Artículo

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Let's Symbiose and Be With: A cross-disciplinary research and expression of amor mundi through electrifying living networks

Simbioticemos y estemos con el otro: una investigación y expresión transdisciplinaria del amor mundi a través de redes vivas electrizantes

Recibido: 09/11/2024
Aceptado: 09/04/2025

Cómo citar este artículo:
Pasco Bolta, A.; Bonné, R. y Manca, J. (2025) «Let's Symbiose and Be With: A cross-disciplinary research and expression of amor mundi through electrifying living networks». Inmaterial. Diseño, Arte y Sociedad, 10(19), pp 10-29
DOI 10.46516/inmaterial.v10.241

Keywords:
Interdisciplinary, cable bacteria, art-science, bioelectricity, symbiosis

Palabras clave:
interdisciplinariedad, bacterias cable, arte-ciencia, microbiología, biodiversidad

Abstract

The sand of the seafloor is filled with electricity. Although it has been like that for millions of years, only about a decade ago, a group of Danish researchers found out that a microscopic hair-like bacterium is responsible for it. These so-called cable bacteria make electrical wires to transport energy over their bodies – a formerly unknown form of life. This unique creature has made scientists excited, intrigued and … in love. The bacterium attracted a lot of interested minds to Denmark. The fascination for cable bacteria crosses all fields of knowledge, initiating the collaborative project between art and science and thus giving the opportunity for different audiences to feel connected to the subject, regardless of their profes-sion or background. The result was an exciting collaboration between scientists Robin Bonné and Jean Manca, and artist Anna Pasco Bolta, to create an art performance where a cable bacterium was fished from the mud and a love letter was read through a cable bacterium. Through the joint cross-disciplinary love letters of artist and scientists, they express their shared amor mundi, love for life and the world, together with their concerns and critical questions related to the fragile connections between life and the world. The cross-fertilisation of this scientific and artistic research connects fundamental questions on biosphere and technosphere, life, love and technology, symbiosis through electrical networks in nature and in our connected digital world. The artwork travelled around Europe, Canada and Egypt, and included a performance in front of 1500 microbiologists.

Resumen

La arena del fondo marino está llena de electricidad. Aunque ha sido así durante millones de años, fue solo hace una década que un grupo de investigadores daneses descubrió que una bacteria microscópica con forma de pelos es la responsable de ello. Estas bacterias, denominadas bacterias cable, crean «cables» para transportar energía a través de sus cuerpos, una forma de vida hasta ahora desconocida. Esta criatura única ha emocionado, intrigado y hasta enamorado a los científicos. La bacteria ha atraído a muchas mentes interesadas hacia Dinamarca. La fascinación por las bacterias cable cruza todos los campos del conocimiento, y de esta forma ha dado inicio a un proyecto colaborativo entre arte y ciencia, lo que da la oportunidad a diferentes públicos de sentirse conectados con el tema sin importar su profesión o formación. El resultado fue una emocionante colaboración entre los científicos Robin Bonné y Jean Manca y la artista Anna Pasco Bolta, quienes realizaron una actuación artística en la que una bacteria cable fue extraída del barro y una carta de amor fue leída a través de varias bacterias de ca-ble. Por medio de las cartas de amor cruzadas entre los artistas y los científicos, expresan su amor com-partido por la vida y el mundo, junto con sus inquietudes y preguntas críticas relacionadas con las frágiles conexiones entre la vida y el mundo. La fecundación cruzada de esta investigación científica y artística conecta cuestiones fundamentales sobre la biosfera y la tecnosfera; la vida, el amor y la tecnología; la simbiosis a través de las redes eléctricas en la naturaleza y en nuestro mundo digital conectado. La obra de arte viajó por distintos países de Europa, Canadá y Egipto, entre los que fue realizada una actuación frente a mil quinientos microbiólogos.

Introducing Cable Bacteria

The sand of the seafloor is filled with electricity (Nielsen *et al.*, 2010). In the depths of the oceans, a bacterium as thin as spider silk transports electrical energy up and down in the sediment (Pfeffer *et al.*, 2012). While it does so merely to stay alive, it shapes its environment by doing so (Nielsen & Risgaard-Petersen, 2015).

