Prototyping and Experiential Knowledge

UNFOLDING SHIFTING VIEWS ON THE USE OF PROTOTYPES IN DESIGN RESEARCH

Edited by
Nithikul Nimkulrat, Silvia D. Ferraris, and Francesca Mattioli

FrancoAngeli
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Contents

6. Slow prototyping in biodesign: designing with the living in hybrid laboratories

Francesco Cianfano, Tommaso Celli, Marco Marseglia, Valentina Rognoli

6.1 Introduction

Prototyping has long been recognized as a fundamental part of the design process for validating, exploring, and understanding ideas in context and iterating them. As demonstrated by Buchanan (1992), Cross (2006) and Lim *et al.* (2008), prototypes serve as epistemic and practical tools, giving tangible form to abstract concepts and enabling designers to think through making. Historically, designers have used prototypes to validate their ideas and to understand, test, develop, and refine them over time. The prototype is a crucial step in bringing design thinking to life. It enables abstract concepts to be translated into tangible realities, allowing possible solutions to be explored through the process of creation. This practice is essential and irreplaceable and will continue to be so (Interaction Design Foundation, n.d.).

However, as the discipline has evolved, the design scope has expanded to include the design of materials themselves, moving beyond the mere shaping of artefacts. In this expanded field, prototyping is no longer confined to exploring the form or function of artefacts; it also increasingly engages with their material qualities. Designers have demonstrated their ability to develop material prototypes to investigate not only technical properties but also sensorial, aesthetic, and expressive potential – in other words, "material experience" (Karana, Pedgley, *et al*., 2014; Karana, Pedgley, *et al*., 2015; Pedgley *et al*., 2021). These practices enable the discovery of new applications and stimulate speculative thinking, positioning materials as active agents in the ideation process.

This evolution of material experimentation is deeply rooted in the DIY-Materials paradigm, which has emerged over the past decade as a robust and accessible form of self-produced materials prototyping (Ayala-Garcia & Rognoli, 2017; Ayala-Garcia *et al*., 2017; Rognoli *et al*., 2015; Rognoli & Ayala-Garcia, 2021). Initially an experimental trend, it has since become a consolidated practice continuing to evolve through designers' curiosity-driven exploration. It provides tools and techniques for low-cost, informal, and decentralized experimentation independent of industrial infrastructure. At its core lies tinkering: hands-on, intuitive, and iterative making (Parisi *et al*., 2017; Rognoli & Parisi, 2021), intended as a helpful method of material research and development. Tinkering fosters a dynamic interplay between ideation and matter, blending observation and action, theory and practice in environments that provide rapid, rich feedback (Gaver *et al*., 2009; Kelley & Kelley, 2013). Rather than prioritizing control or precision, this approach values openness, failure, and emergence as generative conditions for knowledge production and material innovation.

In this context, material prototyping becomes a mode of thinking through the hands (Nimkulrat, 2012), a situated, reflective dialogue with matter. It is a technical exercise and an epistemological process that generates knowledge through direct experience, situated experimentation, and self-production. This approach is exemplified by the increasing recognition of materials designers, professionals who work at the intersection of design, materials engineering and science, craft, life sciences, the humanities and speculative thinking (Duarte Poblete, Anselmi, *et al*., 2024; Duarte Poblete, Guarino, *et al*., 2024). Their role involves more than simply selecting materials; they must also actively shape and co-develop them through iterative, hands-on engagement. Mastering this practice necessitates an understanding of materials experiences, the capacity to create prototypes that transcend form, and an awareness of the socio-cultural and ecological implications of material choices.

Building on this foundation, the ongoing exploration of alternative, less impactful, regenerative materials has led designers to consider living organisms in recent years. This ecological and speculative mindset has expanded the boundaries of material experimentation, resulting in pioneering approaches where life becomes the medium and partner in the design process. This evolution aligns with and extends the principles of Material Driven Design (Karana, Barati, *et al*., 2015).

