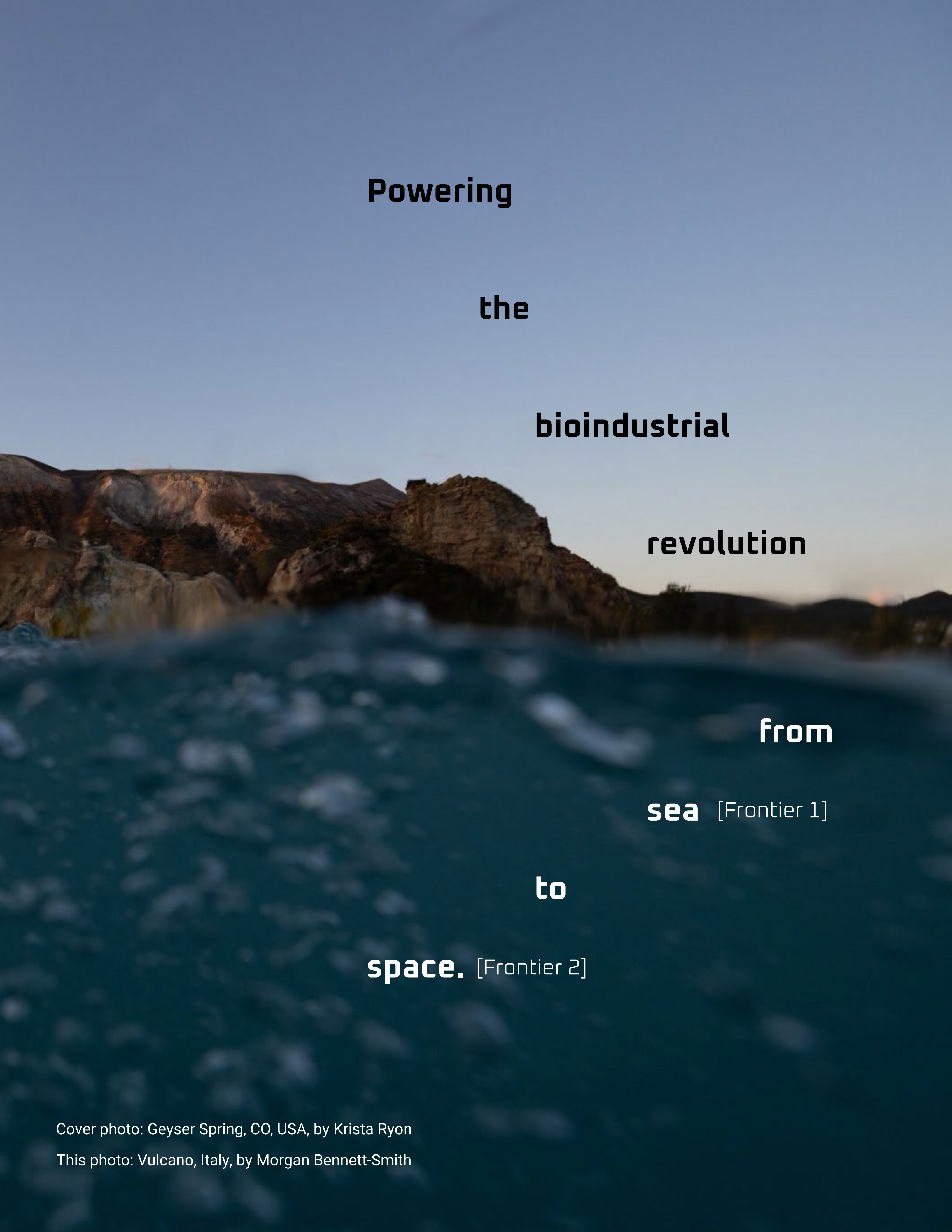
2025

Impact Report



Powering the bioindustrial revolution from sea [Frontier 1] to space. [Frontier 2]