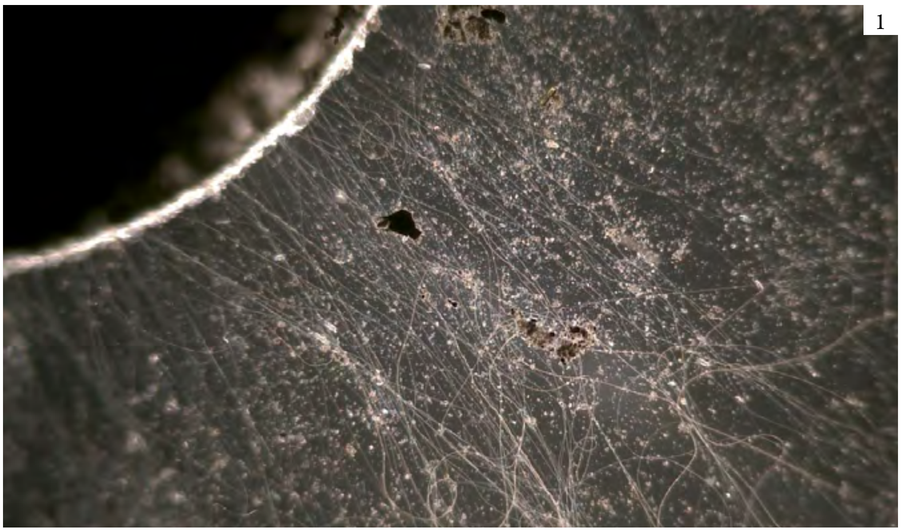
These microbes are called cable bacteria, more specifically, the genera *Electronema* and *Electrothrix* of the family *Desulfobulbaceae*. They form long chains of thousands of cells all on top of each other. Although as skinny as a few micrometres (more than ten times thinner than one of our hairs), they can grow as long as a few centimetres. Yet we do not call this chain a colony: the chain is considered as one single organism, as they share an outer membrane that connects all the cells with each other. Within this membrane, a unique network of electrical wires runs all along the length of the bacterium (Thiruvallur Eachambadi *et al.*, 2020), with which they transport electrical energy to all the cells. It is something extraordinary in nature.

Unique Electrical Organisms

The electrical network shows that the way cable bacteria live is unseen anywhere else in nature (Meysman, 2018). All life forms (bacteria, plants, animals, all the cells in our bodies) need to eat and breathe to gain energy. The food for every organism might be different, but almost all multicellular life breathes through oxygen. Wherever an organism might live, and whatever it might live off, food and oxygen are usually readily available. For humans, the food we consume and the oxygen we breathe is taken into our bloodstream, where it gets transported to all of our cells. This way to gain energy with a very close proximity to food and oxygen was considered a general rule for all oxygen-breathing multicellular life, until we got to know cable bacteria.

Cable bacteria live in the coastal sea sand where oxygen and their favourite food hydrogen sulphide (H^2S) are both present. Yet the food and oxygen are not in close proximity in comparison with the micrometre size of cable bacteria cells, as the sulphide is buried centimetres (i.e.

Figure 1 View of a cable bacteria. Photo credit: Robin Bonné



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a thousand times the diameter of cable bacteria cells) deep in this sediment, while oxygen is only to be found at the top. Therefore cable bacteria display the ingenious feature of forming long chains of thousands of cells, that stretch centimetres long, to reach for both nutrients. The bottom cells eat for the whole organism and send energy up the chain in the form of electricity. The cells at the top use this energy to stay alive, and breathe oxygen for the whole organism.

By transporting electricity, cable bacteria create a measurable electric field in the sediment, which has an influence on the chemistry and biology around them (Nielsen & Risgaard-Petersen, 2015). The electric field moves charges around, changing the availability of different compounds in the soil. Furthermore, other microorganisms interact with cable bacteria by bumping into them for a so-far unknown reason (Bjerg *et al.*, 2023).

Although a unique lifeform, they seem to be ubiquitous on the planet (Dong *et al.*, 2024). They were first discovered in sea sediment, but were soon found in the sediments of lakes and ponds, in the deep sea, in thermal vents, above the arctic circle and on all continents. Evolutionary studies indicate that they have been around for hundreds of millions of years, yet they had never been described before (Kjeldsen *et al.*, 2019).

From Biological Electrical Networks to the Internet of Things

Although cable bacteria are found everywhere and have a significant impact on their ecosystem, they remained completely unnoticed to humans until a decade ago. The transparent filaments are visible to the naked eye, but easily mistaken for a plant fibre.

It was only because a group of researchers based in Aarhus (Denmark), found an oddity in the chemistry of the sediment that humans discovered them.

The sediment at the coasts of Aarhus was more acidic than usual, and two chemical reactions centimetres away from each other were coupled (Nielsen *et al.*, 2010), something that could only be explained by electrical currents running vertically in the sediment. After a long investigation, the Danish researchers found out that silk-like bacteria were responsible for this transportation of electricity (Pfeffer *et al.*, 2012).

The obvious question arose whether the electrical signals of these bacteria could be measured in the lab. This sparked the interest of different scientists from all over the world, including electrochemists, molecular biologists, environmental scientists and physicists, and is how physicists Jean Manca and Robin Bonné got involved.

In collaboration with the team of Filip Meysman in Belgium, Jean Manca and his research group managed to connect cable bacteria to electrodes, showing that the network found in these bacteria conducts electricity both within and out of their habitat (Meysman *et al.*, 2019). Cable bacteria were able to conduct electricity when placed dry between two electrodes, just like a copper wire does.

Jean Manca and Robin Bonné's excitement led them to investigate further whether these bacteria could one day be used for biological electronics, and thus reduce the amount of e-waste. Every year, more than 40 million tons of electronic waste gets created worldwide, of which only 20% gets recycled. It is possible to make different parts of our electronics biodegradable – like bioplastics or degradable glass – but finding a biological alternative to the toxic electronic components has been hard (Bonné & Wouters, 2022).

