just four weeks.[7] In the words of poet Antonio Porchia, "More grievous than tears is the sight of them."[8]

Just as in people, stimuli from the stress neurotransmitter noradrenaline causes Bannier Hélaouët's lacrimal glands to cry. Within half an hour of exposure, the organoids begin to swell

with fluid. In the absence of a human superstructure, these tears become trapped within the organoid. Some of them burst. As Bannier Hélaouët and Clevers write, "The organoids were secreting their tears on the inside: crying, but with nowhere for their tears to go."[9]

1 Joseph Roux, *Thoughts: Meditations of a Parish Priest*, trans. Isabel F. Hapgood (New York: Thomas Y. Cromwell, 1886), 203.

2 Marie Bannier Hélaouët with Hans Clevers, "We Grew Human Tear Glands in the Lab, and Now We're Making Them Cry," *The Conversation*, March 17, 2021, https://doi.org/10.64628/AB.x39dkyam5. See also pages 9–12 of this volume.

3 Alex Fox, "Scientists Make Tiny Lab-Grown Tear Glands Cry," *Smithsonian Magazine*, March 18, 2021, https://www.smithsonianmag.com/smart-news/scientists-make-tiny-lab-grown-tear-glands-cry-180977267/.

4 Snorri Sturluson, *The Prose Edda*, trans. Arthur Gilchrist Brodeur (American–Scandinavian Foundation, 1916).

5 Ovid, *Metamorphoses*, trans. A. D. Melville (Oxford University Press, 2009).

6 Asmir Gračanin, Lauren M. Bylsma, and Ad J. J. M. Vingerhoets, "Is Crying a Self-Soothing Behavior?," *Frontiers in Psychology* 5 (May 2014): 502, https://doi.org/10.3389/fpsyg.2014.00502.

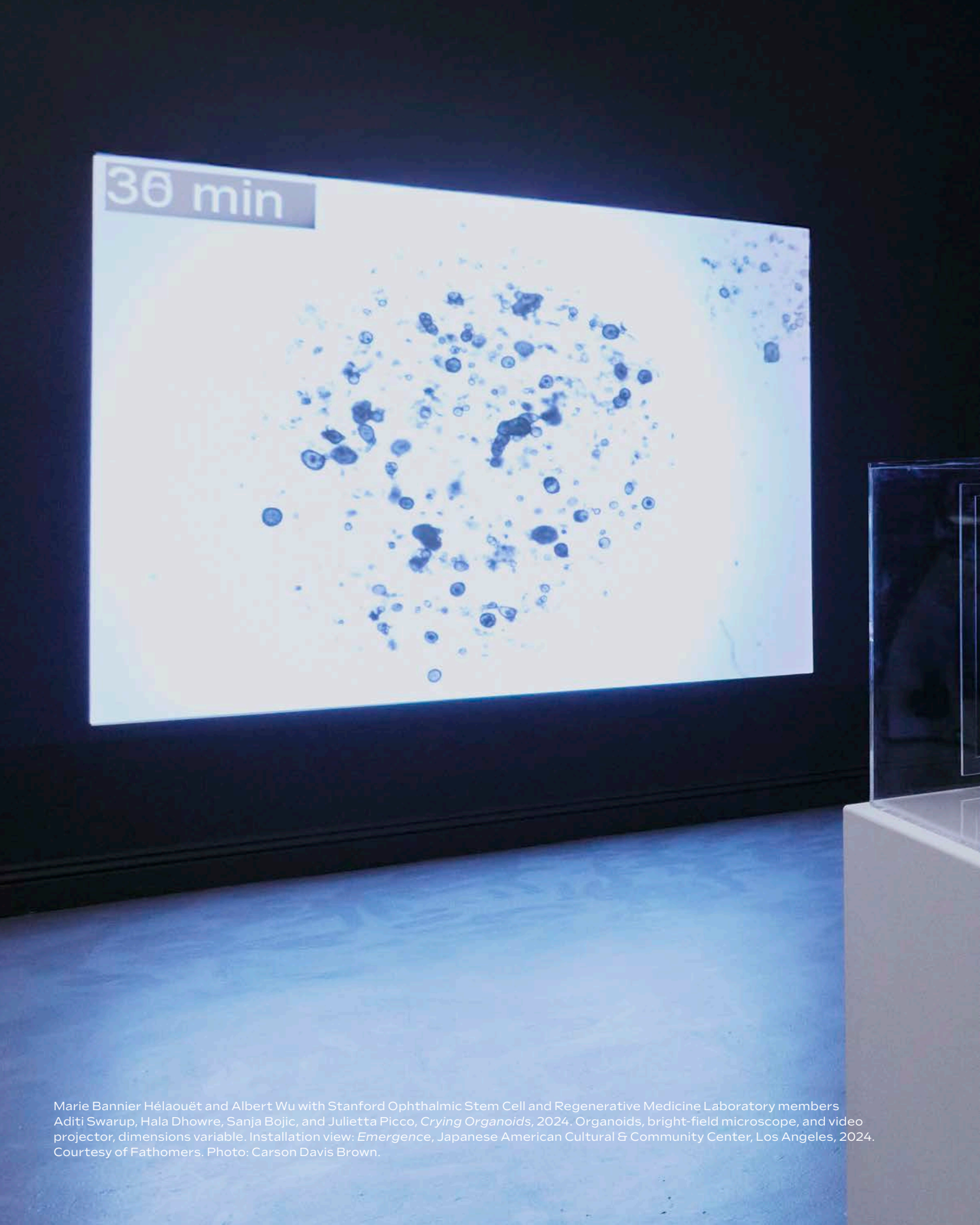
7 Ebru Toker, Özlem Yenice, Mehdi S. Öğüt, İpek Akman, and Eren Özek, "Tear Production During the Neonatal Period," *American Journal of Ophthalmology* 133, no. 6 (2002): 746–49, https://doi.org/10.1016/s0002-9394(02)01393-4.

8 Antonio Porchia, *Voices*, trans. W. S. Merwin (Big Table, 1969), 25.

9 Bannier Hélaouët with Clevers, "We Grew Human Tear Glands."



Human lacrimal gland organoids grown by Marie Bannier Hélaouët. Photo: Cayetano Pleguezuelos Manzano.



Marie Bannier Hélaouët and Albert Wu with Stanford Ophthalmic Stem Cell and Regenerative Medicine Laboratory members Aditi Swarup, Hala Dhowre, Sanja Bojic, and Julietta Picco, *Crying Organoids*, 2024. Organoids, bright-field microscope, and video projector, dimensions variable. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.





An *Emergence* lab technician prepares *Crying Organoids* for exhibition, 2024.

Marie Bannier Hélaouët and Albert Wu





Dr. Marie Bannier Hélaouët is a scientist in Basel, Switzerland, performing research on stem cells and regeneration. After obtaining her master's degree from the École Normale Supérieure de Lyon, she completed her PhD in the Netherlands in the laboratory of Dr. Hans Clevers. For her doctoral research, she used an emerging technology called *organoids* to study how the lacrimal gland produces tears.

Photo: Sylvie Hélaouët

Dr. Albert Wu is an award-winning ophthalmologist specializing in oculoplastic and orbital surgery. He leads Stanford University's Ophthalmic Stem Cell and Regenerative Medicine Laboratory, where his research advances the use of stem cell therapy to treat conditions involving the eye. Wu's research explores how stem cells can regenerate a patient's own tissues. He has presented his findings at numerous conferences and has received awards from the National Institutes of Health, the American Society of Ophthalmic Plastic and Reconstructive Surgery, Icahn School of Medicine at Mount Sinai, the University of Washington, and Yale University.

Photo: Stanford University

We Grew Human Tear Glands in the Lab, and *Now We're Making Them Cry*



Marie Bannier Hélaouët
with Hans Clevers

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Most organs in the adult human body are capable of regeneration, which means they renew their cells to keep the tissue healthy and functional. This capacity is enabled by adult stem cells, which are present in most organs and divide to create new cells that replace older, damaged ones.

It turns out these stem cells can be isolated and grown in the lab.[1] When we do this, the stem cells form tiny replicants of the organs from which they were extracted, which we call *organoids*. Alongside our colleague Yorick Post, who recently moved from Utrecht to the Silicon Valley commercial sector, we've produced a human tear gland organoid, which we've been able to make cry organoid tears—not by being nasty, of course, but by subjecting the organoid to adrenaline, which is released in humans when they're subjected to pain.[2] By studying our organoid tears, we might be able to help develop treatments for dry eye disease, including by transplanting our organoids back into human patients.