Designing with living organisms and microorganisms has recently become a widespread practice within the international design landscape. The intersection of biology, technology, and creative disciplines has led to the evolution of biodesign (Myers, 2012), a field that considers living systems as active participants in the design process rather than passive materials (Camere & Karana, 2018). From this perspective, design is a collaborative process that involves humans and all other living beings. In this model, growth, transformation, symbiosis, and interdependence take precedence over predictability and control. These experimental practices open new possibilities for addressing ecological concerns by challenging extractive models and proposing regenerative alternatives based on collaboration with nature (Antonelli, 2019). From microbial materials to biofabricated structures, biodesign expands materials designers' matter palettes while reconfiguring their role, tools, and methods. This shift reflects a broader cultural and epistemological movement towards ecological thinking and relational ontologies, where materials are not considered inert substances but rather dynamic participants in the creation of regenerative ecologies (Karana *et al*., 2023; Pollini, 2024; Pollini & Rognoli, 2024).

It becomes evident that prototyping is undergoing a profound transformation. While it was traditionally used to test and refine artefacts or materials, in the context of biodesign, it must engage with living entities, such as bacteria, fungi, algae, and other microorganisms that grow, evolve, and respond to environmental stimuli by expressing forms of agency and intelligence. These biological systems resist the logic of rapidity, control, and linear optimization that characterize many conventional prototyping approaches. In this setting, prototypes can be understood as probabilistic artefacts embedded in dynamic, uncertain, and iterative processes rather than stabilizing steps towards predetermined outcomes (Giaccardi *et al.*, 2024). This perspective reinforces our understanding of biological prototypes as living, relational, and agency-driven systems; rather than merely validating form or function, such prototypes act as situated spaces of co-emergence – unstable artefacts participating in the creation of other artefacts and enabling situated, multispecies, and epistemologically generative design practices. Consequently, the laboratory evolves from a production space into a place of care, observation, and negotiation, where designers facilitate conditions for emergence instead of determining outcomes. Within this framework, prototyping is redefined as a relational and situated practice, shaped as much by biological rhythms and ecological constraints as by creative intent.

Experiments conducted in biolab environments suggest that, in the context of biodesign, prototyping is not just a technical act but also an epistemological process. It generates alternative forms of knowledge grounded in observation, co-evolution, and a careful understanding of biological rhythms, dynamics, and uncertainty.

Within this scenario, the notion of "biotinkering" emerges (Pollini, 2024; Pollini & Rognoli, 2024): a practice that combines creative experimentation with scientific knowledge and ethical awareness. Biotinkering is not just about "making with hands"; it responds to the logic of life. Instead of shaping inert matter, biodesigners engage with microorganisms with specific needs, behaviours, and forms of intelligence (Ginsberg *et al.*, 2014; Myers, 2012). This requires a shift in design attitude – from control to engagement and from extraction to collaboration – and necessitates the designer observing, adapting to, and co-evolving with living systems throughout the slow prototyping process.

By tracing the transition from conventional DIY approaches to biodesign, this chapter proposes an expanded and critical vision of slow prototyping, a practice that redefines prototyping not merely as a means to an end but as an open-ended, dialogic, and living process. Through theoretical framing and analysis of three situated case studies, it argues for a broader definition of prototyping in design, transforming the practice into a space of listening, care, and interspecies co-creation (Claire, 2019). This evolving landscape calls for a fundamental shift in the designer's perspective: from control and predictability to adaptability, respect, and co-evolution with living systems. Unlike conventional approaches, often driven by speed, efficiency, and rapid iteration, designing with biofabricated materials requires attunement to the slower, unpredictable rhythms of biological organisms. In this view, prototyping becomes less about optimizing performance and more about cultivating relationships with materials, organisms, and the broader ecological systems in which design operates (Camere & Karana, 2018).

6.2 From DIY materials to biodesign: a shift in the perspective on prototyping

Over the past decade, DIY-materials approaches have emerged as a widely adopted strategy within materials design. Rooted in hands-on experimentation, these practices empower designers to engage directly with matter, bypassing industrial constraints and fostering accessible innovation. Through iterative mixing, heating, testing, and modifying processes, designers explore the potential of raw or waste-based materials, often guided more by intuition than scientific rigour. In this sense, DIY experimentation activates forms of tacit, embodied, and situated knowledge in which material understanding arises through physical interaction and iterative making.

These practices are often characterized by immediacy: the ability to test, fail, and adjust prototypes in short cycles. Whether developing mycelium-based composites, gelatine bioplastics, or starch-based foams, designers working in DIY modalities benefit from short feedback loops that foster creativity and responsiveness. Prototyping here is embedded in a design culture that values speed, visual clarity, and control over form and function.