Jean Manca, Robin Bonné and their team investigated the electrical properties of cable bacteria, testing them at different temperatures and in different atmospheres for their conductive and transitive properties (Bonné *et al.*, 2020). It seems that cable bacteria are strong electricity conductors, with conductivities similar to those of organic electronics already in use today (e.g. OLED-TVs). Furthermore, they have the properties of a transistor, the small building block for computations in computer chips. For the first time, electronic information could be sent over centimetres through a single biological organism.

Artistic Research Meets Scientific Research

The exploration of the materiality of information and media technology and its relation to life has been a subject of study for the artist in recent years. Rethinking new electronic devices and modes of existence was the common ground between the scientists and the artist. Anna Pasco Bolta's research is based on this interest in how life is given through symbiotic relationships with other species and the environment led her to focus on ecosystems of microorganisms.

Information and media technology is never ephemeral, it leaves traces that are intimately connected to the earth, air and water. Therefore, Anna Pasco Bolta was investigating how organic materials support the development of information technology and how the devices of this technology return to nature.

A characteristic of her artistic proposals is to 'let things be'. In this existentialist practice, she constructs scenarios based on questions about life and different forms of existence, about ways of feeling and communicating, and then letting things be. It's not necessarily about where they end up or how they stay. Rather, it is about the process of transformation of subjects and objects and the transformation of the audience, the proactive actors in the aesthetic and conceptual works.

During her artistic research residency in Denmark, she was developing sculptures with bacterial ecosystems from contaminated environmental soils. The curiosity to know who was behind these colours led her to cross paths with a cable bacterium. She could not believe her eyes and, as if it were a movie, discovered that the scientist who was aware of the existence of these fascinating bacteria was 50 km away from her studio.

The 6&6 art and science initiative (Clark *et al.*, 2020), exemplifies how transdisciplinary collaborations between art and science can flourish when rooted in a shared passion for the subjects being explored. This shared enthusiasm often begins with a spark of curiosity and is sustained by the courage to put aside possible embarrassments and introduce oneself to someone unknown, i.e. engage with the unfamiliar. In this case, the invitation arrived within a few days, and with it, the artist's fascination for cable bacteria deepened. The initial conversations between the scientists and the artist flowed organically because they both shared this mutual curiosity and drive.

A Letter to CB

> My love, with you I have discovered that love is not just a feeling. It is a place, it is a shelter. Love is to be found and to find another. As I place my cheeks in the cold structure that holds you, I dive in your known habitat and siento que eres mi lugar. I have found you, you are all I have dreamt of. You brought some beauty in to my days (Pasco Bolta, 2024).

Relationships begin with a discovery, an awareness of the presence of the other. The tradition of writing letters to express emotions and feelings towards something beyond oneself has deep roots, with some writers even addressing other species. One notable example is E. B. White, who, in his *Letters of E. B. White* (1976), writes to his pet duck Stanley, showing a reflective and heartfelt connection to an animal. This form of communication, though unconventional, reflects the human tendency to reach out to those outside our own species to express affection and understanding.

The fascination shared between the artist and the scientists materialised with the performative installation "Let's Symbiose and Be With", which consists of a series of love letters addressed to and transmitted electrically by cable bacteria. The decision to write love letters to the cable bacteria arose from the artist's deep fascination with the organisms, a feeling that the scientists understood perfectly. This emotional connection drove the artist to express her feelings in the form of a love letter, as she found herself in a state of awe and admiration, almost as if she were in love with the bacteria. The act of writing a letter, in this case, became a way to materialise her emotional bond, translating her fascination into a form that both celebrated and explored the unique relationship between humans and other species. The work exemplifies how each discipline, from its field of knowledge, tries to understand reality and its inner workings. While the methodologies and approaches may appear different at first glance, both collaborators soon realised that the primary distinction lay in the languages and forms they used, rather than in the fundamental questions they were asking.

The artist created four love letters addressed to the cable bacteria, which provide a double reading of the physiological properties of the bacteria as a metaphor: the fact that the bacteria are electric and can electrify, 'that you are and you make me electric' (Pasco Bolta, 2024), the fact that it is a long-distance relationship existing on both micro and macro scales, 'Baby, our love is a long-distance electrical split' (Pasco Bolta) or the fact of connectivity '*Si perdemos esta conexión, verás cómo seré yo la mala. Probablemente tu cuerpo eléctrico pueda no encontrarme.*' ('If we lose this connection, you'll see how I'll be the bad guy. Your electric body will probably not be able to find me' (Pasco Bolta)).