Mini Organs

Until recently, it was very difficult to study stem cells in the lab as they could not be cultured in a petri dish. Then, in 2009, the perfect recipe was found to culture stem cells of the intestine, which grew into tiny replicates of the intestine: mini organs.[3] Because of this resemblance, we now call these in vitro models organoids.

Since then, most organs have been made in organoid form, used to study the physiology and illnesses associated with that particular tissue.[4] More recently, organoids have been used to study how SARS-CoV-2 affects different organs. Researchers found that SARS-CoV-2 can infect the human intestine, explaining why some patients with Covid-19 experience diarrhea.[5]

With more and more organs being created as organoids in the lab, we searched for an organ that hadn't been considered yet: the tear gland. The tear gland is actually a very important organ: It produces the tears that lubricate the eye and protect it from infections. When the tear gland doesn't function properly, people experience itchiness and pain, a disease known as dry eye.[6] This occurs in at least 5 percent of the adult population worldwide.[7] Until now, studies of this disease were hindered by the lack of a good human tear gland model. We set out to establish one by creating tear gland organoids.

Gland Designs

To start an organoid culture, you need tissue directly from a patient. We obtained tear gland samples from the hospital and processed them into small pieces. These pieces were placed in a droplet of gel, like a cushion. Importantly, this gel allows stem cells to grow in a three-dimensional environment, enabling them to organize into any shape. By stimulating the tear gland stem cells to divide, we made our culture grow. A few days later, we could actually see the first tear gland organoids in a dish, shaped like a sphere.

This was only the first step, as these tear gland organoids mostly contained stem cells. Tear gland stem cells are different from the mature cells that are present in the tear gland. Importantly, the stem cells themselves are not capable of making or shedding tears. But tear gland stem cells do give rise to mature tear gland cells that are capable of crying. This process is called differentiation, and it takes place as soon as we stop stimulating stem cells to divide into other stem cells.[8] We found it took at least seven days of culturing before our tear gland organoids could produce tears.

Tearjerkers

The final step in our experiments was to make our organoids cry. In humans, crying upon feeling pain is induced by stimuli such as adrenaline. To recreate this process in a dish, we exposed our tear gland organoids to adrenaline.[9] Adrenaline made our tear gland organoid spheres swell like balloons. The organoids were secreting their tears on the inside: crying, but with nowhere for their tears to go.

What can now be done with these tear gland organoids? First, scientists can use them to study how the tear gland works: how it makes tears, what kind of tears it can make, and what happens when the tear gland does not produce tears anymore. At present, people with dry eye disease must constantly apply eye drops to lubricate the ocular surface. With tear gland organoids, scientists can now screen for better, more effective medicines that could help treat dry eye disease. Eventually, tear gland organoids could even be transplanted back into patients with dry eye. This strategy is already being applied in a clinical trial with salivary gland organoids.[10] Patients treated by radiotherapy following head and neck cancers often lose their salivary glands, resulting in dry mouth. It's hoped that transplanted salivary gland organoids could treat this affliction.

One other tissue we have our eye on is the tear gland of a crocodile—which is remarkably similar to human tear glands, but with some interesting differences.[11] One day soon, we may grow crocodile tear gland organoids in our lab, producing "crocodile tears" in the clinical environment of a petri dish for the very first time.



Right: A lab technician maintains cell lines for *Emergence*, 2024. Photo: Jordyn Doyel.



1 Hans Clevers, "Adult Stem Cells and Organoids, Part 1: Discovery and Characterization of Adult Stem Cells in the Gut," iBiology, virtual lecture, September 2019, https://www.ibiology.org/development-and-stem-cells/organoids/.

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8 "Cellular Differentiation," ScienceDirect, accessed April 21, 2025, https://www.sciencedirect.com/topics/neuroscience/cellular-differentiation.

9 Jarrod James, "Animal Instincts of the Human Body: A Psychological and Skeletal-Muscular Analysis of Adrenaline on the Human Body," *PIT Journal* 3 (2012): https://pitjournal.unc.edu/2023/01/15/animal-instincts-of-the-human-body-a-psychological-and-skeletal-muscular-analysis-of-adrenaline-on-the-human-body/.

10 University Medical Center Groningen, "Stem Cell Transplants Should Prevent a Dry Mouth After Radiotherapy," news release, March 11, 2021, https://umcgresearch.org/w/stem-cell-transplants-should-prevent-a-dry-mouth-after-radiotherapy (page no longer available).

11 Arianne P. Oriá, Ariane de J. Lacerda, Ana Cláudia S. Raposo, Nayone L. L. C. Araújo, Ricardo Portela, Marcos A. Mendoça, et al., "Comparison of Electrolyte Composition and Crystallization Patterns in Bird and Reptile Tears," *Frontiers in Veterinary Science* 7 (August 2020): 574, https://doi.org/10.3389/fvets.2020.00574.

In the run-up to the opening of *Emergence*, Dr. Yewande Pearse, the exhibition's director of science editorial and content, spoke with Dr. Marie Bannier Hélaouët, one half of the scientist duo behind *Crying Organoids* (2024), about her groundbreaking work: growing human lacrimal gland organoids, miniature tear glands that can mimic tear production. They discussed the scientific process and therapeutic potential of these organoids as well as the ethical questions surrounding their creation and display. Probing the intersection of science and art, they reflected on how *Crying Organoids* invites the public to engage with thought-provoking advances in biotechnology.



The Science and Wonder of Lacrimal Gland Organoids

Marie Bannier Hélaouët in Conversation with Yewande Pearse

Yewande Pearse

Can you describe the big-picture conceptual and technical aspects of your project?

Marie Bannier Hélaouët The overall aim of the project is to grow lacrimal glands in a dish. Technically, we take a small piece of lacrimal gland tissue, which contains stem cells, from a donor. These stem cells are then expanded in vitro, meaning we grow them outside the body, in a lab, by providing them with growth factors. These factors are naturally present when the body is injured and help tissue regenerate. So, in this controlled environment, the cells grow into what we call organoids—in this case, lacrimal gland organoids.

These organoids don't just grow; they retain the core function of the lacrimal glands, which is to produce tears. They can be stimulated with neurotransmitters like adrenaline, and when exposed to these stimuli, they start to tear up, just as we do when we feel emotional.

YP ## What are you hoping to convey to the public through the display of these lacrimal gland organoids?

MBH I hope it conveys something impactful, but I don't know if I want viewers to take away a specific message. I just want them to be amazed—to feel a sense of wonder and awe.

Above: Marie Bannier Hélaouët at work in the *Emergence* lab during opening weekend, 2024. Courtesy of Fathomers.

YP Absolutely. That sense of wonder is powerful, and I think it's what draws many scientists to their work in the first place. When I worked on brain organoids capable of spontaneous electrical activity, I remember hoping people would find them as mind-blowing as I did—at least initially. Do you feel that working so closely with this technology has desensitized you, or do you still find it awe-inspiring?

MBH Day to day, I'm definitely desensitized. But when I take the time to really look at the cells—especially organoids, which grow in three dimensions—I can see cells dividing, chromosomes condensing and then separating. It's still amazing if I take a moment to appreciate it. But honestly, I don't always have that much time.

YP The ultimate goal of your work with lacrimal glands is therapeutic. Could you expand on what that means outside of the exhibition context?

MBH Yes, there's significant potential for therapeutic impact. One in three adults suffers from dry eye disease, where in some cases the lacrimal gland doesn't produce enough tears. The symptoms are severe: Some people need to apply artificial tears every fifteen minutes, and they can't work or even be in the light due to photosensitivity. What we're hoping is that we can use these organoids as platforms for drug testing, to develop more effective treatments for dry eye disease. Right now, there isn't a cure. In the future, we're also exploring the possibility of using these organoids for transplants. Since they contain the stem cells of the lacrimal gland, we might be able to grow these cells in vitro and inject them back into the patient's own gland to restore tear production. It's a long-term goal, but it's not beyond the realm of possibility.

YP *Emergence* focuses on the intersection of art and science. How do you feel about presenting your work in an artistic context?

MBH I'm still processing it. To be honest, I don't consider myself an artist; I'm just showing what I do in the lab. I see the beauty in the science itself, but I'm not sure how it fits into an art context yet. I think that's something I'll discover through the exhibition.