However, the emergence of biodesign, which engages directly with living organisms, biological processes, and cellular systems, introduces a radical shift in both methodology and mindset. Prototyping in biodesign is no longer about fast iteration or material control but about co-evolving with biological rhythms, where the agency is shared with microbes, fungi, bacteria, or tissue cultures (Myers, 2015). These systems grow slowly, respond non-linearly, and behave unpredictably. The designer must accept delays, failures, and ambiguities as integral to the process.

This shift extends beyond materiality; it demands an epistemological transformation. Those most familiar with living organisms – life science scholars such as biologists – all rely on a common epistemological tool: the scientific method. This method is the primary means for investigating the processes and structures characterizing living systems. To date, the scientific method arguably remains the most effective framework for understanding the complexity of biological phenomena.

Rather than seeking control, the designer becomes a facilitator of conditions, enabling growth, reacting to change, and learning from the living material itself. This shift marks the transition from object-centred design to processual and relational design, where material expression is neither fully predictable nor entirely authored (Ginsberg *et al.*, 2014; Myers, 2012).

6.3 Prototyping with the living: agency, ethics, and co-evolution

Prototyping with living organisms opens up a radically different understanding of material agency. In this context, matter is not inert but active, capable of growth, transformation, and response. Living materials such as bacteria, fungi, algae, or yeast exhibit behaviours that are not entirely predictable or controllable, introducing degrees of autonomy into the design process. As Rognoli *et al.* (2022) note in their discussion of living artefacts, these bio-based systems blur the line between product and process, object and organism. The implications of this shift are profound: the designer no longer interacts with a passive medium but enters into a dynamic and evolving relationship with the living material. Living organisms are open systems that exchange energy and matter with their environment, constantly responding to external stimuli. As such, the design process cannot be based on a one-sided intervention by the designer. Instead, the organism itself contributes independently, reacting and adapting in ways that are often unpredictable. These responses vary depending on environmental conditions, making the designer's role one of observation, interpretation, and dialogue. Understanding these biological mechanisms becomes essential for meaningful interaction, as the act of prototyping becomes a co-creation, designing not *for* the organism but *with* it. Rooted in the principles of slow design, slow prototyping values time, reflection, and ecological responsiveness (Spoelstra, 2023). It embraces delays, irregularities, and uncertainty as essential components of the process rather than obstacles to overcome. What may initially appear as limitations become opportunities for deeper engagement, unexpected discoveries, and more responsible design outcomes. Prototyping becomes a dialogic process shaped by environmental variables such as temperature, light, humidity, and nutrient availability. The artefact itself responds to these factors, and the designer's role shifts from controlling outcomes to enabling conditions for growth. This calls for a new ethical stance rooted in care and attentiveness. Designers must learn to work with, rather than against, the rhythms and needs of biological systems. This ethic of care echoes posthumanist design approaches (e.g., Haraway, 2008; DiSalvo, 2009), which advocate for multispecies respect, interdependence, and co-evolution. Instead of viewing the organism as a tool or resource, the designer becomes a facilitator or caretaker who cultivates relationships across biological and technological domains. In this scenario, the environment plays a crucial role, not as a static backdrop but as a co-author of the prototype.

For instance, subtle shifts in humidity or temperature can dramatically affect the behaviour of bacterial colonies or fungal networks. Designers can work within these fluctuations or choose to actively manipulate them, using bioreactors or controlled ecosystems to "hack" specific outcomes. However, such interventions should come after a period of observation and attunement, where the designer learns what the organism needs before attempting to steer its development. This is the essence of biotinkering: iterative, respectful adaptation based on lived interaction with the organism. The prototype thus becomes an unstable, open-ended system, defined not by completion but by becoming. Its indeterminacy is not a flaw but a feature: a productive space for speculation, emergence, and learning.

This approach repositions the prototype as a living artefact, sensitive to change, deeply relational, and responsive to both human and non-human actors. By embracing this instability, designers are invited into a humbler and situated practice that foregrounds observation, collaboration, and long-term engagement with life itself.

6.4 Biotinkering as design practice

Tinkering is commonly understood as an intuitive, hands-on, and iterative approach to experimentation. It relies on trial and error, exploration, and direct engagement with materials. This approach values openness, unpredictability, and emergence over precision and control. It has proven particularly effective in the context of DIY materials design, where accessible, generative, low-tech, decentralized experimentation can be carried out (Parisi *et al.*, 2017; Rognoli & Parisi, 2021). Thus, tinkering can be defined as a material practice grounded in empirical exploration, improvisation, and an openness to the unexpected – a way of learning and creating through doing, where design outcomes emerge from the process rather than being predefined.