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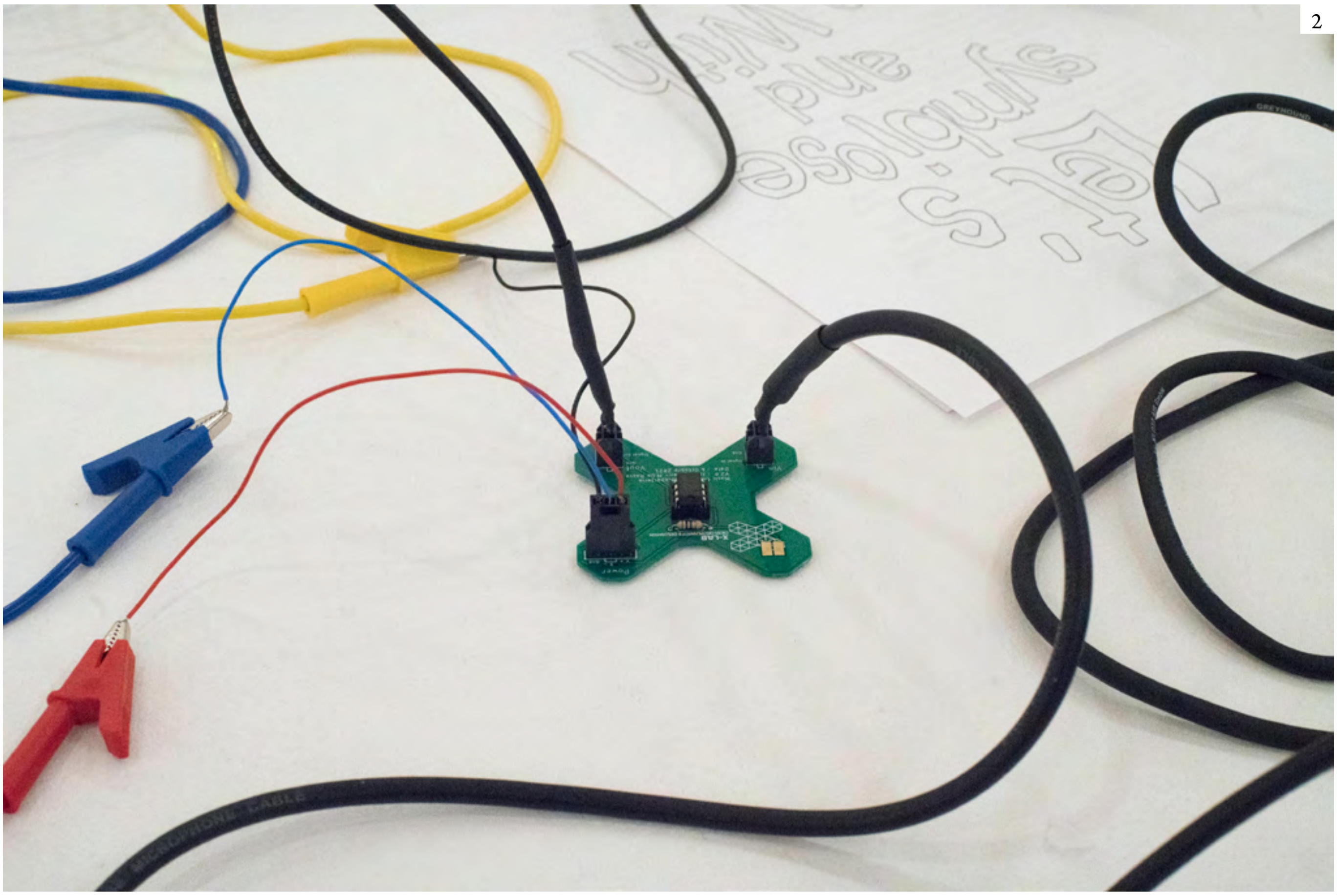

Figure 2 Installation circuit. Photo credit: Anna Pasco Bolta

Reading the Love Letter to Cable Bacteria

The fact that the letters were addressed to the cable bacteria, gave rise to the question of whether it would be possible to read the letter to the bacteria themselves.

So far, cable bacteria cannot be grown in isolation. They are bound to the specific conditions of the sediment for growth, for reasons that are unknown up to now. Robin Bonné and his colleagues do multiple investigations on the survival of bacteria in other environments, for example on a carbon electrode. Imagining different ways to exist is the basis of the collaboration between Robin Bonné and Anna Pasco Bolta. During one of the visits to the lab, Anna Pasco Bolta started to imagine different ways to communicate and asked Robin Bonné the question, 'If the bacteria can conduct an electrical signal, it means that I can pass an audio signal, that my voice could pass through your body.' Robin Bonné smiled and presented her with his past research in collaboration with scientist Jean Manca, in which they used the cable bacteria in an electrical circuit to transmit music. In one such experiment, a single cable bacterium was fished out of the mud under a microscope, washed in ultrapure MilliQ water, and placed on the circuit, forming the connector between a smartphone and a loudspeaker. With this, the song *Bad Guy* by Billie Eilish was played through the microbe.

The circuit is constructed from two gold electrodes of about 10 mm^2 that are positioned 0.5 mm apart. The space between these is where a (number of) cable bacterium filament(s) is meant to be placed. Both contacts are connected to a small operational amplifier that will amplify the tiny current that flows between the two gold electrodes. For this project, the circuit was redesigned so that the input signal was a microphone, while the output signal remained connected to a speaker. In this configuration, any audio signal that is spoken into the microphone travels through the cable bacteria and is amplified to end up at the speaker.