Cover photo: Geyser Spring, CO, USA, by Krista Ryon

This photo: Vulcano, Italy, by Morgan Bennett-Smith

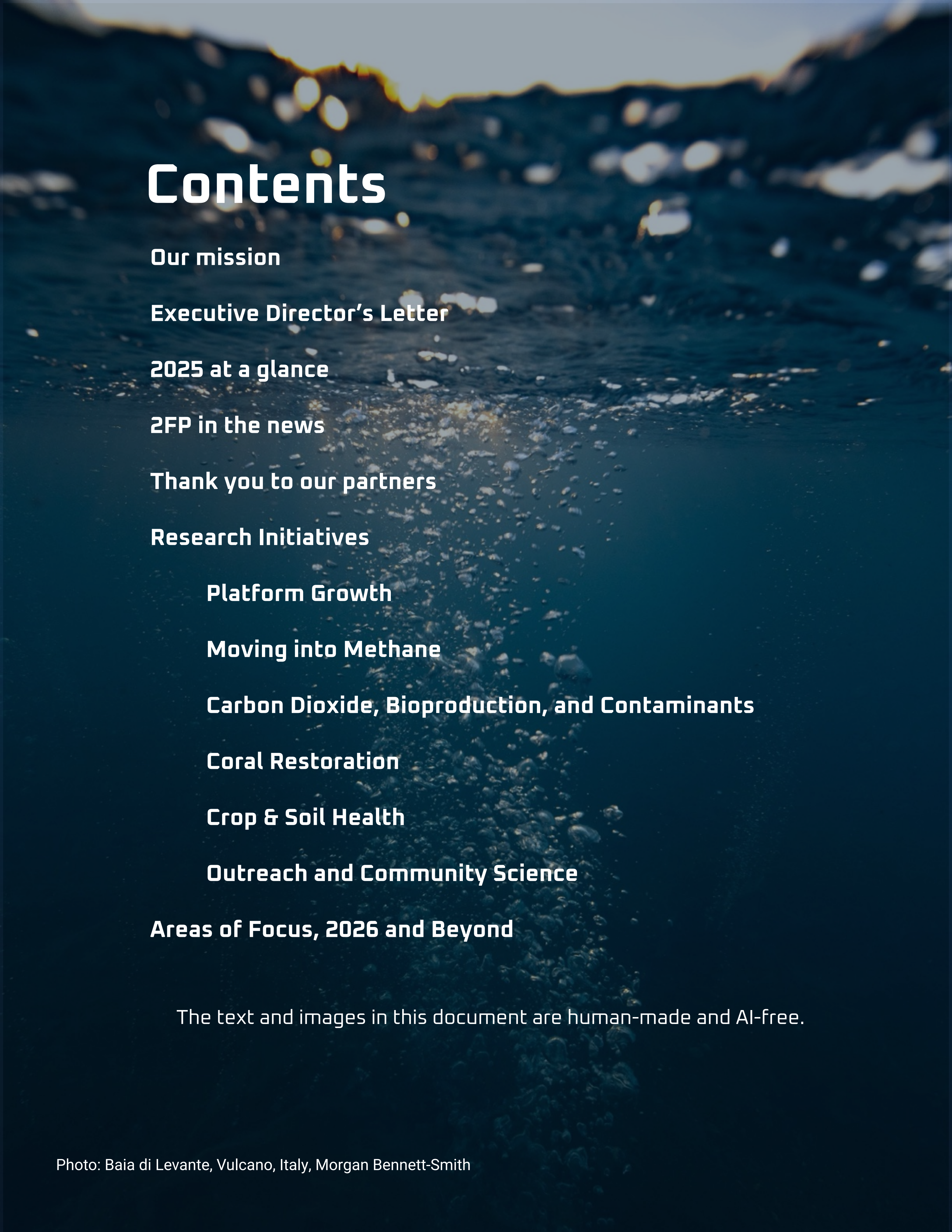


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Photo: Baia di Levante, Vulcano, Italy, Morgan Bennett-Smith

