Degrees of Life

Human-Bacteria Interaction in Architectural Space

Daniela Mitterberger, Tiziano Derme, Barbara Imhof

Degrees of Life is a responsive environment exhibited in February 2022 at Zentrum Fokus Forschung in Vienna. The project explored the interaction between humans and living systems at an architectural scale. The research aims to develop interactive environments within an architectural space that learn, grow, and decay in relation to human presence and behavior (Figures 1, 2). The space reflects on the concept of biomediality and biofacts (Karafyllis 2003), the possible applications of living technologies, and human sensory interfaces in architecture (Hauser 2017, Groutars et al. 2022). *Degrees of Life* is the result of a larger artistic research context called *Co-corporeality* that weaves together architectural design, sensor systems, machine learning, and microbiology.

Environmental Setup

The exhibition was articulated around three distinct self-sustaining closed environments, hosting three types of bacteria: Escherichia coli, Sucrofermenta, and Cyanobacteria strains (Figures 3, 4, 5). The three enclosed environments are named according to the bacteria: ECo, SuCr, and CyA. Although the enclosed environments provided the necessary environmental conditions for the bacteria to survive, they relied on human interaction and mechanical actuation to thrive.

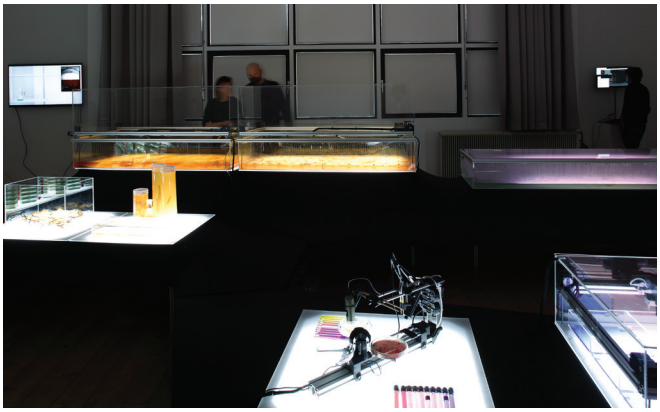
Human Interaction System

Human interaction was registered in real-time by a wearable eye-tracking device that recorded the human visitor's local position and pupil gaze direction (Figure 6). The

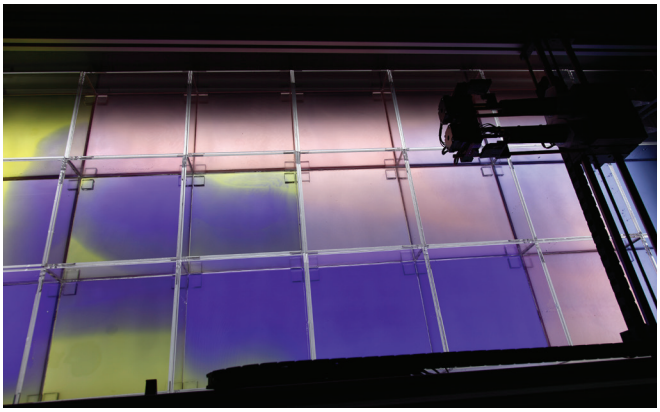
PRODUCTION NOTES

Architect:	Co-corporeality, MAEID
Status:	Exhibition / Built
Site Area:	91 sq meters
Location:	Zentrum Fokus Forschung
	Rustenschacherallee 2–4
Date:	2022

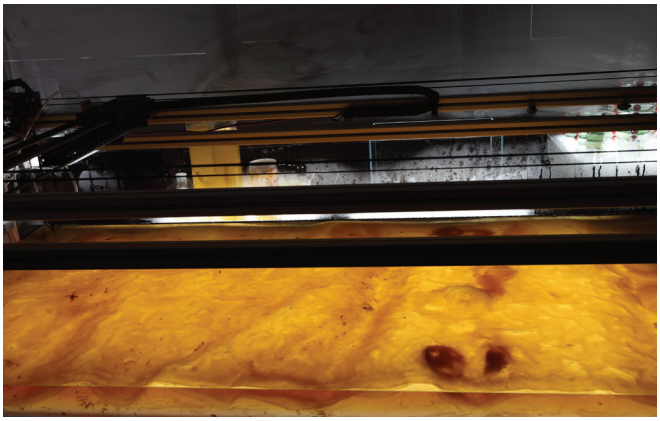
1 Visitor wearing the eye-tracking device and interacting with environments