The performance itself is an immersive exploration of these principles. The artist prepares the cable bacteria by 'fishing' them from the sediment, cleaning them and constructing a 'skeleton' using soap. Once the bacteria are ready, she reads four love letters aloud consecutively, while a live sound composition by thatsoundsmart (Martin Linka) accompanies her words. This creates an intimate, multisensory experience where the bacteria act as both the medium and the metaphor for connection, bridging the microscopic and human worlds through sound and poetry.

Collaboration

The collaboration between the scientists and the artist in this case arose from a common interest in cable bacteria and the individual initiative and genuine interest of the people involved, especially since there was no pre-established framework or specific programme to bring the two disciplines together and no external funding was created for it. This entailed some key conditions regarding personal motivation, funding, time and infrastructure resources.

Without a formal support programme, genuine interest in learning and approaching the other discipline is essential. It became the driving force that initiated and sustained the collaboration, prompting both parties to engage autonomously and align their expectations intuitively, without knowing exactly where the process would lead. This collaboration exemplifies a shift in perspective, where the focus moves away from immediate deliverables and toward the process itself. While there is confidence that there will be an outcome, it is not the primary driver of the work.

As in any project, financing is usually a challenge. In this case, the first phase of the collaboration was possible because the artist was already in the city as part of an artistic research residency. This facilitated coordination and allowed for a funded first stage. Subsequently, the resources were obtained by sharing the financing between the University (which provided the circuit for the work) and the artist herself and the cultural institutions interested in presenting the work (which covered the materials for the installation). The collaboration was characterised by its fragmented funding and the need to constantly adapt to the available sources of support.

In terms of the time commitment of both parties, there was a great difference in availability and priority within their agendas. For the artist, the collaboration was one of her main activities, which allowed for complete dedication. For the scientists, however, it was an additional project, carried out in their spare time alongside other responsibilities.

In terms of infrastructure, the laboratories and workshops of the University and the Scientific Research Centre played a central role, providing access to tools and technical materials. This physical space became a key site of experimentation and creation. In addition, videoconferences extended the collaboration into a virtual environment, ensuring continuity and communication across distances. This aspect aligns with Daniel López del Rincón's (2015) observation that while the laboratory has traditionally been the domain of experimental sciences, it has also been adopted by the arts as a space of experimentation and innovation. However, in bioart, artists work within scientific laboratories in their original form, utilising these highly specialised spaces not just as sources of techniques and materials but as integral parts of the creative process. This blurring of boundaries transforms the laboratory into a place where disciplines converge, challenging traditional roles and fostering new interpretations of biotechnological processes through an artistic lens. In general, the collaboration addressed the need to be adaptive and flexible in terms of resources and time, relying heavily on personal commitment.

Despite logistical challenges, sustaining joint work was made possible by the collaboration of different institutions. Beyond these practicalities, the collaboration echoed a defining characteristic of the 6&6 programme (Clark et al., 2020): the joy and playfulness that the initiative fosters by bringing together artists and scientists from entirely different personal and professional worlds, creating unexpected connections and a vibrant sense of community. This element of play not only enriches the creative process but also cultivates a deeper appreciation for the environment and a broader openness to integrating artistic and scientific approaches in one's work.

This collaboration is an illustration that – besides the financial and logistical aspects – openness, shared interests, enthusiastic drive, mutual respect and the willingness to try to understand each other's language are crucial foundations for developing a successful transdisciplinary collaboration. In this transdisciplinary collaboration, the artist and scientists have found common ground and symbiosis – through the electrifying cable bacteria – to express their shared *amor mundi*, or love for life and the world, together with their concerns and critical questions related to the fragile connections between life and the world.

Let's Symbiose and Be With: The Result

This interaction with cable bacteria places the work within a tradition of artistic exploration of interspecies relationships, particularly in the realm of bioart. Heather Barnett's practice with *Physarum polycephalum* (slime mould) serves as a compelling example of how the arts have long engaged with non-human organisms to question, learn and collaborate. Barnett reflects on her work, stating, 'my understanding of the organisms' preferences and their underlying physiological mechanisms grew through a combination of empirical study, coupled with explicit knowledge gleaned from the abundant scientific papers.' (Barnett, H., 2023). Her approach intertwines empirical observation with artistic curiosity, creating a space where learning from and with the organism becomes central to the creative process.

Both Barnett's work and 'Let's Symbiose and Be With' share common ground in exploring relationships between humans and unicellular organisms, focusing on how these connections can be translated into sensory experiences. While Barnett's work explores how to convey the shifting scales of perception through moving images, 'Let's Symbiose and Be With' focuses on creating a sensory, textual, and auditory experience. Using cable bacteria, we question how such interspecies connections can evoke emotions and reshape our understanding of life’s interconnectedness.

‘Let’s Symbiose and Be With’ frames three key points. On the one hand, it invites us to understand a work of art as a living organism. The bacterium remains conductive for only about an hour in air, thus determining the duration of the performance and emphasising that the performance is not developed with a metal or mineral, but with a ‘living’ being.

On the other hand, on the basis that we are in constant contact with other forms of life on different scales, the work focuses clearly on the symbiosis with the environment through the relationship with other species. It does so by considering the existence of an individual as part of a relationship *with*: *with* the environment; *with* another form of life (cable bacteria); and *with* the inorganic (the soil where cable bacteria live).