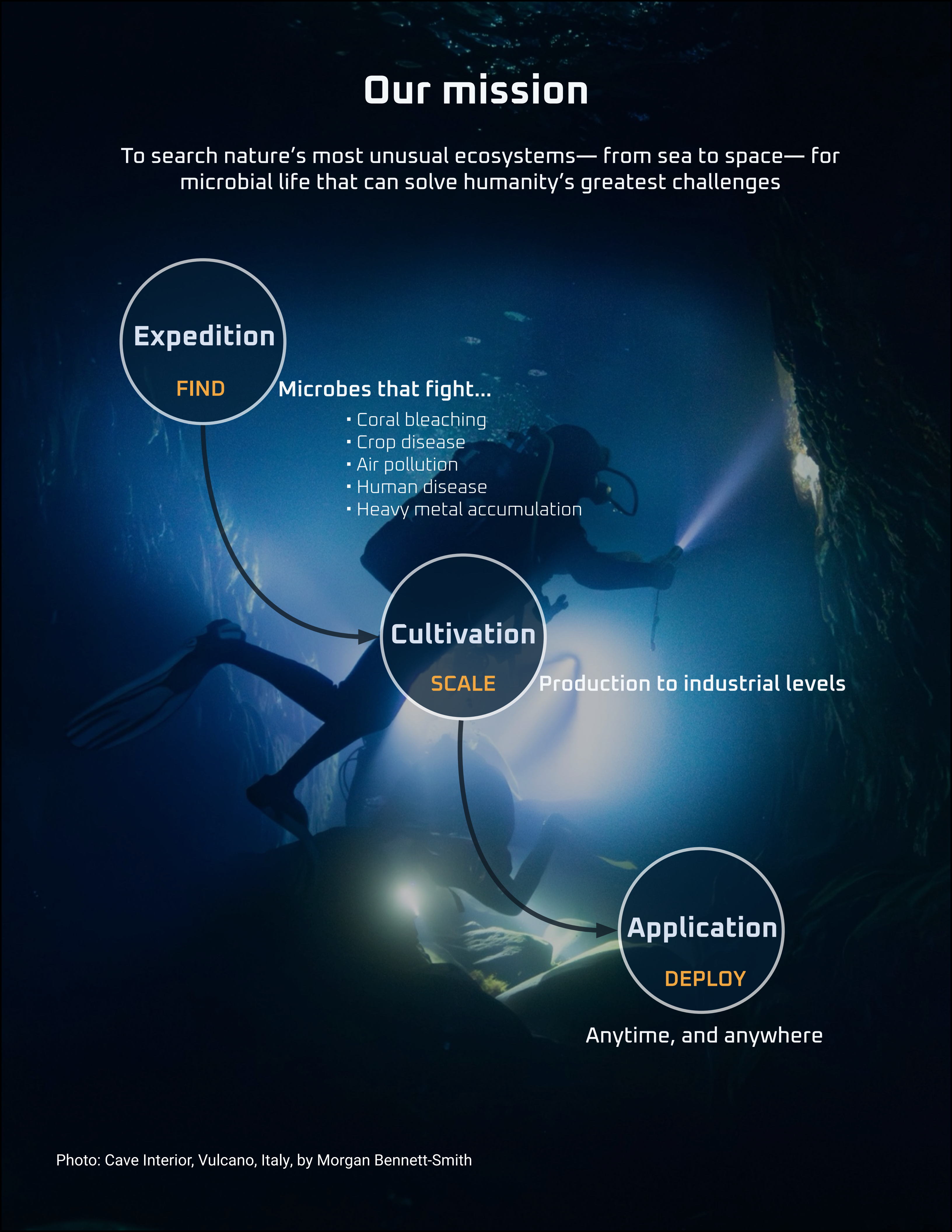


Photo: Cave Interior, Vulcano, Italy, by Morgan Bennett-Smith

Executive Director's Letter

Dear friends of 2FP,

Imagine a world where each AI company must first build its own computing chips – that is the world of microbial biotechnology. Commercialization in biotech faces a tragedy of the commons: every firm must independently surmount identical, universal challenges, from dataset construction to large-scale fermentation. For-profit organizations are not incentivized to collaborate, so companies burn capital to the point of insolvency on the same early-stage problems; the more difficult, downstream challenges are rarely even reached.

This is why 2FP is a non-profit. We are not the only organization looking to nature's microbes for new technologies, but we are unique among our peers in our approach. We do research, publish papers, and share our data, **all in the name of driving down the universal costs of microbial biodiscovery**. We **will** spin out companies, but not until we've built a clear roadmap to productization. Our dedication to open-access cost reduction is how we saved tens of thousands of dollars in the field with custom-built methane sensors. It's why you can find our protocols, 3D-printed tools, and software online. It's how we operate at ~5X capital efficiency compared to similarly minded biotechs. Above all else, it's why we focus on nature-based solutions: over billions of years, **evolution has figured out how to solve our problems more efficiently than we could on our own**.

For 2FP, 2025 was the "year of the platform." In 2024, in the volcanic vents of the Aeolian Islands, we validated our central hypothesis: that biotech's missing microbial tools are locked away in nature's most unusual ecosystems. **This past year, we built a skeleton key**.

As of January 2025, we had a narrow focus to our technical infrastructure; it heavily emphasized culturing organisms relevant to carbon sequestration. By December, we had constructed a scientific platform that – through custom software and high-throughput culturing – can access microbes of all kinds: from those that can clean up forever chemicals to new probiotics for aquaculture.

During this window, we spent **$394,187**. This budget left little room for error. Accordingly, we only pursued projects that (1) would yield scientific novelty with (2) commercializable outcomes and (3) would expand our technical capabilities. For example, we built a methane capture initiative, aiming to discover treatments for rice-paddy-based methane emissions. We used this program as an opportunity to develop low-cost, in-field anaerobic culturing workflows, unlocking a number of other application spaces. From coral aquaria to biosurfactants to ingredient production – **every target you will see described in this report was pursued with analogous strategic intention**.

None of this would have been possible without the support of many of you reading this document. Beyond the innovation, beyond the expeditions, the most essential component of 2FP is the community of people who believe in our mission. Everyone – our volunteers, our donors, our collaborators around the world – you are the heart of 2FP. I feel so lucky to work with you all.

Enjoy this deep dive on what we've been up to, and I hope you'll join us as we charge into 2026.