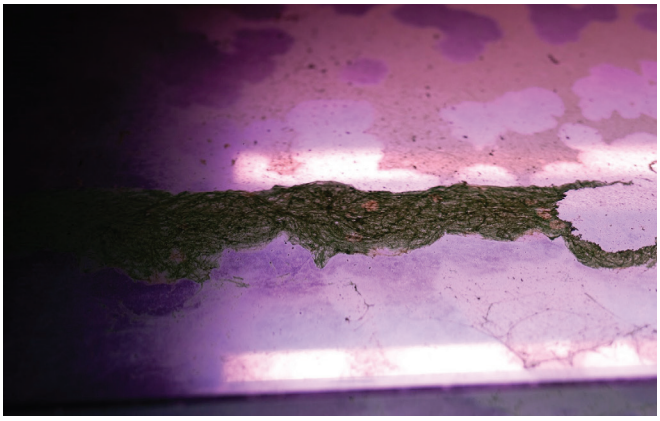
2 Responsive environments reacting to human presence and behavior



3 ECo is an enclosed environment hosting *Escherichia coli* bacteria



4 SuCr is an enclosed environment hosting Sucrofermentas bacteria and microbial biomass production



5 CyA environment with Cyanobacteria reacting to different light stimuli

local position and gaze direction were defined using three cameras: a world camera, an eye camera, and a tracking camera (Figure 7). This setup allowed the authors to record conscious actions, such as gaze direction, and unconscious human actions, such as gaze duration and pupil diameter (Figure 8). The visitor wore the eye-tracking device, and a Raspberry Pi sent the gaze data via ethernet to a server in the exhibition room. The server ran the pupil core software and 3D localization and activated the visualization and interaction routine. The interaction routine included the activation of machines according to different rulesets. These rules included the selection of the environment that has been looked at, the exact gaze location within this environment, and the intensity of the gaze (pupil diameter, time of gaze, frequency). This eye-tracking data was then used to activate a machine within the selected bacterial environment. This machine distributed chemicals or activated a light setup to stimulate, visualize, or direct bacterial growth and behaviors (Figure 9). Each environment had its own set of environmental parameters that could be stimulated, including the chemical setup of the environment, lighting conditions, and the dispersion of nutritional supplements. All three environments were triggered according to the needs of the hosted bacteria.

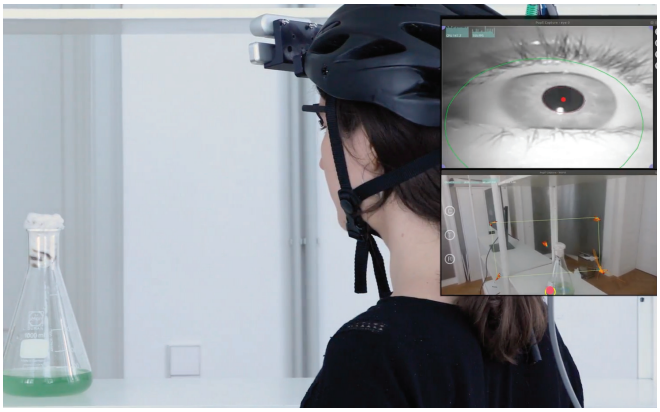
The ECo-environment

ECo was inhabited by the Escherichia coli (E. coli) bacteria. The metabolic process of E. coli led to a change in culture medium pH level, easily detected using pH-sensitive compounds commonly known as pH indicators. The direction of gaze and the pupil diameter of the visitor activated the machinery distributing specific amounts of sodium hydroxide (NaOH) at a precise point into the liquid glucose medium where E. coli were cultured. The release of NaOH results in real-time reversibility of color change in the medium. After that, the metabolic process of the bacteria slowly changes the pH level again and thus also the color of the medium.