Biotinkering builds upon these principles while introducing specific considerations required when working with living organisms. It can be defined as a design approach that merges creative experimentation with ecological sensitivity and scientific awareness. The presence of living organisms, such as bacteria, fungi, algae or yeasts, transforms the practice: rather than simply manipulating inert matter, designers must engage in a dialogic process with entities that grow, evolve, and respond to their environments. As some scholars (Guarino *et al.*, 2024; Pollini, 2022) highlight, biotinkering is about crafting alongside life, fostering new relations of care, responsibility, and mutual transformation, not just crafting with life.

Unlike traditional tinkering, which is usually driven by intuition and open-ended improvisation, biotinkering requires specific consideration of biological rhythms, the ethics of intervention and environmental complexity. It is based on observation, iterative adaptation, and the co-evolution of the designer, the organism, and the surrounding ecosystem. The designer's role has shifted from that of an author to that of a facilitator of conditions. They must balance creativity with scientific rigour, navigating protocols and operating technical equipment while remaining open to emergence and unpredictability.

This dual capacity often necessitates navigating multiple layers of scale – biological, material, ecological, and technological – thereby introducing significant methodological complexity. To address this, our research adopted a transcalar methodology, which is a conceptual and practical approach connecting actions and insights across different scales – from the microscopic (e.g., microbial behaviour) to the systemic (e.g. environmental impact) (Goidea *et al.*, 2022; Scholte, 2019). Within this framework, biotinkering is one of the operative modes of a transcalar design process offering hands-on, situated experimentation that generates new materials and fosters new ways of knowing and relating to the living world.

This connection was made explicit in the collaboration between the Politecnico di Milano (Materials Design for Transition research group) and the University of Florence (Celli & Cianfano *et al.*, 2025), in which designers and biologists co-developed biofabricated materials by oscillating between laboratory-scale material manipulation and design-scale application scenarios. In this context, biotinkering acted as a bridge between empirical processes and systemic thinking, enabling local material actions to inform broader ecological reflection.

The methodological value of biotinkering lies in its nature as a form of research-through-design (Giaccardi *et al.*, 2024; Pollini, 2024; Vu *et al.*, 2024). Knowledge does not precede action but instead emerges from it. Insights are generated through material interaction: observing how organisms respond to environmental variables, adjusting protocols in real-time, and reflecting on outcomes. As Gatto and McCardle (2016) point out, this integration of scientific and design logic requires the development of a shared language and conceptual framework, one capable of translating across disciplinary boundaries. The designer in this setting becomes a mediator between worlds. They must gain literacy in scientific processes while embracing the ambiguity and open-endedness of design. Biologists, conversely, are encouraged to iterate beyond fixed protocols and engage in framing problems rather than merely solving them (Hall *et al.*, 2019). This mutual transformation is critical to building a genuinely shared epistemological space (Hashemi Farzaneh, 2020). Ultimately, biotinkering is not just a technique but an attitude that values life, embraces complexity, and seeks to co-produce knowledge in ecologically responsive ways. It repositions design as a relational and multispecies practice, where uncertainty, failure, and transformation are not limitations but essential conditions for learning. In this light, biotinkering offers a methodological model for future design education and transdisciplinary research that prepares designers to operate with humility, rigour, and care in collaboration with living systems and scientific partners.

6.5 Slow prototyping: case studies

This section presents three case studies that demonstrate diverse and innovative approaches to biodesign, based on collaborations between designers, living organisms, and material processes. These cases were selected for their use of different biological agents – microbial cellulose, fungal mycelium, and ureolytic bacteria – and explore distinct material behaviours, growth dynamics, and design challenges. Each project demonstrates how biotinkering is manifested in practice by engaging with the agency of living matter, fostering iterative and hands-on experimentation, and reframing the designer's role as a co-creator and facilitator of growth conditions rather than an individual author. Beyond their material outcomes, the case studies also represent different scales of intervention – from craft-scale prototyping to architectural experimentation and bio-cementation – thereby illustrating the transcalar potential of biodesign. Importantly, all three cases exemplify "slow prototyping" as a temporal and methodological attitude: a process of making that is attuned to biological rhythms, open to contingency, and grounded in care and responsiveness. Together, they demonstrate that working with living systems can generate alternative materials and new design values based on sustainability, care, and speculative thinking.