We may share the same habitat, but our ‘sense of belonging with’ is a changing process. This collaboration remarks how the relationship with other species and inorganic material is constructed and how art works can engage in a more holistic way of relating, without pushing a hierarchical, neo-liberal system further. Or without supporting the idea that the natural environment is only a resource to exploit. In this context, transmitting love letters as electrical signals through cable bacteria, as artistic expression, touches on the bioethical question of how to deal with other forms of life.

Finally, the purpose of collaboration between art and science, as well as collaboration

Figure 3 Installation view at ÉCART, Canada. 2023. Photo credit: Anna Pasco Bolta

with other species, is to establish new ways of relating to the world, promoting a more holistic existence and understanding ourselves as a co-creative part of biodiversity.

Rather than seeing the artist's role as an illustrator of a research topic, and the scientist's role as the technical workshop for the material realisation of an artistic concept, we understand it is their role to look for common points, such as concerns, questions, challenges and objectives, which generate an exchange and bidirectional communication, which inspires each party's own research. Art and science collaborations are especially relevant for society precisely to address issues that concern both of us, where each field of uses different tools and ways, so the meeting point between art and science allows us to rethink our own tools and approach, and take another perspective.

In this sense the link with the environment and other species, especially if they are species that involve different scales, is nourished not only by the imaginative capacity in, for example, speculating about other forms of life, but also by scientific knowledge and technology. Thanks to the development of instruments such as the microscope or other measuring tools, we are able to experiment and create knowledge of reality, which is complemented by the more sensory knowledge of the human being – imagination, feelings and intuition – characteristic sensors for artistic research. That is why we believe that the collaboration between art and science is fundamental to achieve a more complete and holistic approach to the world.

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As a final remark, our experiences at the nexus of art and science have taught us that when the collaboration between art and science is founded on openness, shared interests, enthusiastic drive, mutual respect and the willingness to try to understand each other's language, it can develop from a multidisciplinary collaboration into a truly transdisciplinary collaboration, in which art and science are in symbiosis.

Figure 4 Installation view at Haus der Kunst, Germany. 2024. Photo credit: Marlene Mauer

Watch the video recording of the full performance

Vídeo 1 Installation view at Haus der Kunst, Germany. 2024. Photo credit: Anna Pasco Bolta

Bibliography

Barnett, H. (2023). Drawing out the superorganism: Artistic intervention and the amplification of processes of life. In G. Anderson-Tempini and J. Dupré (eds) *Drawing Processes of Life: Molecules, Cells, Organisms* (pp. 193–218). Intellect Books.

Bjerg, J. J., Lustermans, J. J. M., Marshall, I. P. G. *et al.* (2023). Cable bacteria with electric connection to oxygen attract flocks of diverse bacteria. *Nat Commun, 14*, 1614.
https://doi.org/10.1038/s41467-023-37272-8

Bonné, R., Hou, J. L., Hustings, J., Wouters, K., Meert, M., Hidalgo-Martinez, S., Cornelissen, R., Morini, F., Thijs, S., Vangronsveld, J., Valcke, R., Cleuren, B., Meysman, F. J. R., & Manca, J. v. (2020). Intrinsic electrical properties of cable bacteria reveal an Arrhenius temperature dependence. *Scientific Reports 2020 10:1, 10*(1), 1–8.
https://doi.org/10.1038/s41598-020-76671-5

Bonné, R., Wouters, K., Lustermans, J. J. M. & Manca, J. v. (2022). Biomaterials and electroactive bacteria for biodegradable electronics. In *Frontiers in Microbiology* (Vol. 13). *Frontiers Media S.A.*
https://doi.org/10.3389/fmicb.2022.906363

Bonné, R., Marshall, I. P. G., Bjerg, J. J., Marzocchi, U., Manca, J., Nielsen, L. P., Aiyer, K. (2024). Interaction of living cable bacteria with carbon electrodes in bioelectrochemical systems. *Appl Environ Microbiol90:*e00795-24.
https://doi.org/10.1128/aem.00795-24

Clark, S. E., Magrane, E., Baumgartner, T., Bennett, S. E. K., Bogan, M., Edwards, T., Dimmitt, M. A., Green, H., Hedgcock, C., Johnson, B. M., Johnson, M. R., Velo, K. & Wilder, B. T. (2020). 6&6: A transdisciplinary approach to art–science collaboration. *BioScience, 70*(9), 821–829.
https://doi.org/10.1093/biosci/biaa076

Dong, M., Nielsen, L. P., Yang, S., Klausen, L. H. & Xu, M. (2024). Cable bacteria: Widespread filamentous electroactive microorganisms protecting environments. In *Trends in Microbiology* (Vol. 32, Issue 7, pp. 697–706). Elsevier Ltd.
https://doi.org/10.1016/j.tim.2023.12.001

Kjeldsen, K. U., Schreiber, L., Thorup, C. A., Boesen, T., Bjerg, J. T., Yang, T., Dueholm, M. S., Larsen, S., Risgaard-Petersen, N., Nierychlo, M., Schmid, M., Bøggild, A., van de Vossenberg, J., Geelhoed, J. S., Meysman, F. J. R., Wagner, M., Nielsen, P. H., Nielsen, L. P. & Schramm, A. (2019). On the evolution and physiology of cable bacteria. *Proceedings of the National Academy of Sciences, 116*(38), 201903514.
https://doi.org/10.1073/pnas.1903514116

Linka, M. (n.d.). *Thatsoundsmart*. Retrieved March 27, 2025, from
https://thatsoundsmart.com/

López del Rincón, D. (2016). Arte, biología y tecnología: Relaciones interdisciplinares en el laboratorio científico. *Arte, Individuo y Sociedad, 28*(2), 235–252.