Braden Tierney
Executive Director
The Two Frontiers Project

Photo: Spring, Colorado, Sean Greene

2025 at a glance

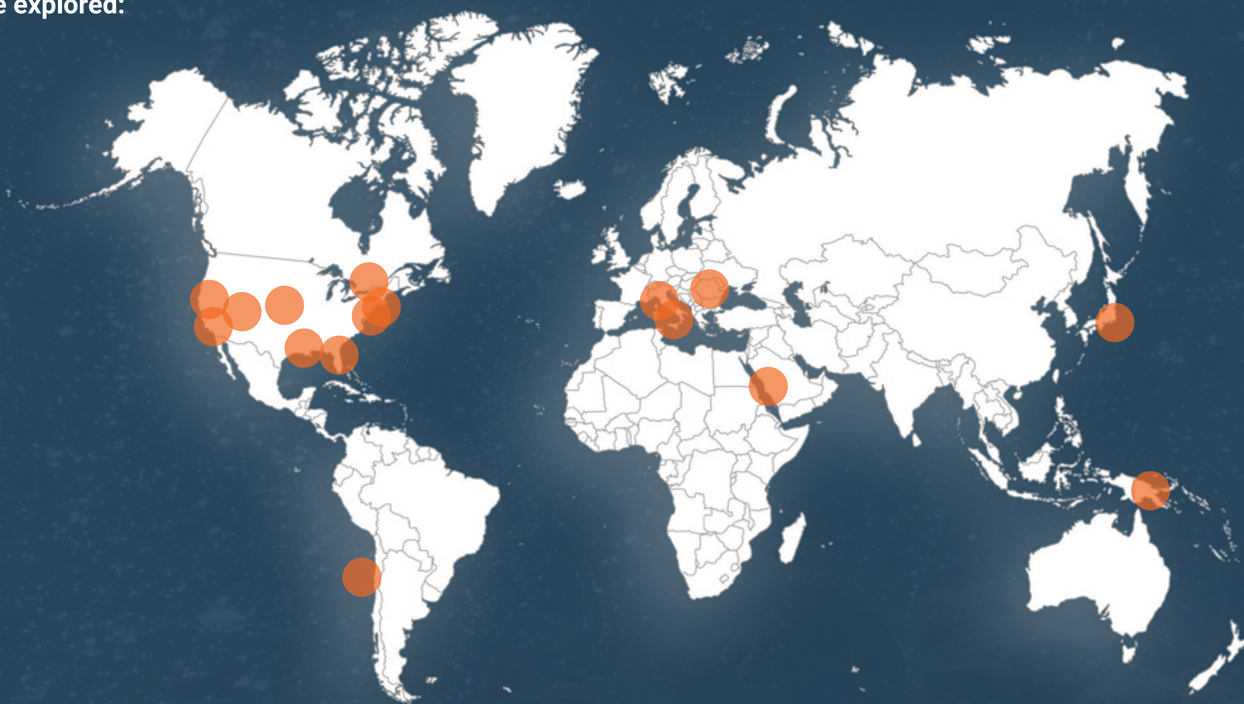
- 30% more funds raised than 2024
- 40% growth in 2FP sample collection
- 12 terabases of DNA sequenced
- 36 product leads validated in live culture
- 1 New York Times front page profile
- 3 US-wide community science campaigns
- 4 manuscripts released
- 2 spinouts prepped

Total spent: $394,187 — 5X capital efficiency vs typical discovery programs

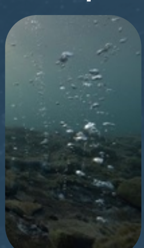
Total raised: $433,836 — Remaining runway: 20 months

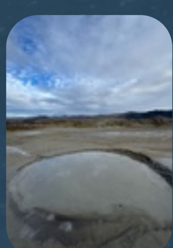
Typical costs of expeditions + sequencing + analysis + lead generation: ~$2,000,000

We explored:

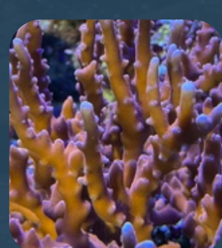


We sampled:


Volcanic vents


Cold seeps


Hot and cold springs


Disease-resilient corals

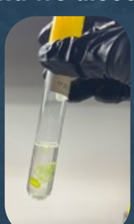

Drought-tolerant plants

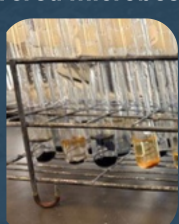

Mine drainage


Soils


The built environment

And we discovered microbes for:

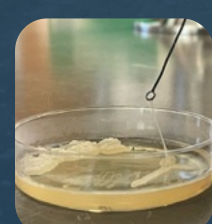

Carbon Capture


Methane Capture


Pigment & Antibiotic Production


Coral Reef Probiotics


Ingredient Production


New biomaterials


Crop health

Photo: Vulcano, Italy, by Morgan Bennett-Smith

2025 in the news

Throughout 2025, our work was featured in national and international media – take a look at some of the highlights below. Additional coverage can be found at twofrontiers.org/media.