YP That's the whole goal of PST ART: *Art & Science Collide*, to bring the two worlds together. I think it's interesting to reflect on how your work is being presented in this context, even if you don't see yourself as an artist.

MBH Yeah, I'm really curious to see how it will be perceived in the artistic space because I'm still very much in the scientific space. I've shown the organoids to people and they've been amazed, but I'm interested to see how it will be received artistically.

YP *Emergence* invites the public to explore deep questions about creation, destruction, and what it means to be human. How do you see your work with organoids contributing to these themes, and how do you hope it will provoke thought and dialogue among viewers?

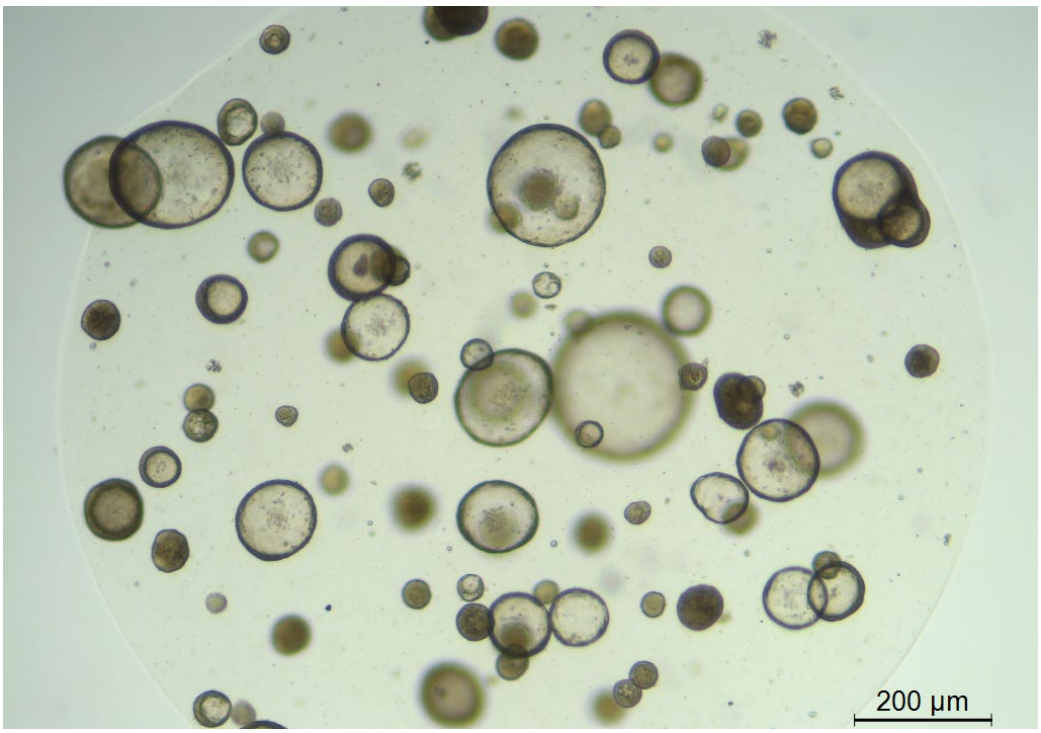
MBH I hope people become aware of what we're capable of doing in the lab. Organoids are an established technology—they've been around for about fifteen years now—but many people still don't know that we can grow mini organs. They're never going to be as complex as real human organs, at least not for the foreseeable future, but they're getting closer and closer.

What's exciting is that this technology allows us to better understand how the human body works. We can recreate organs like the lacrimal gland, the gut, even parts of the brain, and this gives us a much deeper understanding of how these organs function. But it also raises ethical questions. This technology is expensive, resource-intensive, and still relies on things like animal-derived materials. So while we're making incredible scientific advances, we also have to ask: Do we have the resources, and should we be pursuing this path?

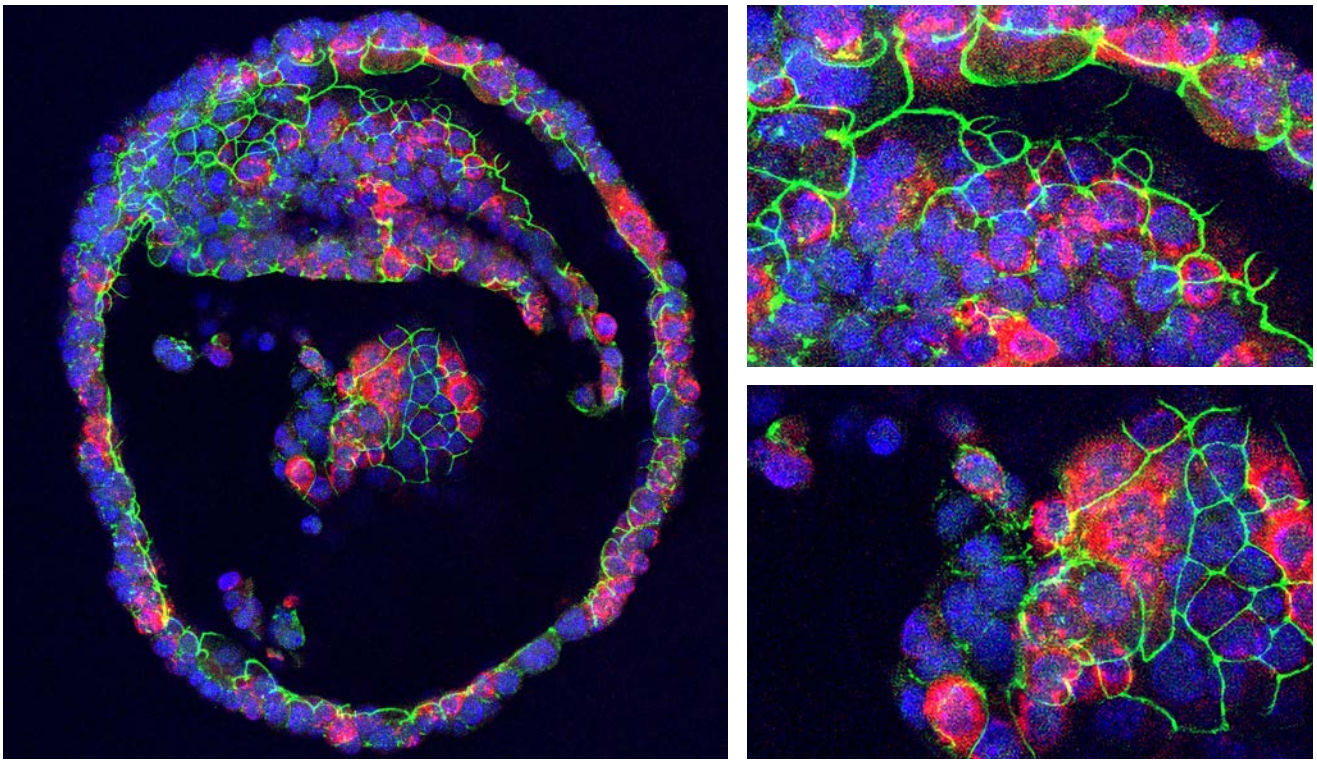
YP That's an important point, especially given the ethical implications. Another fundamental question is about the ethics of creating this tissue in the first place. How do you view your role as a scientist in bringing these organoids into existence? What responsibilities do you feel toward the life-forms or entities you create and study?

MBH I feel a deep responsibility to the people who donate tissue samples. Donating a piece of your body for research isn't a straightforward decision. I sometimes wonder if I would be comfortable knowing that a piece of me is growing somewhere in a lab. While I see the potential benefits—helping develop new medicines or understanding how the body works—it's still a complex decision. When an experiment doesn't work, I feel the weight of that responsibility. The person who donated the tissue might have had great hopes for what it could achieve, but in research, failure is part of the process and may lead to success further down the line. It's difficult to balance those expectations. I also feel a responsibility to the people that emailed me after the lacrimal paper came out, desperate for help. It's sad not to be able to help them right away, but I hope in the long run, this work will make a difference.

As for what generating these organoids means for society, I don't feel the same kind of responsibility as I might if I were creating brain organoids. There are ethical questions about brain organoids and whether they might develop some level of consciousness—they probably won't—but with lacrimal organoids, that's not at all a concern.