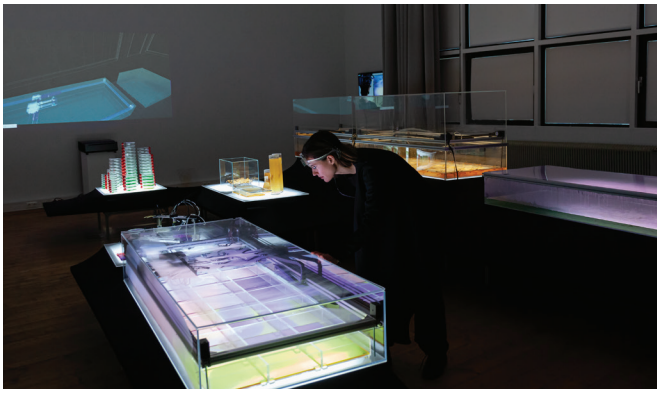
SuCr-environment

The SuCr environment supported the Sucrofementas bacteria strain. The cellulosic bacteria secrete out of its

6 Eye-tracking device (prototype 2)



7 Eye-tracking device (prototype 1) detects the gaze direction and position of the visitor

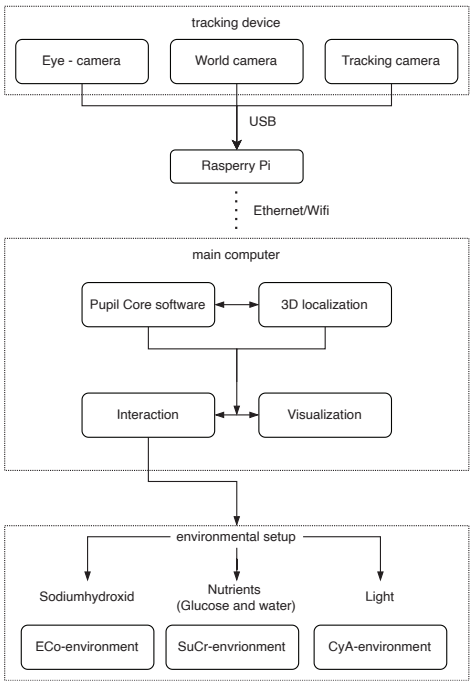


8 Image showing typical interaction of visitors with the ECo environment; visualization projected onto back wall shows the ego-perspective of the visitor