CSU | SOURCE WARNER COLLEGE OF NATURAL RESOURCES

Could the goo and gunk in your home be solutions to climate change?

npr

These researchers think the sludge in your home may help save the planet

The Romania Journal

Buzău Land UNESCO Global Geopark, explored by a team of American scientists in search of life in extreme conditions

The New York Times

The Very Hungry Microbes That Could, Just Maybe, Cool the Planet

They feast on bubbles of methane seeping out of the ocean floor. Could their appetites be harnessed to slow climate change?

FAST COMPANY

Have an aquarium at home? You can help scientists discover how to save coral reefs

Seed Health and the Two Frontiers Project want home aquarists to send in samples of their corals, to learn what conditions the vital organism can—and can't—survive in.

Grist

Scientists are looking for CO2-gobbling microbes in extreme environments – like your home

How the microorganisms lurking in your dishwasher could turn out to be climate superstars.

TRIPLE PUNDIT

A Citizen Science Project is Looking for Carbon-Capturing Microbes in Springs

The second iteration of The Extremophile Campaign is taking citizen scientists outside of their homes and into the wild, continuing the search for microbes that can advance carbon capture efforts and other climate solutions.

Atmos

EARTH'S ANCIENT MICROBES OFFER LESSONS FOR A MORE LIVABLE FUTURE

RESEARCHERS FROM THE TWO FRONTIERS PROJECT AND SEEDLABS LOOK TO EXTREMOPHILES FOR CLUES ON IMPROVING PLANETARY HEALTH.

Photo: Vulcano, Italy, by Morgan Bennett-Smith

Thank you to our partners

Our partners make our 2FP possible – we are so grateful to work with each of the organizations below. These collaborators are essential to turning exploration into open, scalable benefits for ecosystems, human health, and the future of life on (and off) Earth.

Photo: Vulcano, Italy, by Morgan Bennett-Smith

Research Initiatives

Photo: Mud volcanoes of Buzău geopark, Romania, by Braden Tierney

Platform Growth: Fieldwork, Software, and High-Throughput Culturing

In 2024, we showed how nature harbors new microbial biotechnologies.

In 2025, we scaled our platform. Given the breadth of our work, we need the capacity to harness diverse microbial physiologies at low cost, from **organisms that breathe iron to those that survive on hydrogen gas**. This involved investing time in standardizing fieldwork methods, software, and high-throughput growth of microbes in the lab.

In December, we simultaneously shared three manuscripts detailing our progress:

The 2FP Handbook and Open Tools Resource

This resource comprises our open-source software/3D-printing toolkit and field handbook. It demonstrates how we've built one of the most diverse collections of paired cryopreserved and sequenced samples on the planet.

Read the paper

Access the tools

XTree

XTree is a best-in-class DNA sequence classifier -- it is how we can figure out what bacteria, viruses, and eukaryotes are in a sample or, more interestingly, exactly where we can look on Earth to discover new species.

Read the paper

Access the tool

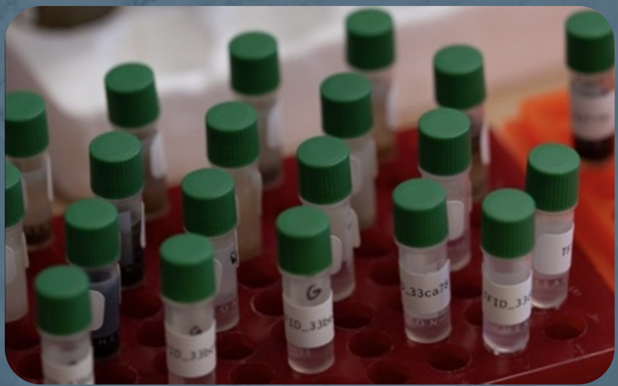
MAGUS

MAGUS is our bespoke toolkit for gene and genome discovery via "iterative assembly." It can analyze genomes of any organism, and it is how we are building the most biologically informative and diverse microbial genetic datasets out there.

Read the paper

Access the tool

In parallel, we leaned heavily into scaling our culturing approaches. We are now at the point where **samples that come into our facility are inoculated into a standard panel of growth media** to screen for consortia that can do anything from **forever chemical remediation to hydrocarbon degradation to carbon sequestration to antibiotic production**. Further, our software tools and cryopreserved, sequenced samples can be used to **identify novel functions or species in the data and design bespoke culturing media to grow them**. So let's say we see a novel gene cluster that may be highly effective at plastic degradation – we can figure out which microbe has those elements, design media panels to grow it, and immediately evaluate the resulting cultures for their plastic degradation ability.