6.5.1 SCOBY leather: experimental material cycles by designer-makers
Symbiotic culture of bacteria and yeast (SCOBY) is a cellulose matrix generated by the fermentation of sweetened tea into kombucha,

mediated by microorganisms. This case explores how independent designers and grassroots labs are cultivating SCOBY to prototype alternative "leather-like" materials for fashion and product design.

The process begins with the fermentation of black or green tea using a live culture in wide, shallow containers. Over a period of 10–20 days, a thick cellulose mat forms on the surface. This layer is harvested, rinsed, and dried under controlled conditions to create a translucent, flexible sheet. Depending on drying methods and additives, such as glycerol for plasticization or natural dyes for pigmentation, the material can emulate the properties of leather, parchment, or rubber. What distinguishes SCOBY from synthetic biomaterials is its regenerative nature: it grows from simple, low-cost ingredients and can be cultivated repeatedly with minimal waste. However, its unpredictability, varying thickness, fragility, and sensitivity to humidity require designers to adapt to their expectations and aesthetics. In this context, prototyping becomes less about stabilization and more about attunement. Designers track microbial growth, experiment with fermentation durations, and engage in trial, failure, and transformation cycles. The SCOBY becomes not just a material but a collaborator with its own growth rhythms and constraints.

This practice embodies biotinkering: the iterative and relational making-with-life that values slowness, care, and responsiveness. Rather than seeking industrial scalability, many SCOBY practitioners frame their work as critique, offering alternative narratives about luxury, temporality, and sustainability in material design. As documented by the Future Materials Bank (2023), SCOBY leather exemplifies how microbial processes can be reimagined for production and for rethinking material culture.

6.5.2 Cultivating change: mycelium-based structures by ALEA Studio

This case study investigates the design methodology of ALEA, an experimental studio based in Paris and founded in 2021 by designers Miriam Josi and Stella Lee Prowse. Known for their work on *Back to Dirt*, ALEA cultivates fungal mycelium in combination with agricultural waste to prototype biodegradable materials rooted in regenerative design principles. Their practice is rooted in principles of regenerative design, aiming to develop biodegradable architectural components by cultivating mycelium in combination with agricultural waste.

The research began by identifying locally available waste substrates, such as corn husks, coffee grounds, and sawdust, suitable for fungal colonization. These substrates were sterilized and inoculated with Pleurotus ostreatus, a fast-growing edible fungus. The inoculated matter was then cast into modular moulds of varying geometries to explore the spatial potential of the material. Rather than treating the fungal composite as a static medium, the studio embraced its agency and time-based behaviour. During the growth phase (7–12 days), designers monitored humidity, temperature, and contamination risks, observing how different mould shapes and substrate compositions influenced the density and mechanical properties of the mycelial structures. The resulting blocks were dried to terminate fungal growth and enhance stability. The team emphasized that the final form was not entirely “authored” but emerged from a co-productive process between the designer, organism, and environment. This approach exemplifies slow prototyping: iterative, relational, and deeply embedded in biological temporality.