Meysman, F. J. R. (2018). Cable bacteria take a new breath using long-distance electricity. *Trends in Microbiology*, *26*(5), 411–422.
https://doi.org/10.1016-/j.tim.2017.10.011

Meysman, F. J. R., Cornelissen, R., Trashin, S., Bonné, R., Hidalgo-Martinez, S., van der Veen, J., Blom, C. J., Karman, C., Hou, J. L., Eachambadi, R. T., Geelhoed, J. S., Wael, K. de, Beaumont, H. J. E., Cleuren, B., Valcke, R., van der Zant, H. S. J., Boschker, H. T. S. & Manca, J. v. (2019). A highly conductive fibre network enables centimetre-scale electron transport in multicellular cable bacteria. *Nature Communications*, *10*(1).
https://doi.org/10.1038/s41467-019-12115-7

Nielsen, L. P., Risgaard-Petersen, N., Fossing, H., Christensen, P. B. & Sayama, M. (2010). Electric currents couple spatially separated biogeochemical processes in marine sediment. *Nature*, *463*(7284), 1071–1074.
https://doi.org/10.1038/nature08790

Nielsen, L. P., & Risgaard-Petersen, N. (2015). Rethinking Sediment Biogeochemistry After the Discovery of Electric Currents. *Annual Review of Marine Science*, *7*(1), 425–442.
https://doi.org/10.1146/annurev-marine-010814-015708

Pasco Bolta, A. (2024). *Let's Symbiose and Be With* [Artwork]. Haus der Kunst, Munich, Germany.
https://annapascobolta.com/symbiose.html

Pfeffer, C., Larsen, S., Song, J., Dong, M., Besenbacher, F., Meyer, R. L., Kjeldsen, K. U., Schreiber, L., Gorby, Y. A., El-Naggar, M. Y., Leung, K. M., Schramm, A., Risgaard-Petersen, N. & Nielsen, L. P. (2012). Filamentous bacteria transport electrons over centimetre distances. *Nature*, *491*(7423), 218–221.
https://doi.org/10.1038/nature11586

Thiruvallur Eachambadi, R., Bonné, R., Cornelissen, R., Hidalgo-Martinez, S., Vangronsveld, J., Meysman, F. J. R., Valcke, R., Cleuren, B., & Manca, J. v. (2020). An Ordered and Fail-Safe Electrical Network in Cable Bacteria. *Advanced Biosystems*, 2000006.
https://doi.org/10.1002/adbi.202000006

White, E. B. (1976). *Letters of E. B. White* (D. L. Guth, Ed.). Harper & Row.

Anna Pasco Bolta

Born in Barcelona in 1990, she graduated in Fine Arts at the University of Barcelona and at the Akademie der Bildenden Kunst München with honors. Her works are part of the collection of the Stadtmuseum Munic, Staff Stiftung and Curt Wills Stiftung and have been exhibited at the Biennial Kairo off, Haus der Kunst München, the Speculum Artium Festival in Slovenia, the German Microbiology Congress, the International Symposium of Electronic Art ISEA'22, La Capella Barcelona, Lothringer 13 München, Kunsthalle Kempten or Eingen+Art Lab Berlin. She has published Stickers with Bom Dia Books and has done artistic residencies within the programs Entorno al crear y lo creado organized by A Cobert (ES) & FAAD University of Temuko (CL), Arctic Circle Program (NOR), ArtWaves/UN Ocean Decade at Helmholtz Institute of Oldenburg University and the Institute for Advanced Studies in Delmenhorst (DE), ÉCART (CAN), Malt AiR (DK), Almresidency (DE), DAAD Graduate Study Residency in Vienna (AT), and Junge Kunst der Alten Hansestadt Lemgo (DE). She has also been curator in residence at Fabrikken Copenhagen (DK) thanks to the program of the Goethe Institut Denmark and Kulturreferat Munich. Anna Pasco has been teaching at the Department of Fine Arts of the Faculty of Architecture of the Technische Universität München (DE), as well as having taught multiple workshops in different cultural centers.

Her projects have been funded by the Hans Rudolf Foundation and she was awarded the Ambargent'15 prize (ES), the Windmann Kunstpreis'16 (DE), the XXI Biennial of Catalan Con-temporary Art (ES), the 15HOCH2 prize (DE), Barcelona Production'21 (ES), Junge Kunst Neue Wege Scholarship of the Bavarian Ministry of Science and Art (DE), NEUSTART KULTUR Scholarship of the BBK (DE), the special program of the Stiftungkunstfonds (DE), the Neue Medien Munich Scholarship (DE), and the Production Scholarship of the Alexander Tutsek Foundation (DE).