These tools represent the core strength of what we do – uniting fieldwork, sequencing, and high-throughput microbiology to extend the boundaries of what is possible in biotech.

Moving into Methane

Our methane-capture initiative, like our carbon dioxide capture work, began with a rejected grant.

In early 2025, we wrote a proposal asking for $80,000 over one year to look for microbes that consume methane; given our success with carbon dioxide capture, this seemed to be a rational extension of our effort. We proposed (1) sampling sites where methane is released naturally in massive quantities, (2) searching for novel genes associated with its remediation, and (3) sharing that data with the scientific community.

We received the following feedback from peer reviewers:

You can't possibly do that in only a year

You can't possibly do that for only 80k

You can't possibly find something new -- people have studied methane capture for decades

As of today, we're quite pleased to report that:

In the span of eight months

for ~25% of the proposed cost

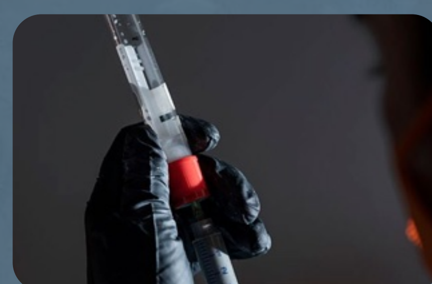
We found new genetic tools for -- and we think new forms of -- methane capture

Here's how it all came to be:

We decided to sample places that (1) no one had ever characterized and/or (2) had biogeochemical conditions that we hypothesized would hold new forms of life. Thanks to our ongoing partnership with Seed Health, we could support a portion of the work; we also had to develop ways to do anaerobic microbiology in the field on the cheap (normally done in a $50,000 anaerobic chamber) and develop our own, home-built methane sensors (**saving ~$16,000 per sensor**).

In July, we sampled the Scoglio di Africa in Italy; it contains some of Earth's shallowest marine "mud volcanoes" – cold seeps that bubble methane constantly.

In December, we collected samples from the eternal flames (burning methane seeps) and ancient terrestrial mud volcanoes of Romania's Buzău lands.



We anaerobically inoculated samples on-site in tubes with pre-filled media designed to grow biotech-relevant and novel methanotrophs.

Sequencing revealed **new methane-capturing organisms and variants of methane monooxygenases,** as well as numerous other relevant and novel genes. Culturing, in turn, has yielded what appears to be a naturally occurring **symbiosis between a phototrophic microbe and a methane capturing organism**. This relationship has been posited to exist in theory, and it would be ideal for deployment in rice paddies, sunlit areas of extremely high methane release. You can expect to see a manuscript detailing these results soon.

We were also joined by Raymond Zhong of the New York Times on our work in Italy; he wrote a profile of our work that you can read here.

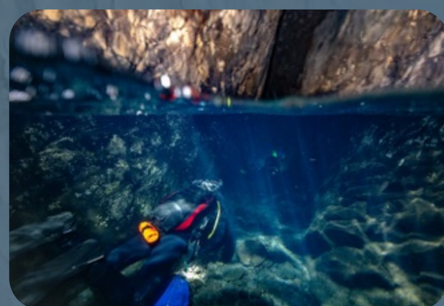
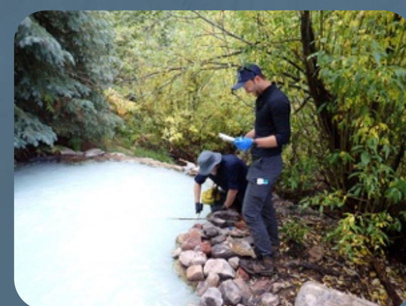
Photo credits, left and right: Giacomo d'Orlando/New York Times; middle: Tori Ferenc

Carbon Dioxide, Bioproduction, and Contaminants

We closed out 2024 describing *Cyanobacterium aponinum var. vulcano* – or "chonkus" – one of the most effective microbes for carbon capture ever discovered. We learned in 2025 this was the most read paper in *Applied and Environmental Microbiology* that year (read it here).

We stepped up our focus on application in 2025. In addition to multiple expeditions to other high-carbon dioxide sites around the world, we started exploring how we can build an engine for discovery of "pollutant to value" applications, where any pollutant – carbon dioxide, mining runoff, forever chemicals – can be broken down/sequestered and converted to a useful product.

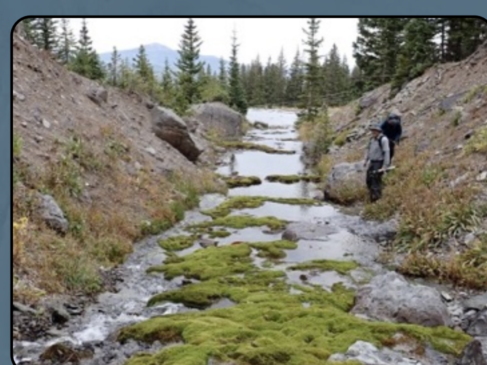


We rounded out our carbon initiative this year, collecting more samples from high carbon dioxide sites around the globe, from the caves of the Mediterranean to the hot springs of Colorado. Expect to see more data and useful strains from these sites soon.