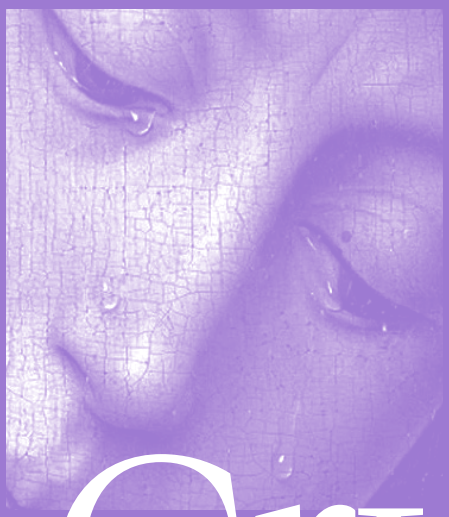
Human lacrimal gland organoids. © 2021 Hubrecht Institute. Photo: Marie Bannier Hélaouët.



VP That's a great answer. I think it's important to underline the difference between these entities: organoids, whether brain or lacrimal gland, are not fully living, even though they reflect aspects of life. To cry is to be alive, and that's why this has such an impact on patients. I have one last question. *Emergence* encourages us to reflect on the forms of life we choose to cultivate and the agency involved in making, learning, and living with these new life-forms. What do you hope visitors will take away from this exhibition?

MBH I hope they'll walk away amazed at what we can do in the lab. The fact that we can take a piece of human tissue and grow mini organs—that's something potentially astonishing. Beyond the wow factor, though, I hope they see the potential this technology has for helping people. It can lead to new drug discoveries, new treatments, and a better understanding of how our bodies work. But it all starts with this incredible ability to grow organoids in a dish.

Above: A human lacrimal gland organoid. Blue shows the cell nucleus, red shows a tear protein called lipocalin-2 (LCN-2), and green shows a channel by which the gland secretes water. © 2021 Hubrecht Institute. Photos: Marie Bannier Hélaouët.



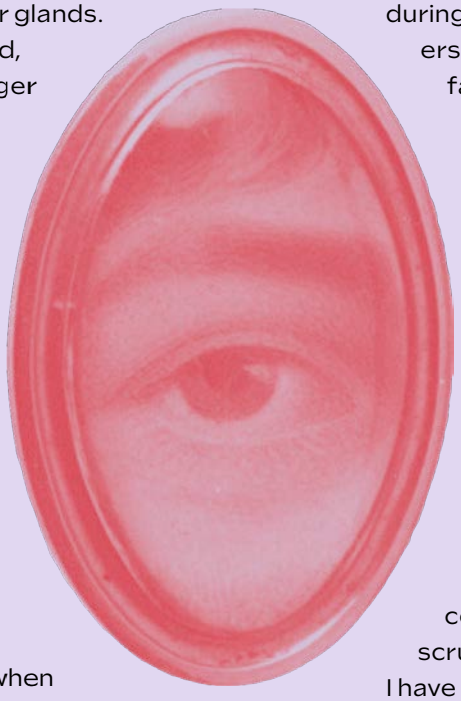
Crying Inside



Claire L. Evans

These days, it seems I can't stop crying. It's not that I'm sad. My eyes seem to well of their own accord even when I'm perfectly happy; on sunny days, long sheets of bitterly salty tears can wear down my skin until it's red and raw. I've determined that it's not me—it's my tear glands. They simply act of their own accord, springing into action on a hair-trigger and misinterpreting the world as one great tragedy, which perhaps it is.

They've had a lot of practice, since I've always been a good crier. In the shower, in parking lots, and especially in the aisles of fluorescent-lit grocery stores. As any good crier can tell you, there are different kinds of tears. Some flush your eyes; others flush your soul. The latter—emotional tears—are a uniquely human phenomenon.



It's still a mystery why people cry when they're upset, moved, or angry. Cries of distress are common in nature: Baby birds, primates, humans, and other mammals cry aloud when separated from their mothers. The difference is that animals grow out of it. Of course, my cat whines, but only because the sound solicits attention from her human master, who cries still in adulthood—and often at inopportune moments.

Animals don't shed tears of emotion; they cry in voice alone. In people, the dry howls of infancy are replaced by the discreet tears of adulthood. As the clinical psychologist Asmir Gračanin points out, humans have extended childhoods during which we depend on our caregivers for years, a state of affairs that favors tears—a "silent strategy" to elicit support from specific individuals—over tantrums, which lose their effectiveness.[1] This brings me to the evolutionary function of tears, why we make them in the first place: They're social glue. Crying is an invitation for care and kinship. Of course, I always cry alone, but honing an evolutionary advantage has never been my strong suit.

For me, crying is cathartic. I come out the other end lighter, scrubbed clean of dread, and indeed, I have been scrubbed: Tears physically siphon away stress hormones. But there are still two schools of thought on emotional tears. Some peg crying as an *arousing* behavior, part and parcel of the angst that causes it. Others are certain it's a *soothing* behavior, a release.[2] That we still don't know which of these two models is accurate is testament to crying's complex psychophysiology, which yokes together both

This brings me to the evolutionary function of tears, why we make them in the first place: They're social glue. Crying is an invitation for care and kinship.

Opposite page: Rogier van der Weyden, *The Descent from the Cross*, before 1443 (details). Oil on panel, 80 1/2 × 102 in. Museo del Prado, Madrid (Wikimedia Commons, CC BY-SA 3.0). **Above:** British painter, *Eye Miniature*, ca. early 1800s. Ivory, 3/4 × 1/2 in. The Metropolitan Museum of Art, New York, gift of Mr. and Mrs. John W. Starr, 1954.

the sympathetic and parasympathetic nervous systems and touches multiple interrelated areas of the brain. It's also evidence of the limited research that has been done on this subject.

her tears, although evocative, have more to do with slide preparation and photographic technique than any inherent material difference between, say, tears of frustration and tears of pain. But there is another, more rigorous way to study tears under a microscope. This is what Dr. Marie Bannier Hélaouët, formerly of the Hubrecht Institute in the Netherlands, has done. Along with her colleague and advisor, the geneticist and molecular biologist Hans Clevers, she replicated the entire tear gland in miniature and made it cry.

The tears of these glands were not emotional tears, exactly; that would presume that the glands can "feel" on their own, untethered from the brain and the neurochemical system that floods them with hormones.

Tears are, after all, slippery. It's very difficult to measure their precise onset or to trigger them consistently. While emotional films and music might get some people reliably weepy, emotional reactions are highly subjective, specific to individual tastes, cultural backgrounds, and experiences. All studies of emotional tears are stymied by the subject's inherent subjectivity. Might it be possible to engineer a universally tear-inducing prompt? To discover what sets tears of true sorrow apart from the baser reflexes of everyday eye hygiene? Such a task may be beyond the purview of science.

In 2008, the artist Rose-Lynn Fisher began a project of capturing her own tears and photographing them under a microscope. In the face of overwhelming grief, she found solace in focusing on the material quality of crying, its textures. She let her tears evaporate on slides and pressed them between wafer-thin glass. In the resulting images, her tears look like aerial photographs of ruined cities, imaginary coastlines, and computer chips edged in crystalline salt flats. "The topography of tears revealed to me a momentary landscape, transient as the fingerprint of someone in a dream," Fisher wrote.[3]

This was not an empirical study of tears but a deeply felt one—Fisher's own natural history of grief, joy, and catharsis. The varying textures of

In every organ in the body, adult stem cells serve as internal engines of renewal, occasionally awakening from quiescence to divide and regenerate replacements for damaged cells. They are so good at doing this that when these cells are removed from the body and left to their own devices, they will naturally self-assemble into miniature working models of the organs from which they were drawn. The first such "organoid" was created in 2009, using stem cells from the intestine; in the busy years since, biologists have miniaturized nearly every major organ in the body, including the brain. Despite their tiny size, organoids are faithful models. Gut organoids digest; brain organoids crackle with electrical activity; lacrimal gland organoids, it turns out, cry.

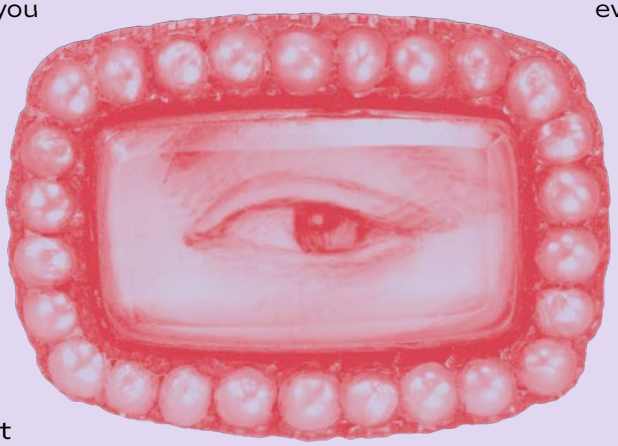
Bannier Hélaouët began with stem cells surgically extracted from human lacrimal glands—the bean-shaped glands, just below our brow bones, that produce tears. She laid the cells in a sugary cushion of nutrients known, poetically, as a "human expansion medium." Under her care, the cells set

about doing, in the medium, what they ordinarily do in our heads. After a week, they'd formed spherical, functional tear glands no wider than a human hair. There was only one thing left for Bannier Hélaouët and her colleagues to do: cajole them into crying.