Nacida en Barcelona en 1990, se licenció en Bellas Artes en la Universidad de Barcelona y en la Akademie der Bildenden Kunst München con mención honorífica. Sus obras forman parte de la colección del Stadtmuseum Munic, Staff Stiftung y Curt Wills Stiftung y han sido expuestas en la Bienal Kairo off, Haus der Kunst München, el Festival Speculum Artium en Eslovenia, el Congreso de Microbiología Alemán, el Simposio Internacional de Arte Electrónico ISEA'22, La Capella Barcelona, Lothringer 13 München, Kunsthalle Kempten o Eingen+Art Lab Berlin. Ha publicado "Stickers" con Bom Dia Books y realizó residencias artísticas dentro de los programas Entorno al crear y lo creado organizado por A Cobert (ES) & FAAD Universidad de Temuko (CL), Artic Circle Program (NOR), ArtWaves/ UN Ocean Decade en Helmholtz Instituto de la Universidad Oldemburgo y el Instituto de Estudios Avanzados en Delmenhorst (DE), ÉCART (CAN), Malt AiR (DK), Almresidency (DE), la Residencia de Estudios de Postgrado del DAAD en Viena (AT) y Junge Kunst der Alten Hansestadt Lemgo (DE). También ha sido comisaria en resi-dencia en Fabrikken Copenhague (DK) gracias al programa del Goethe Institut Denmark y Kulturreferat de Múnich.

Anna Pasco ha sido docente en el Departamento de Bellas Artes de la Facultad de Arquitectura de la Technische Universität München (DE), además de haber impartido múltiples works-hops en diferentes centros culturales. Sus proyectos han sido financiados por la Fundación Hans Rudolf y fue galardonada por el premio Ambartgent'15 (ES), el premio Windmann Kunst-preis'16 (DE), la XXI Bienal de arte contemporáneo catalán (ES), el premio 15HOCH2 (DE) , Barcelona Producción'21 (ES), Beca Junge Kunst Neue Wege del Ministerio de Ciencia y Arte de Baviera (DE), Beca NEUSTART KULTUR de la BBK (DE), el programa especial del Stiftungkunstfonds (DE), la Beca Neue Medien Munich (DE) y la Beca de producción de la fundación Ale-xander Tutsek (DE).

Robin Bonné

Robin Bonné is a scientist and science communicator from Belgium. He obtained his master's in physics and astronomy at Ghent University (BE, 2015), along with a teacher's degree in physics (2016). Afterwards, he obtained a PhD at Hasselt University (BE, 2020) on the electrical properties of conductive bacteria. In 2021 he started a postdoc at the Center for Electromicrobiology at Aarhus University (DK) on the same topic. In 2023, Robin started a freelance business in science communication called Robin Talks Science. Today, Robin is a full-time freelancer while continuing as a voluntary scientist at Aarhus University.

Robin Bonné es un científico y divulgador científico belga. Obtuvo un máster en física y astronomía en la Universidad de Gante (BE, 2015), junto con un título de profesor de física (2016). Después obtuvo un doctorado en la Universidad de Hasselt (BE, 2020) sobre las propiedades eléctricas de las bacterias conductoras. En 2021 comenzó un postdoctorado en el Centro de Electromicrobiología de la Universidad de Aarhus (DK) sobre el mismo tema. En 2023, Robin comenzó un negocio independiente de comunicación científica llamado *Robin Talks Science*. En la actualidad, Robin trabaja como freelance a tiempo completo mientras continúa como científico voluntario en la Universidad de Aarhus.

Jean Manca

Prof. Dr. Jean V. Manca is full professor of Experimental Physics at Universiteit Hasselt (Belgium). He received the Bachelor's degree in Physics at Universiteit Hasselt (Belgium) in 1988 and the Master's degree in Physics at Katholieke Universiteit Leuven (Belgium) in 1990. Manca obtained his PhD in Physics at Universiteit Hasselt in 1994, where he continued as a postdoctoral researcher. From 2001 to 2014 he was group leader of the research group ONE2 ('Organic and Nanostructured Electronics & Energy Conversion') at the Institute of Materials Research (IMO-IMOMEC) of Universiteit Hasselt and IMEC. In 2015 he founded the cross-disciplinary research group X-LAB.

El profesor Dr. Jean V. Manca es catedrático de Física Experimental en la Universiteit Hasselt (Bélgica). Obtuvo la licenciatura en Física en la Universiteit Hasselt (Bélgica) en 1988 y el máster en Física en la Katholieke Universiteit Leuven (Bélgica) en 1990. Manca obtuvo su doctorado en Física en la Universiteit Hasselt en 1994, donde continuó como investigador postdocto-ral. De 2001 a 2014 fue jefe del grupo de investigación ONE2 («Electrónica orgánica y nanoestructurada y conversión de energía») en el Instituto de Investigación de Materiales (IMO-IMOMEC) de la Universiteit Hasselt y el IMEC. En 2015 fundó el grupo de investigación inter-disciplinar X-LAB.