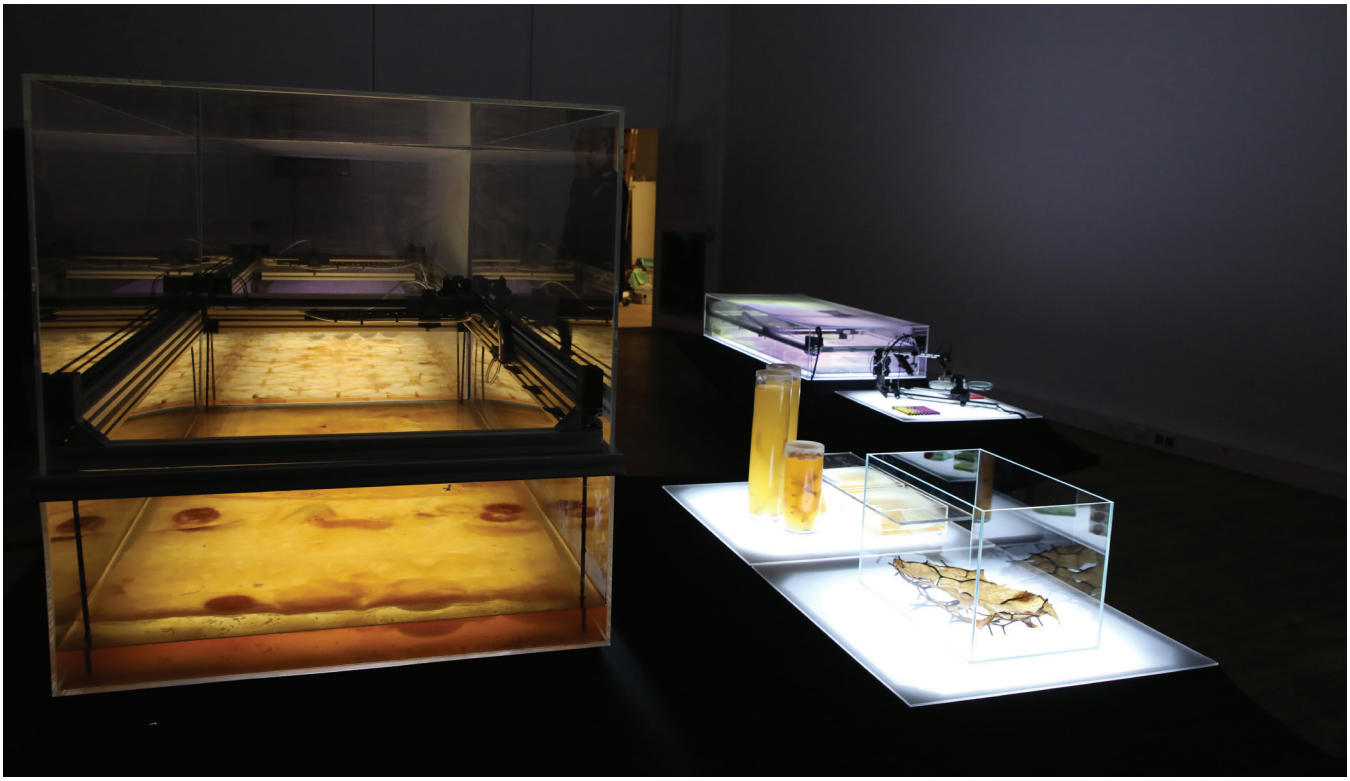
metabolic activity, a thick mat of biomass. The growth of the microbial mat was controlled via a spray nozzle, which moved in two axes and sprayed a nutritional solution (glucose, water, and acetic acid) at a specific location (Figure 10). Human gaze interaction with at specific points in the environment defined the spray location and relatedly the growth rate of the microbial mat.

CyA-environment

The CyA environment hosted the Synechocystis, a genus of cyanobacteria. This bacteria obtains energy via photosynthesis. Human interaction changed the light conditions of the environment by switching the bacteria's growth strategy from photo-autotrophy (light period) to heterotrophy (dark period). The interaction was visualized in real-time by continuously measuring/monitoring dissolved oxygen and pH kinetics. This change in light conditions either activated the photosynthetic activity of the bacteria or reversed it (Figure 11). The environments were placed alongside a visual interface depicting the ego-perspective of the human visitor, the data collected from the visitor's



9 Interaction diagram



10 SuCr enclosed environment and supplementary microbial prototypes

gaze, and the head position in real-time (Figure 8). A soundscape made the interaction audible and assisted the human visitor in using the system.

Degrees of Life was exhibited for three weeks and evolved depending on the interaction of the human visitors with the environment. The ECo and CyA environments flourished, and no contamination was detected. Conversely, the microbial activity of the SuCr environment, due to its acidity level, accelerated the rusting of the machine's mechanical components. The growth of this environment was primarily automated and only partially attributed to human interaction. The exhibition pursues the idea of interactive architecture as a living system (Maturana and Varela 1980; Beesley 2010), in which physical presence and new modes of observation (Barad 2007) are intertwined with tangible forms of computation (Hauser and Strecker 2020).