The tears of these glands were not emotional tears, exactly; that would presume that the glands can "feel" on their own, untethered from the brain and the neurochemical system that floods them with hormones. Rather, after much trial and error, the tears were brought on by the introduction of adrenaline—something closer to a reflex reaction, although Bannier Hélaouët is still unsure what variety of tears her organoids produced. As the organoids watered, Bannier Hélaouët was flooded with relief. "That was my PhD moment, getting them to cry," she says.

Bannier Hélaouët is a crier, like me. "I am very emotional," she tells me. "I cry for nothing—I'm tired, I cry. It feels like a baby mechanism: You're tired, you cry. You're mad, you cry. You're sad, you cry. You're happy, you cry." In the lab, however, she beamed as tears welled up inside the tiny glands. Some swelled; the smallest burst like water balloons.

I can't help but think of the human stem cell donors whose lacrimal glands were biopsied during surgery, going about their lives. Did they know that somewhere in a lab in Utrecht, a very small part of them wept? We all contain billions of cells, bacterial and human. None of those individual cells constitute who we are, exactly; it's the assemblage of them all, an emergent pattern we call "self," that looks back at us from the mirror.



Without that larger human context, a tear gland cries for nothing. It doesn't invite care and kinship; it is not catharsis; it is not emotional.

A tear without anyone there to cry it: sounds like a Zen koan. It's a beautiful image, but where does it belong, exactly—in a laboratory or in an exhibition space? Bannier Hélaouët does not consider herself an artist. "I'm very rational, normally," she tells me. I tell her rational people can produce beauty too. She hesitates. "But is that art?" she asks.

Perhaps—in the eye, so to speak, of the beholder. It's certainly good science: The recently minted Dr. Marie Bannier Hélaouët earned her PhD on the strength of this research, and her organoids will be used to screen for treatments for dry eye disease. Clinical trials are a long way off, but someday, lacrimal organoids might be transplanted back into patients, helping them to cry again. Science is often beautiful, and the science of life is most beautiful of all. Biology resists tidy categorization; it's dynamic and ever-changing, always greater than the sum of its parts. The discovery of some clever cellular clockwork never stays on the petri dish. At every scale, it implicates us and implicates the world.

Organoids allow scientists to externalize and examine under the microscope the dynamic, often mysterious forces at play within our bodies. It's uncanny that even in our absence, our cells still come together, compelled to create living structure, to heal, to coordinate themselves, to cry. The process by which this morphogenesis happens is still poorly understood. As Bannier Hélaouët tells me, stem cells

"Eye" Brooch, ca. early 1800s. Portrait miniature, possibly on ivory; pearls; rock crystal; and gold; 7/16 × 5/8 × 1/4 in. The Metropolitan Museum of Art, New York, bequest of Mrs. Charles Wrightsman, 2019.

seem to have a built-in limit; after they've grown to about one thousand cells, they stop. We don't know why. "Potentially, they sense that there is enough," she says. At this point the organoids have to be split and their pieces propagated again, like cuttings from a strange houseplant. Only then can the process begin again. Cells, it seems, are driven by a hardwired biochemical, bioelectric language—something very ancient indeed.

As the novelist Steven Millhauser writes, a miniature is "an attempt to reproduce the universe in graspable form."[4] It's a way of momentarily possessing the unknown and the unknowable—and indeed, there's nothing more unknowable, at least for now, than the relentlessly self-organizing force we call life. It's just too vast for us; it has been the project of generations of human effort merely to sketch its outlines. In art as in science, the sensation of reducing something so complex to a working model—finishing a novel, building a dollhouse, or watching a single tear form under the microscope—is a profound enchantment.

But that enchantment is bittersweet, too. By isolating life from its context, we also irrevocably isolate ourselves. It may be satisfying to trace a boundary around complexity, to name it—but in the case of organoids, that complexity is also something we have drawn out from *within ourselves*. In order to see what force animates our cells, we're stuck standing outside them, looking in like lonely giants gazing into a dollhouse we can never inhabit. No matter how detailed, the dollhouse world of the organoid will always be beyond our grasp. The real action is somewhere else—beneath, within, on the scale of cells and molecules, bound up in the unseen patterns that yoke life to itself, defying entropy. It is both infinitesimally small and all-pervasive, fleeting and ancient.

Bannier Hélaouët's question echoes: *Is it art?* I think so: if not in intent, then in effect. Many artists would see themselves in this image of the lonely giant at the threshold of the dollhouse door. We artists draw precious complexities from within ourselves, too. Stories, images, memories, emotions—all those life-giving things we store in our marrow, and which, like stem cells, heal us from within. Transferred carefully to the "human expansion medium" of canvas, screen, or page, they will stay alive—up to a point. But the end is the same. We can never be wholly *of* the magic that illuminates us. Millhauser writes:

> Here is the farthest I can see into the mystery of the miniature: its separation from myself, its banishment of me. Hence the sadness, the secret poignance, of dollhouses, model whaling ships, glass animals, little automatons. No, it is not enough to be God, I wish to be my own creature. And is it possible that the deepest fascination of the miniature lies here, in the unfulfilled yearning to be part of that world? For we are in disharmony with the world, we do not fit in anywhere.[5]

It's so sad, isn't it? I could almost cry.

1 Asmir Gračanin, Lauren M. Bylsma, and Ad J. J. M. Vingerhoets, "Why Only Humans Shed Emotional Tears: Evolutionary and Cultural Perspectives," *Human Nature* 29, no. 2 (2018): 104–33, https://doi.org/10.1007/s12110-018-9312-8.

2 Lauren M. Bylsma, Asmir Gračanin, and Ad J. J. M. Vingerhoets, "The Neurobiology of Human Crying," *Clinical Autonomic Research* 29 (April 2018): 63–73, https://doi.org/10.1007/s10286-018-0526-y.

3 Rose-Lynn Fisher, "The Topography of Tears," Rose-Lynn Fisher, 2024, https://rose-lynnfisher.com/tears.html.

4 Steven Millhauser, "The Fascination of the Miniature," *Grand Street* 2, no. 4 (1983): 135, https://doi.org/10.2307/25006539.

5 Millhauser, "Fascination of the Miniature," 135.

Opposite page: Marie Bannier Hélaouët and Albert Wu with Stanford Ophthalmic Stem Cell and Regenerative Medicine Laboratory members Aditi Swarup, Hala Dhowre, Sanja Bojic, and Julietta Picco, *Crying Organoids*, 2024. Detail: bright-field microscope with organoids. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.


Leica



The *Emergence* lab at the Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers. Photo: Carson Davis Brown.


EMERGENCY
EYE WASH KIT
EMERGENCY
EYEWASH STATION KIT
CLASS II, TYPE A2
BIOLOGICAL SAFETY CABINET

Growing Visions

Marie Bannier Hélaouët in Correspondence with Stacy Switzer and the *Crying Organoids* Team

Crying Organoids (2024) began with my visit to Dr. Marie Bannier Hélaouët at the Hubrecht Institute in Utrecht, the Netherlands, in summer 2022. I had read about Marie's groundbreaking work on lacrimal gland organoids in the popular press and was smitten by the idea of tiny flesh objects that could be coaxed to weep on their own. In that first meeting, Marie was open to the idea of working on something together, if a bit uncertain as to why Fathomers would want to feature her research in a contemporary art exhibition. As we chatted, she noted a key technical and regulatory hurdle: In order to show living lacrimal gland organoids in Los Angeles, we'd need to source stem cells from somewhere in the state of California. A short time later, back in LA, Fathomers research assistant Natasha Boyd set out to find a local partner for the project, prioritizing university-based ophthalmic researchers who might have some interest in contemporary art. Our top choice was Dr. Albert Wu, director of oculoplastics research at the Ophthalmic Stem Cell and Regenerative Medicine Laboratory at Stanford Medicine and a founding editor of the *Journal of Narrative Visions*, a creative online journal of "narrative ophthalmology, optometry, and vision care."