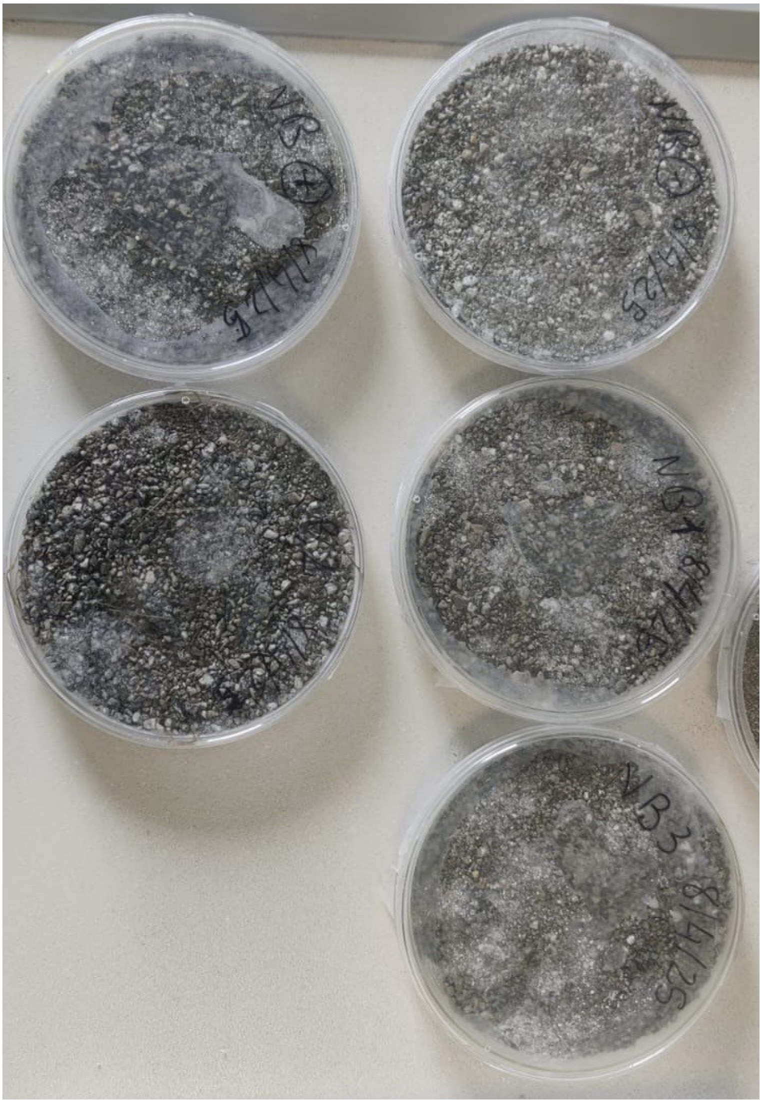
ALEA’s practice highlights how prototyping in biodesign shifts from form-driven processes to condition-making, creating environments in which living matter can express its own logic of formation. It also reveals how biodesign can serve speculative and pedagogical functions, challenging extractive paradigms in architecture and material culture.

6.5.3 Biocalcification with Sporosarcina pasteurii

This case study explores the potential of *Sporosarcina pasteurii*, a ureolytic bacterium capable of inducing microbially induced calcite precipitation (MICP), in the development of biofabricated composite materials made from recycled aggregates and textile fibres. The aim was to investigate biocalcification as a sustainable alternative to cement-based binding, proposing a regenerative approach to material assembly.

The project emerged from a collaboration between designers and biologists, initiating a cross-disciplinary dialogue to understand the conditions required for bacterial growth and calcification. The early stages of experimentation were informed by microbiological protocols and consultations with laboratory experts, who provided insights into the handling and environmental requirements of S. pasteurii. The substrate was prepared using sieved recycled concrete aggregates combined with discarded textile fibres, specifically linen and cotton selvedges, chosen for their porosity and structural entanglement. This porous matrix was designed to host bacterial activity and facilitate the diffusion and crystallization of calcium carbonate throughout the composite.

Figure 6.1. Petri dishes with the bacterium (S. pasteurii) and the substrate (recycled concrete).



The intended treatment consisted of two main phases: first, the application of the bacterial culture, followed by immersion in a calcifying solution that triggers mineral bonding. This sequence was designed to initiate a bio-cementation process, transforming loose particles into cohesive and structured material through the organism's metabolic activity. This experiment (Figure 6.1) positions material making as a co-productive process, where design parameters, such as fibre orientation, aggregate size, and form, are carefully tuned in response to the biological rhythms of the living agent. The designer's role shifts from author to environmental facilitator, orchestrating conditions for life to act as a materializing force.

Biocalcification is not only a method of consolidation but also a design gesture: a practice where industrial waste and microbial life come together to form hybrid matter with dual origins, technical and biological. The result is a speculative material language that redefines notions of authorship, temporality, and sustainability in design (Cianfano, 2025).

6.6 Discussion

The three case studies presented – SCOBY-based microbial cellulose, ALEA's mycelium biofabrication, and the bio-calcification process using Sporosarcina pasteurii – provide different yet complementary insights into slow prototyping in biodesign. Despite their differences in biological agents and application contexts, the studies converge around a shared methodological approach that is grounded in iterative experimentation, attention to biological temporality, and relational engagement with living materials.

In each case, slow prototyping is a conscious departure from conventional design workflows, which prioritize control, predictability, and efficiency. Instead, it embraces unpredictability, emergence and continuous adaptation. Designers shift from acting as individual authors to becoming facilitators who create and maintain conditions for life to flourish and influence material outcomes. This requires close observation of biological rhythms, responsive adjustments through feedback loops, and acceptance of failure and transformation as integral to the process.