For carbon dioxide remediation, we focused on **sugar production**, aiming to discover a suite of organisms that can both capture carbon dioxide and produce **high-value sugars** (glucose, allulose, etc.) with potential use by ingredient manufacturers; these can **also be used for crop protectants, biopolymers, soil restoration, and many other interesting applications**. Microbes are capable of producing much higher concentrations of sugar than sugarcane, faster, with lower land and overall resource use. We'll be writing this manuscript up in 2026 and pursuing a few other pollutant-to-value targets with potential commercialization relevance.

Microbial sugar production, close up



Sampling contaminated mine drainage

We also sampled at an abandoned mine in Southern Colorado, where actively draining, acidified water contaminates the nearby land. **Our goal was twofold: to identify organisms that could clean the water while, simultaneously, extracting rare earth elements.** This would enable both ecosystem restoration and next-generation mining practices here in the U.S. We have some promising preliminary data from this first outing and are actively seeking additional funding to support this work.

Coral Restoration

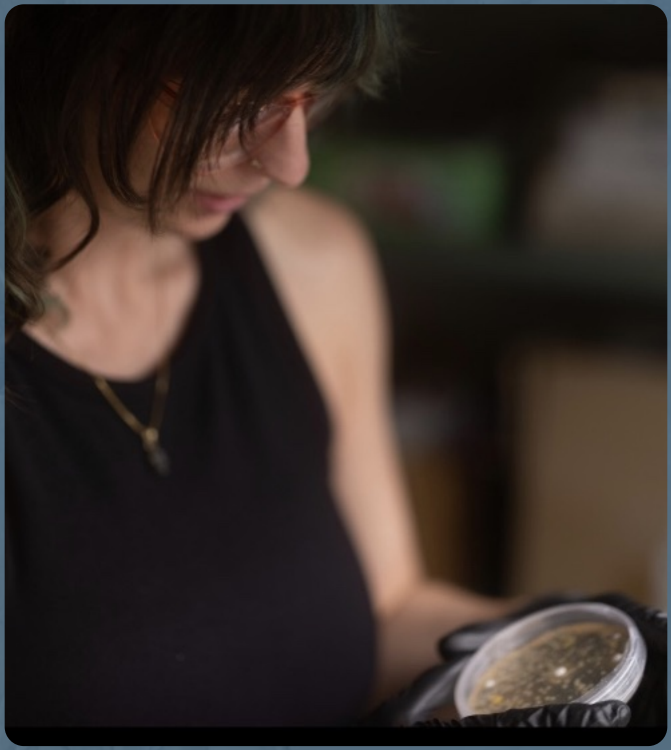
The goal of our Coral Initiative is to build microbial biotech to preserve and repair coral reefs in light of disease and environmental stressors. We finished 2024 with Carbon4, our expedition to Shikine-jima, Japan, where we studied naturally acidified coral reef systems created by CO_2 seeps around the volcanic island. These environments serve as powerful real-world analogs for future ocean conditions. This "living lab" enabled us to collect and study how corals and their associated microbial communities respond to -- and become resistant to -- environmental stressors.

We wanted to use this dataset to understand the role of microbes in maintaining coral health during ocean acidification. To do so, we recruited a new team member: April Johns, a PhD student at Colorado State University, whose work will look at microbial markers of dysbiosis across coral species, environments, and health states. All of these efforts have brought us closer to informed steps on how we can provide interventions to enable future reef resilience.

In parallel, we launched Project ReefLink, our coral-focused community science initiative, where we invited owners of coral tanks to contribute both data and coral samples for study. These miniaturized coral reefs are small, unique, experimental ecosystems shaped by individual environments and maintenance routines. By comparing the microbiomes of diseased versus healthy samples from aquaria, we can discover mechanisms of coral disease resistance and new probiotic treatments for reefs -- in both aquaria and in the oceans.

Finally, we have continued to add to our open-access dataset of coral genomes and microbiomes, enabling research on these samples to be conducted not only by 2FP, but by the broader scientific community.

A 2FP diver looks prepares to sample an acidified reef



April Johns, our new PhD student, examines a plate of microbes isolated from healthy corals

A tank belonging to one of our project ReefLink participants

Crop & Soil Health

This was the first year of substantial effort on our Crops initiative. At the end of 2024, we embarked on an expedition to the Mojave Desert, an expansive region in the southwestern United States that is frequently used as a lunar analog environment. Its volcanic surfaces and extreme aridity replicate key stressors relevant to conditions on the Moon. Samples collected during this expedition are key to understanding plant–microbe interactions in extreme environments and can inform strategies to improve crop resilience across diverse ecosystems, including drought-prone and high-salt environments, advancing both space agriculture and food security on Earth.