Albert was quick to count himself and his team—Dr. Aditi Swarup, Dr. Hala Dhowre, Dr. Sanja Bojic, and Julietta Picco—in on the project. It was a gift to have the Wu team contribute their own cutting-edge research and creativity. Free of early notions about whether our collective project could or should function as a readymade art object, scientific experiment, something in between, or something else entirely, the expanded team in Utrecht, Palo Alto, and Los Angeles brainstormed concepts, practicalities, research value, and the aesthetics of various possibilities over a number of months. I was gobsmacked when Albert suggested that we might even try to fuse corneal organoids (a research focus of his lab) with lacrimal gland organoids to create a hybrid semblance of a *whole eye*. Though we didn't ultimately pursue such an assembloid for *Emergence*, our group conversations about whether and why we might do so—alongside our efforts to work through countless other variables—are to me a key part of the project. These conversations illustrate aspects of the most successful art-science collaborations: Mutual respect abounds, roles and disciplines can be somewhat porous, and everyone is open to being influenced by what emerges.

—Stacy Switzer

This conversation has been lightly edited for length, clarity, and confidentiality.

On Wednesday, June 12, 2024, at 5:38 AM, Marie Bannier Hélaouët wrote:

Dear Stacy,

Do you know if they are already growing the lacrimal gland organoids in the lab and what kind of assembloids they will make? So is the plan still to have living organoids in the exhibit the whole time?

Marie

On Thursday, June 13, 2024, at 8:32 PM, Stacy Switzer wrote:

Hi Marie,

I don't believe that Dr. Wu's team has begun.

If you would be willing to check in with Aditi at the lab about her plans, I'd welcome it. And we would gladly defer to you and Aditi on what kind of assembloids would be possible and most interesting. Are there ones that would be of more or less scientific interest? Or would any such assembloid be mostly an absurd surrealist object? I'm open to the full range of interpretations and possibilities here.

We are hoping to exhibit living organoids for as long as we can, but are still researching what will be permitted and how we can best care for all of the living works in the show. In addition to the gallery display, we have been investigating trying to have a BSL2 mobile lab (in a Sprinter van) on site for medium changes, etc., but were recently dissuaded by some other folks who had tried a similar thing but failed because the permitting was too onerous. No surprise there, really—but we are still trying to find the right path. We have a job post circulating for part-time lab technicians to care for the organoids and other living works, and are looking for a biosafety consultant in LA who can give us definitive answers on what will be allowed. We are also looking at community labs in the area in case the organoids need to be shuttled back and forth. Otherwise, I wonder about revisiting the idea of having the organoids frozen in the gallery and thawing new ones for display every other day or so? Perhaps we could hop on a Zoom with Aditi to discuss?

Thank you, Marie!

Stacy

On Friday, June 14, 2024, at 8:20 AM, Marie Bannier Hélaouët wrote:

Hi Stacy,

I can check with Aditi what her plans are for growing the organoids. Regarding the assembloid part, I have not talked directly with Aditi so I don't know if they have expertise in making assembloids. If they have never done it before, I would assume it would be complicated. For instance, if I were to start this now, I would count on a good 6–12 months to get a protocol running and to characterize the assembloids (I assume you want to know what you are exhibiting also, no?). As nobody has done this very type of assembloid before, we can't know what it would look like. That's why we can't know in advance what added value it would have in the exhibition. It might look amazing and have additional features that would be cool to show, or it might not be able to do more than the individual pieces taken separately.

All the best,

Marie

On Tuesday, July 23, 2024, at 12:55 AM, Stacy Switzer wrote:

Hi all,

For the run of the exhibition, we would ideally like to have at least one living organoid on view each day. If it happens that we have only one kind of organoid on view on any given day, then I expect we would have the other(s) represented through fixed samples/additional documentation.

Additionally, it would be great if it were possible to stimulate swelling of a lacrimal gland organoid once each day (understanding that the swelling process is long and slow; we can think of it as a kind of durational performance art.[1] More on that here[2]). Alternatively, we could stimulate the crying once per week on, say, Saturday afternoons.

A lot also depends on how we choose to represent lacrimal, corneal, and any possible assembloids in relation to each other, e.g. "crying" and "seeing"? Are there any parallels in the way that these two different types of organoids behave/function in the dish? E.g., does the corneal organoid "see" to a similar degree that the lacrimal organoid "cries"? Aditi, I was also curious about your suggestion of fluorescing tears. Do you think this might actually be possible? Perhaps we can discuss these things in our Part II soon.

With gratitude and looking forward!

Stacy

On Tuesday, July 30, 2024, at 9:19 AM, Marie Bannier Hélaouët wrote:

Hi everyone,

Touching base following our previous conversation, I was wondering @Albert Wu and @Aditi Swarup, when do you think you will be able to start growing lacrimal gland organoids? Beyond the legal concerns for transferring the organoids to LA, if you haven't been able to start yet, I think it would be good to do it as soon as possible. It would leave us sufficient amounts of time to troubleshoot in case something is not working as we wish, and to produce enough organoids for the exhibition. If that helps, I am happy to have a round 2 meeting to discuss more concrete details: (a) the total amount of organoids needed for the exhibit, and (b) when they should be delivered to Fathomers.

@Stacy, just to clarify, I think that rather than having a single organoid every day, you'd like to have a droplet matrix containing organoids (cf. minute 3:10 of this video[3]). Each droplet contains 20 uL of extracellular matrix, hosts ~50 organoids, and has a diameter of 2–3 mm.

For the exhibition, I think we should consider/look further into the following aspects:

1) At what growth stage do we want to show the organoids? Just after splitting, the organoids are small pieces that look like in the left panel below (probably a bit larger than that, but I don't have a better picture at hand—sorry!). 2–5 days after splitting, organoids would look like the "p0d5" panel. Anything later than that would look like the last two panels. I personally find the last three panels most interesting to look at, and maybe more impressive for someone who doesn't know anything about organoids.[4] If you'd opt for displaying only the larger organoids, I think we should have two droplets running in parallel, with opposite splitting times. This means that, since human organoids require 7–10 days between each split, there would be a split every 4–5 days. On the other hand, it can also be interesting to show organoids in growth. They start small and grow into something big. You could also take snapshots once or twice a day and make an animation out of it. It wouldn't show the crying, but the growth over ~10 days.

2) How many extra organoids do we need for the crying assay and when should we prepare these? Be aware that to perform a crying assay, one needs to "differentiate" the organoids beforehand. This process takes 11 days after splitting. That means that if you would want a swelling assay on October 8, the organoids for this assay should be plated on September 27. For the first two days (till September 29), the cells are fed with human expansion medium, and for the next 9 days cells are fed with human differentiation medium. The human differentiation medium contains very few factors (essentially we remove the growth factors that allow the stem cells to proliferate and, since they cannot proliferate anymore, they differentiate into functional and

mature tear-producing lacrimal gland cells). The 11 days are noncompressible if you want the swelling to work on the day. If you'd want to have it running every day in the exhibition, it means that the organoids would need to be split every day starting September 27. If so, you would need a larger amount of organoids to start with, at least 1 droplet of organoids grown for 7–10 days every day.

Overall, I think it would make things easier to perform the swelling assay on a single day per week, but it is not impossible to run it every day provided we are very well organized. The larger the stock of organoids we have, the easier it will be to set this up. To give you a timeline, I think it is best (maybe even required) to start growing the lacrimal gland organoids in the next two weeks if they are not yet in culture. Otherwise, we will be tight on cells for the opening if we want a swelling assay.

Regarding the suggestion of Aditi to make fluorescent tears, I don't know any dye that would allow us to do that. Maybe you have one in mind @Aditi Swarup? What I know of is calcein green. It is a dye that stains living cells. The tears themselves wouldn't be fluorescent, but the organoids would be. Keep in mind that for that, we would need a microscope capable of imaging green fluorescence.