The case studies also operate across different scales of intervention, from small-scale DIY SCOBY fermentations to architectural mycelium composites and experimental bacterial mineralization, demonstrating how biotinkering fosters deeper attunement to time, material instability, and ethical responsibility as a mode of making-with-life. Rather than viewing slowness and uncertainty as limitations, these practices reveal them to be generative conditions that encourage innovation through care, co-evolution, and critical reflection.

Ultimately, these examples demonstrate how slow prototyping challenges established ideas about material production and authorship. They open up the possibility of new material cultures that are rooted in ecological sensitivity and transdisciplinary collaboration. At the same time, they redefine the role of the designer as one of co-creation with biological entities. This shift produces innovative and sustainable materials and invites broader reflection on temporality, responsibility, and the ethics of intervention in design practice.

6.7 Conclusions and future developments

With the emergence of biodesign, prototyping is undergoing a profound epistemological and methodological transformation. No longer conceived merely as a phase in product development, it becomes a relational and situated practice – one in which knowledge is co-produced through direct engagement with living systems. The inherently interdisciplinary nature of biodesign – where design converges with biology, engineering, environmental science, and the humanities – demands a reconfiguration of roles, methods, and expectations.

As demonstrated throughout this chapter, prototyping with biofabricated materials involves navigating a dynamic negotiation between the intentions of the designer and the emergent behaviours of biological agents. Far from being passive recipients of form, organisms such as bacteria, fungi, or algae express agency, grow according to their own temporalities, and resist the logics of speed, control, and predictability that often characterize conventional design paradigms.

In this context, the designer is called to adopt a new stance – one rooted in attentiveness, humility, and care. Designing becomes a dialogic process, not of imposing form, but of listening and negotiating with other-than-human collaborators. Prototypes are not static endpoints but evolving systems: spaces of becoming shaped by feedback, uncertainty, and ecological interdependence.

This shift has significant temporal implications. Biological growth unfolds on a slower timeline than industrial processes. What might be perceived as limitations – delayed outcomes, irregular behaviours, or lack of control – are, within the framework of slow prototyping, reframed as opportunities. Time becomes a resource for reflection, observation, and co-evolution. Failure becomes a site of learning. Instability becomes a condition for emergence. As Spoelstra (2023) suggests, these are not flaws to eliminate, but characteristics to cultivate within a new design logic.

The case studies discussed in this chapter – from microbial cellulose and mycelium structures to bacterial mineralization – have illustrated how biotinkering enables this shift. They exemplify slow prototyping as a generative method, capable of producing not only innovative materials but also new design values based on sustainability, multispecies care, and systemic awareness.

Looking ahead, this approach invites further exploration along several lines. First, there is a need for new educational frameworks that prepare designers to operate in hybrid labs, bridging intuitive practice and scientific method. Second, future research should continue to develop transcalar methodologies capable of connecting microscale material processes to macroscale ecological and cultural questions. Finally, as the field matures, it will be essential to engage in critical reflection on ethics, responsibility, and the politics of life at the core of biodesign.

Rather than offering fixed models or prescriptive methods, this chapter contributes to an ongoing, evolving conversation. In embracing the uncertainties of working with living matter, slow prototyping opens up space for experimental, inclusive, and ecologically responsive forms of design – ones that are not only about making things, but about making sense, together with the living world.

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Felicita Devlin is an artist and educator from South Florida, currently living in Providence, RI. They are a studio member of Binch Press / Queer.Archive.Work. Their practice uses craft & technology to express the supernatural dimensions of nature, the mystical presence of disabled, trans, and queer ancestors, and how technology can be used as an extension of survival. Their work relies on experimenting with textiles, printmaking, riso, and digital remixing through coding, 3D design, and sound.

Dr. Rose Dumesny is a designer with a PhD in Design Sciences and Information-Communication Sciences. Trained in product design at

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Dani Epstein received her Master of Industrial Design at the Rhode Island School of Design and her Bachelor of Fine Arts in Metal from the State University of New York at New Paltz. Her work explores forms, materials, and systems that challenge pre-existing formats, promoting greater sensitivity and flexible futures.

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Dr. Joy Ko is an artist and educator. Her teaching, research and writing explore the use of computation and digital technologies to augment and extend the creative process. Since 2021 she has guided the work of the Virtual Textiles Research Group (VTRG) based at the Rhode Island School of Design (RISD).