The lunar-like landscape of the Mojave holds plant life that beats the odds to survive -- we think microbes play a part in their reslience.

This year, we sequenced these samples and used that information to culture organisms that can be used as crop protectants in extreme, drought-ridden environments. With our collaborators at Colorado State University -- Professor Christie Peebles and her student Paycen Harroun -- we've identified 12 candidate strains that fix nitrogen and produce extracellular, water-sorbing polymers that we believe will be beneficial for plant health in the stressful environment of lunar regolith. In 2026, we'll be testing this hypothesis on plants grown in regolith simulant with our collaborators at the University of Florida, Professor Rob Ferl and Professor Anna-Lisa Paul.



We've collected organisms from all kinds of desert-life - from bone white holly bushes to bright yellow lichens.

With over **4,000 crop-associated bacterial strains in our database**, we are enthusiastic about continued effort in agriculture and soil health. In 2025, we **formalized a collaboration with the USDA** to interrogate the roots of Kernza (an ancestral wheatgrass) for beneficial microorganisms lost during industrialization, and we began pursuing partnerships in developing microbe-derived products to improve soil structure. We will soon pilot **screening soil samples for microbes that can remove toxicants and other contaminants, including PFAS.** We're looking forward to actively pursuing funding and research in these areas in the coming years.

Outreach and Community Science

Education and outreach are central to our mission; they ensure that discovery is not confined to laboratories but rather embedded in everyday environments and shared spaces.

We collected samples with hundreds of community scientists in 2025. Through these initiatives, 2FP empowers participants to contribute meaningful samples and data from the home, the wild, and aquariums, expanding both the scale and diversity of microbial observations. These efforts lower barriers to participation while maintaining rigorous scientific standards, enabling non-experts to become active contributors to research.

Our flagship community science projects (launched with our collaborators at CitSci and Seed) were the “In the Home” and “In the Wild” Extremophile Campaigns. People sampled extreme environments on their own properties, from hot water heaters (which have been reported to house organisms similar to those in Yellowstone’s hottest springs) to strange slimes in their yards. These “overlooked” environments tend to house all manner of interesting and useful microbes, including those that could be pertinent for carbon capture or bioremediation.

As we mentioned in our section on Coral Restoration, in the fall we launched Project ReefLink, where we are working with private aquarists around the nation to design, build, and test coral probiotics and prebiotics that can combat reef disease.

Air conditioning drainage is one of the places to look for carbon-sequestering and toxicant-cleaning microbes

Observations from our Extremophiles in the Home campaign spanned the globe

Outside of community science, we remained committed to our practice of education and scientific communication. In addition to numerous talks at academic conferences, we continued our efforts to develop short-form coursework for high school and college students. Through partnerships with institutions such as the UC Berkeley Gump Station, we integrated field-based learning, hands-on sampling, and microbiology into a program for students on the island of Mo’orea in French Polynesia. These teaching efforts emphasize practical skills, ethical sampling, and open science, helping to educate the next generation of scientists to see microbial life as a vital, interconnected foundation of our continued planetary health.

Areas of Focus, 2026 and Beyond

Sampling, sequencing, and culturing

- New forms of bioproduction
- PFAS and other toxicant remediation
- Winnowing existing leads

Deploying the 2FP Living Database

- Paired sequencing and cryopreserved samples
- Open for the scientific community
- Tools for media design and culturomics
- Supported by Lillypad: A new take on microbial gene-level analysis

Publication Output

- Carbon/Coral initiative manuscripts
- New modes of methane capture
- Software and open-access biodiscovery tools

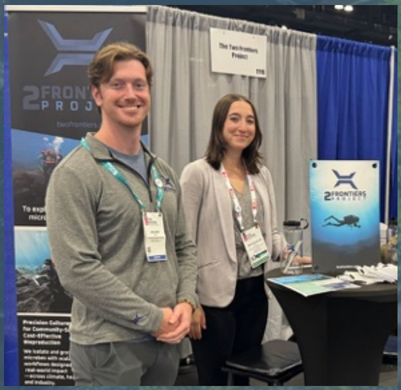
Funding and deploying commercialization

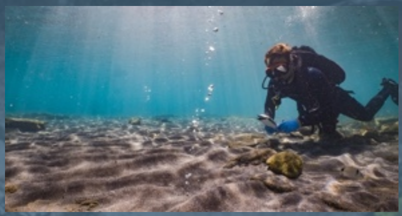
- Spinout #1
- Spinout #2

Above all else-- thank you to our amazing team and supporters for making this all possible.









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