I was also wondering, how are things going with regards to BSL2? The largest equipment you need is the following:

- CO_2 incubator at 37°C if organoids are kept on site (12 hours outside an incubator can be fine, but you cannot always keep them like that)
- Microscope such as AutoEvos for live imaging/recording and/or a benchtop microscope for people looking through it
- A BSL2 hood
- A bench
- Ice and a fridge (if the organoid splitting is done on-site, the extracellular matrix needs to remain cold, otherwise it solidifies and you cannot resuspend the organoids in it)
- A centrifuge able to run at up to 500 x g
- Pipettes, plastic plates, plastic pipettes, pipette tips, culture media

All the best,

Marie

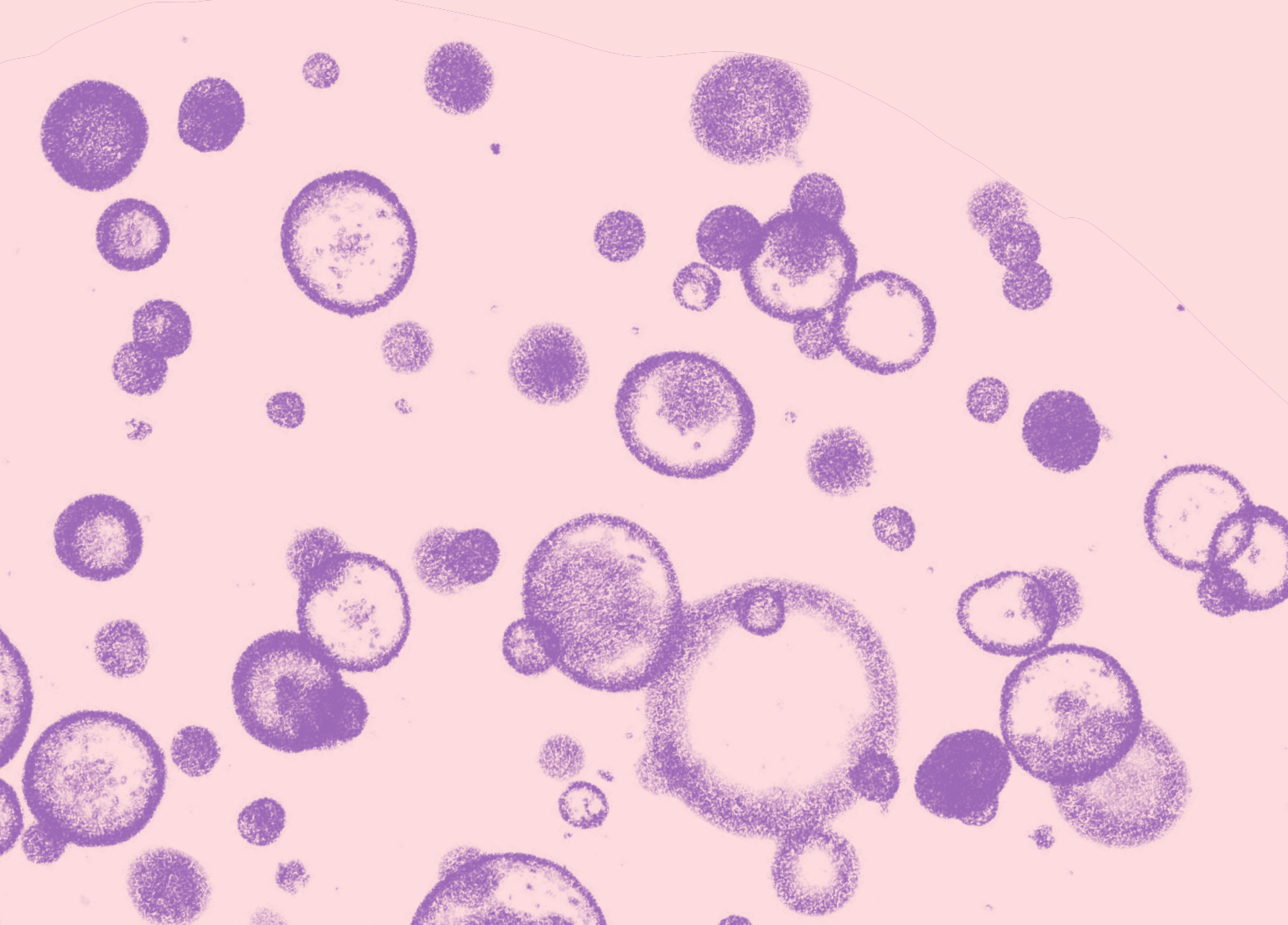


1 "Durational and Endurance Performance Art," Performance Art Resources, accessed May 10, 2025, https://performanceartresources.com/home/what-is-performance-art-live-art-action-art/performance-art-live-art-action-art-literature-books-information-and-more/durational-art/.

2 Andrew Russeth, "Art About Waiting—and What It Takes to Endure," *T: The New York Times Style Magazine*, September 17, 2020, https://www.nytimes.com/2020/09/17/t-magazine/Tehching-Hsieh-endurance-art.html.

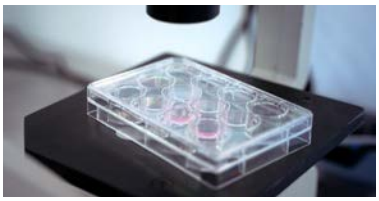
3 Marie Bannier Hélaouët, Maarten H. Geurts, Jeroen Korving, Harry Begthel, and Hans Clevers, "Establishment, Maintenance, Differentiation, Genetic Manipulation, and Transplantation of Mouse and Human Lacrimal Gland Organoids," *JoVE Journal*, February 23, 2023, video, 10 min., 49 sec., https://www.jove.com/v/65040/establishment-maintenance-differentiation-genetic-manipulation.

4 See figure 1B in Marie Bannier Hélaouët, Yorick Post, Jeroen Korving, Marc Trani Bustos, Helmuth Gehart, Harry Begthel, et al., "Exploring the Human Lacrimal Gland Using Organoids and Single-Cell Sequencing," *Cell Stem Cell* 28, no. 7 (2021): 1221–32, https://doi.org/10.1016/j.stem.2021.02.024.



Dr. Yewande Pearse, the director of science editorial and content for *Emergence*, sat down with Dr. Albert Wu—ophthalmologist, researcher, and *Crying Organoids* (2024) collaborator—to discuss his pioneering work in regenerative medicine. Together, they contemplated the dimensions of scientific discovery, unpacked ethical and regulatory questions around displaying living biological materials, and reflected on how witnessing laboratory-cultivated tissue perform deeply human functions, such as crying, can profoundly move audiences beyond the confines of medical research. While acknowledging the significance of Wu's organoids in offering new treatment possibilities for patients who have lost the ability to produce tears, he and Pearse also invite us to consider how scientific innovation can shift when placed in conversation with artistic expression.

Opposite page: Living cells under a microscope in the *Emergence* lab, 2024. Photo: Jordyn Doyel.



From Laboratory to Gallery: Reimagining Medicine Through Art

Albert Wu in Conversation with Yewande Pearse

Yewande Pearse

How does it feel to step out of the traditional medical and scientific space and into a more artistic context with *Emergence*? What do you hope viewers will take away from seeing your work presented in an exhibition?

Albert Wu It feels great to be able to wear a different cap. When you're a scientist or physician, there are certain constraints that do not allow for a full range of creative expression. Being involved with *Emergence* has allowed that part of my brain to be more fully utilized—it feels more free and untethered.

I hope viewers will see firsthand how life starts as a single cell and, as that cell divides, it can become many things—like an embryo or, in the case of our organoids, it can turn into mini organs. The individual cell, the process, and the finished product are all beautiful in their own right and in their own way.

YP Both science and art are inherently creative fields. How do you express creativity in your scientific work, and how do you think that creativity manifests in the way you approach solving medical and biological challenges?

AW In scientific work, my creativity is expressed in the solutions to problems: how efficiently and simply one can show or prove something. Human beings are not easily described or explained in ways that are compatible with science. When you treat patients, creativity informs how you navigate emotion: pain and despair, or hope and joy.

YP What, if anything, do you think scientists can learn from the art world? Do you feel that artistic interpretation offers a different perspective on your work and on the field of synthetic biology?

AW I think art lets you see things in a different light. That fresh perspective is useful when applied to a scientific problem: to break through barriers and to think differently.





Albert Wu (left) and Marie Bannier Hélaouët (right) speak at the opening of *Emergence*, 2024. Courtesy of Fathomers. Photos: Jordyn Doyel.

VP As the public engages with your work in the exhibition, do you have any concerns about potential misunderstandings regarding your research?

AW The greatest potential misunderstandings are likely related to how the stem cells can be used and to the ethical considerations of using them. It may be less a misunderstanding than an incomplete understanding of what the cells can become and what they truly are.