ACKNOWLEDGMENTS

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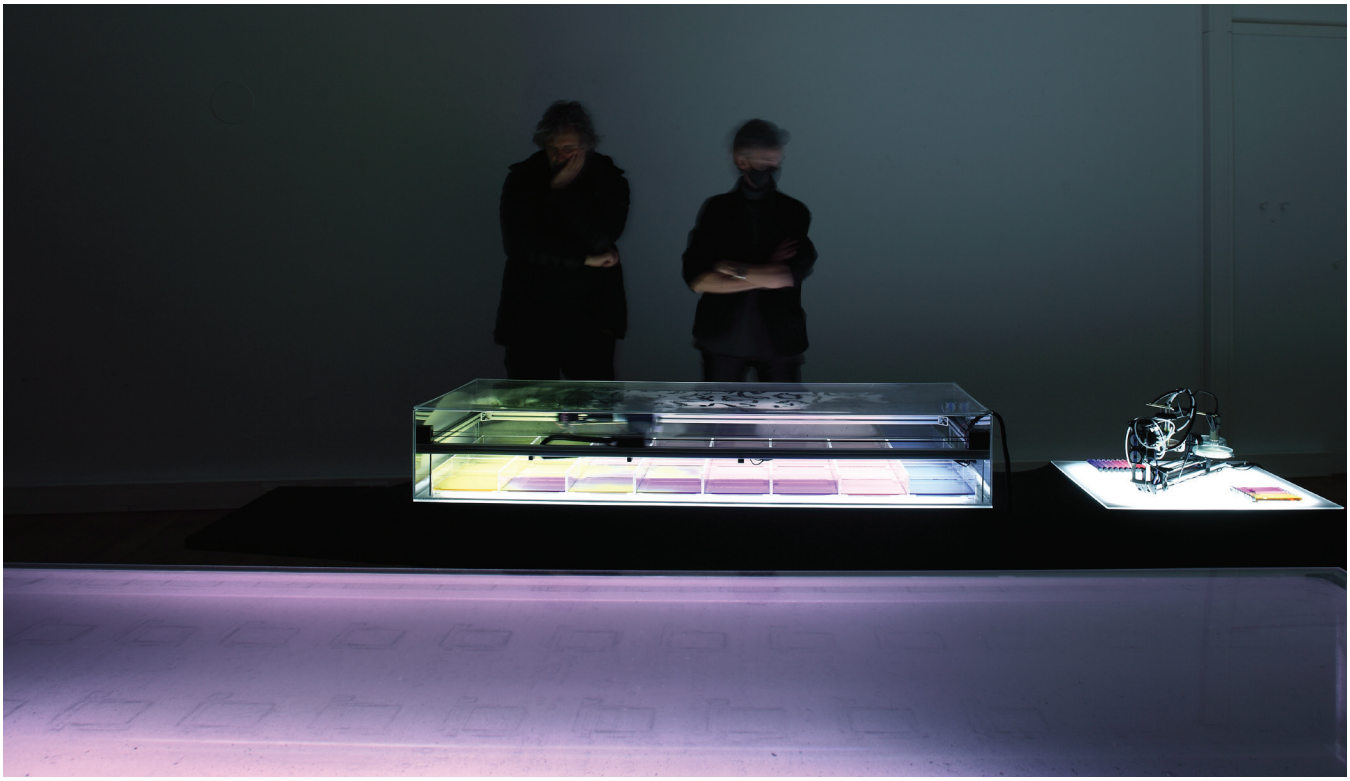

11 CyA enclosed environment hosting colonies of Synechocystis bacteria (front), ECo environment hosting E.coli bacteria (back)

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IMAGE CREDITS

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Daniela Mitterberger is an architect and researcher with a strong interest in new media, the relationship between the Human/Body within digital fabrication, and emerging technologies. She is co-founder and director of MAEID Büro für Architektur und transmediale Kunst, a multidisciplinary architecture practice based in Vienna. Daniela is a PhD researcher and A&T PhD Fellow at ETH Zürich at Gramazio Kohler Research, focusing on human-machine collaboration in digital design and robotic fabrication. Daniela is also a researcher at the University of Applied Arts and co-leader of an FWF PEEK project titled *Co-corporeality*.

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Barbara Imhof is a Vienna-based internationally renowned architect, design researcher, and educator. Her projects deal with spaceflight parameters such as living with limited resources, minimal and trans-formable spaces, resource-conserving systems, and all aspects imperative to sustainability. After *Biornametics*, *GrAB-Growing As Building*, *Co-Corporeality* is the third FWF-PEEK funded project she is co-leading. She is the co-founder and co-managing director of LIQUIFER Systems Group (LSG). She has also been teaching at renowned institutes worldwide for over twenty years. Educated in Vienna, London, and Los Angeles, Barbara holds multiple degrees including a PhD.