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Geoff Langridge is a mechanical engineer with experience in a range of mechanical design roles. Problem solving and analysis skills compliment his design and drafting knowledge, offering a broad knowledge base and diverse skills suitable for a broad range of roles and customers. Geoff has a deep understanding of CAD systems and best practices.

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Simon Modra, an expert in interior architecture, furniture design, building design, and project management, holds a Master of Architecture, Master of Design (Design Construct), and Bachelor of Architectural Studies. A PhD candidate and researcher at the University of South Australia, he co-founded the Studio for Complex Human Environment Design. His research focuses on using simulation tools to optimize design methods for human spaces in capsule environments.

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Dr. Rowan Page is an industrial design practitioner and researcher investigating the intersections between theory and practice, between artefacts and systems, and between making and discourse. His award-winning industrial design practice is underpinned by research rigour, collaboration, detail, process, and context. His work demonstrates the role of design in research translation and explores how artefact creation materializes ideologies and fundamental research. He has collaborated with leading Australian manufacturers (Cochlear, Blundstone, and General Motors Holden), hospitals, and fundamental and clinical researchers. He also explores emerging design practices through self-directed practice. He is based at Monash University in Narrm/Melbourne as a Discovery Early Career Researcher Award (DECRA) Fellow (2024–2027) with the Australian Research Council.

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Dr. Valentina Rognoli is a designer and researcher working at the intersection of materials design, biodesign, and regenerative futures. She is the leader of the Materials Design for Transition research group at the Politecnico di Milano. Combining critical enquiry with hands-on experimentation, her work promotes a materials-driven design approach informed by ecological thinking and more-than-human perspectives. She teaches and collaborates internationally, developing projects and publishing work on materials design, biodesign, regenerative design, and sustainable innovation in design education. Her other research interests relating to materials include craft practices, indigenous knowledge, and multispecies design approaches.

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Caroline Silverman is an interdisciplinary artist who focuses on the intersection of object, narrative, and context. Working predominantly with textiles, her work explores how the soft things that people live with reflect the realities and records of their experiences. In the process of exploring what draws people to their objects, she has made quilts, writing, embroideries, tools, poetry, garments, books, and paintings to help her better understand this relationship.

Aldo Sollazzo is an Italian entrepreneur and technologist who has established himself as a dynamic figure in the fields of robotics, computer vision, and AI. With a career marked by dedication and innovation, Sollazzo's contributions have had a meaningful impact on these dynamic industries. Within the NOUMENA GROUP, Sollazzo's responsibilities encompass leading roles that reflect his commitment to sustainable engineering and architectural innovation. The group is constituted by the three companies of Noumena Data, LAMÁQUINA 3d, and PURE.TECH: the common focus is to establish novel protocols for the definition of built environments informed by data, material technologies, and built through a novel approach of manufacturing.

After an education in experimental physics (MSc 1984), **Pieter Jan Stappers** made the switch to Industrial Design Engineering (IDE) at TU Delft and followed a research path which led from human perception, spatial imagery, Virtual Reality (PhD in 1992), to design tools and participatory design techniques. As a professor of design techniques (as of 2002), he has pursued developing research and education in design techniques for the early phases of design. Core elements in his work are 'research through design', 'experiential prototypes', and participatory techniques such as "contextmapping". On each of these subjects, he has published both in academic books and journals, and developed education materials for broader impact.

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This volume examines the evolving role of prototypes in design research, emphasizing their function as intentional and transient objects that facilitate the transition from abstract concepts to concrete design outcomes. Through a range of disciplinary and methodological perspectives, the book investigates how prototyping contributes to knowledge generation, design process development, and the articulation of experiential understanding. The chapters are organized into four thematic parts – Envisioning, Exploring, Comprehending, and Developing the Design Process – each addressing distinct aims and contexts of prototyping. Contributions include studies on low-fidelity tactics, collaborative learning environments, multisensory material translation, biodesign practices, data engagement, and political dimensions of design. These inquiries foreground prototyping as a situated, relational, and epistemic practice.
The volume concludes that prototyping in design research extends beyond technical validation to encompass pedagogical, ecological, and speculative dimensions. It demonstrates that prototypes can serve as vehicles for interdisciplinary collaboration, critical reflection, and the negotiation of complex design challenges.

FrancoAngeli
La passione per le conoscenze