VP You collaborated on this project with Dr. Marie Bannier Hélaouët, who also works with lacrimal glands to treat dry eye disease. The specific lacrimal glands featured in the exhibition were cultured by your lab. Can you explain the process of creating them and, specifically, how you are harnessing synthetic biology techniques to advance your own research goals?

AW By taking tear gland cells and allowing them to propagate to become functional, we are able to maintain and transfer the ability to tear. This is very useful in dry eye disease, especially in patients who have lost the ability to tear.

VP Cell cultures are protected by significant ethical, regulatory, and safety standards. What challenges did you face in navigating these justified barriers to bring live tissue from the lab into public spaces for *Emergence*? How has this experience shaped your perspective on interdisciplinary collaboration across art and science, and on making science more accessible to the public?

AW There are many safeguards to make sure the materials are used in an ethical way. With any technology that is potentially hazardous, it is good to protect the public. I think it requires true motivation and passion to overcome the frustrations that occur when going through the necessary red tape.

YP The lacrimal gland organoids can produce tears, which is a deeply human, emotional action. Do you think this biological function, when presented in an art exhibition, can evoke a deeper emotional connection between viewers and the science behind it?

AW Yes. Seeing a very human action take place without the human can be startling. But it also touches us all to see that showcased, and it's potentially even more powerful to imagine the people who can be made "whole" again with the transplantation of these cells.

YP Scientists and artists both tell stories, though in different ways. How do you feel your work with organoids, when displayed as part of *Emergence*, contributes to the broader narrative about what it means to create life, restore function, and push the boundaries of what's possible?

AW The work opens people's eyes to what is possible, not just in the imagination but in reality. Seeing is believing. When we actually see something new happen, something we didn't think was possible, that is a key moment—that can inspire and change people and society.

YP Art often encourages us to step back and consider the broader meaning and implications of our work. Has participating in this exhibition shifted your perspective on your research in any unexpected ways?

AW Seeing firsthand the impact of this work on people has strengthened my resolve to bring the benefits of regenerative medicine to the world. I've seen people's hope that cures are now within arm's reach and that we can start tackling aging—which is core to the human experience.



Marie Bannier Hélaouët and Albert Wu with Stanford Ophthalmic Stem Cell and Regenerative Medicine Laboratory members Aditi Swarup, Hala Dhowre, Sanja Bojic, and Julietta Picco, *Crying Organoids*, 2024. Detail: live projection of human lacrimal gland organoids. Installation view: *Emergence*, Japanese American Cultural & Community Center, Los Angeles, 2024. Courtesy of Fathomers.

FATHOMERS

Emergence
創発
Art from Life

October 8–December 15, 2024

Japanese American Cultural & Community Center, Los Angeles

Featuring the work of

AfroRithm Futures Group: Ahmed Best, Dr. Lonny J. Avi Brooks, and Jade Fabello, in collaboration with Dr. Drew Endy, Jesse Gilbert, Raquel Horsford, Malaya, and Oguri

Dr. Marie Bannier Hélaouët, Organoid Group, Hubrecht Institute of the Royal Netherlands Academy of Arts and Sciences and Oncode Institute, The Netherlands; and Dr. Albert Wu, Ophthalmic Stem Cell and Regenerative Medicine Laboratory, Stanford University, with lab members Dr. Aditi Swarup, Dr. Hala Dhowre, Dr. Sanja Bojic, and Julietta Picco

Dr. Callie R. Chappell and Dr. Nasa Sinnott-Armstrong

Michael Jones McKean, with assistance from Dr. Stephen Fong, Professor of Chemical and Life Science Engineering, Virginia Commonwealth University, in cooperation with the Museu de Leiria, Portugal

Eduardo Padilha

Dr. Pat Pataranutaporn

Corinne Okada Takara

Henry Tan, Masato Takemura, Pakchira Chartpanyawut, Weeratouch Pongruengkiat, Woraporn Pongsamart, Dr. Pat Pataranutaporn, Jirapat Thaweechuen, Tanis Phongpisantham, Pongsakorn Wechakarn, Sumeth Klomchitcharoen, and Kookpedz Studio

Tissue Culture & Art Project: Oron Catts and Ionat Zurr, with assistance from the UCLA Art|Sci Center and the California NanoSystems Institute

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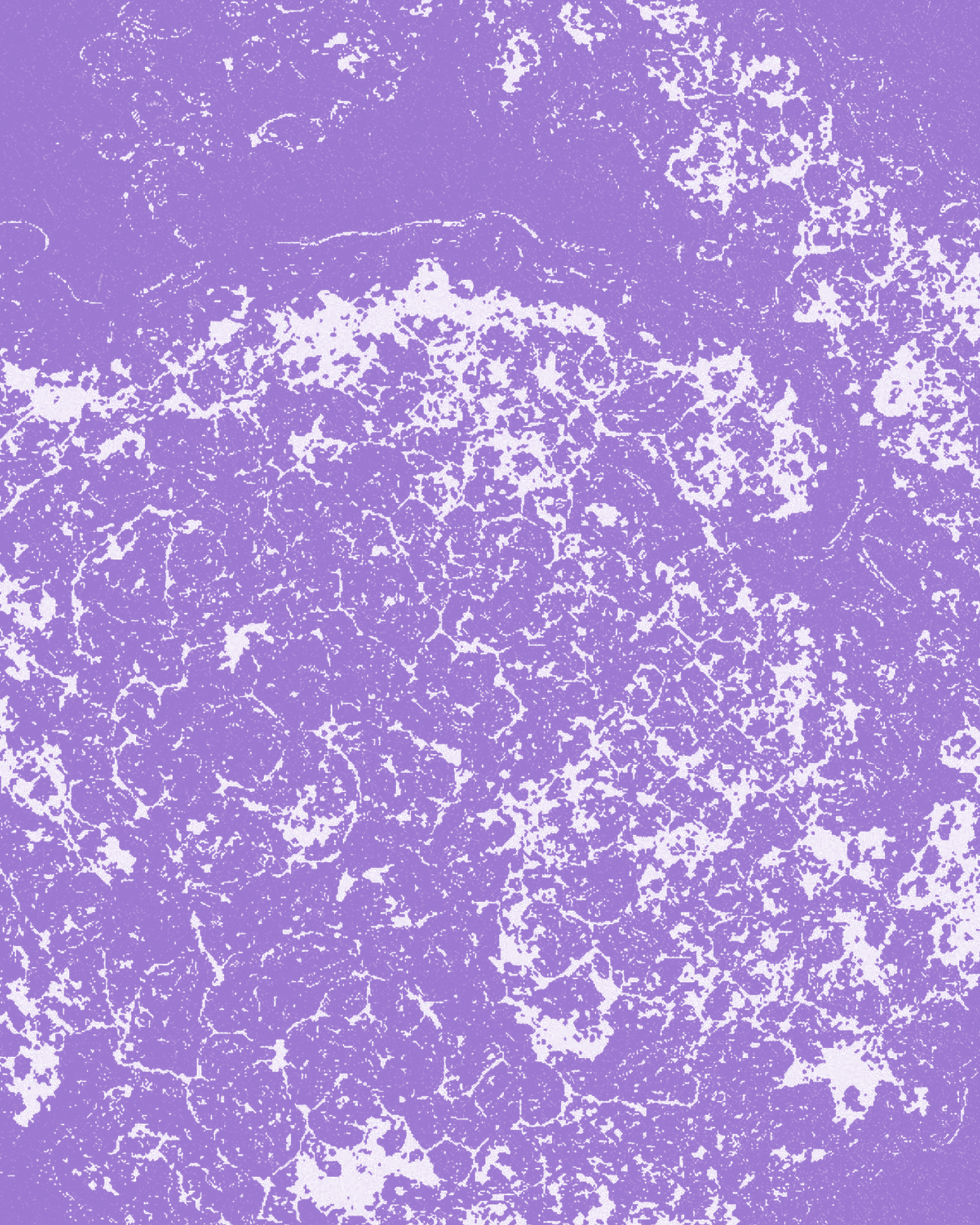
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Tissue Culture & Art Project

Edited by Dr. Yewande Pearse and Stacy Switzer

Emergence explores how artists, scientists, and artist-scientists engage with synthetic biology to imagine new forms of life, agency, and authorship. First as an exhibition and now in print, *Emergence* asks: Who has power in this moment of making, learning, and living with? What forms of life are we choosing to cultivate? What will we nurture, and what might we leave behind?

Fathomers is a creative research institute in Los Angeles, CA.

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