Material Trajectories

Perraudin
Winkler
Mareis
Held

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Future Ecologies Series
Edited by Petra Löffler, Claudia Mareis
and Florian Sprenger

Material Trajectories: Designing With Care?

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Léa Perraudin, Clemens Winkler,
Claudia Mareis and Matthias Held

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Series Foreword: Future Ecologies

Petra Löffler, Claudia Mareis, and Florian Sprenger

The future of life on Earth has generated ongoing debates in academia, through which the concept of ecology has gained status by being able to connect disciplines across the natural sciences, humanities, arts, design and architecture. Criticism of the effects of climate change, which exacerbate existing inequalities in our global population, has spread from academia to the political and public spheres. At a time when the future of life on this planet is more uncertain than ever, the urgency of exploring other ways of thinking, acting and dwelling together is evident. This book series investigates emerging ecologies in uncertain worlds – ecologies that are open to the interests of other-than-humans and that care for plural modes of existence. By providing a platform for these topics and debates, we hope to contribute to a nature contract with the Earth as the shared common ground of water and minerals, air and birds, earth and woods, living and non-living, active and passive matter.

Future Ecologies is about a "time-space-mattering" that calls into question common knowledges about the relationship between space, place, territory, and the linearity of time in light of the circulation of matter, energies, and affect. It also questions the meaning of past ecologies and unsustainable futures for emergent ecologies, while problematizing the ambivalent histories of environmental knowledge, especially in the interplay of modernity and coloniality. Reading research in the *Future Ecologies* series allows you to take the many facets of past ecological thinking into account, to reveal its differentiated and often contradictory political implications and effects – and to criticize its, sometimes, naïve promises. Studying *Future Ecologies* means not taking for granted what ecology means.

The series promotes a relational thinking that is aware of the environmental, economic, social, and individual complexities of such a pluriverse driven by equally complex technologies and infrastructures. As Donna J. Haraway said, in a shared world "nothing is connected to everything, but everything is connected to something". This connection generates and discloses different scales of responsibility. We dedicate this book series to all earthly critters who want to invent and try out new forms of life and styles of cohabitation, who ask which risks we want to and are able to take, and which futures we dream of. We invite contributions that address the geopolitical inequalities of climate change and capitalist extractivism, that deal with politics of (un)sustainability and (de)futuring, technologies of recycling and environing, non-anthropocentric epistemologies and practices of world-making.

The *Future Ecologies* series advocates for interdisciplinary approaches towards the numerous aspects of ecology. We invite junior and senior scholars from various disciplines in media, cultural and literary studies, anthropology, design, architecture, and the arts to build collaborations between different voices, practices and knowledges – that is: heterogeneous communities of practice. By endorsing open access publishing, the series also aims to partake in the current transformation of the ecologies and economies of knowledge production.

Preface

Claudia Mareis and Matthias Held

This edited volume is the outcome of the 2021 Annual Conference of the German Society for Design Theory and Research (DGTF), organized in cooperation with the Cluster of Excellence "Matters of Activity. Image Space Material" at the Humboldt-Universität zu Berlin and the weißensee kunsthochschule berlin. The constellation of these three institutions shaped the theme of the conference, "Material Trajectories. Designing with Care" as they all have a long history of exploring the possibilities and complications of design and material culture in theory and practice. This book is thus conceived as a collaborative attempt by interdisciplinary scholars and design practitioners to explore the foundations of a new material culture. It is about exploring and problematizing material trajectories and entanglements, as well as opening up new and different ways of designing with modesty, complicity, and care.

The contributions we have gathered in this edited volume are united by the conviction that matter is not simply passive and malleable, but that new and other creative configurations and design principles can emerge from insight into the inherent *activity* of matter. This renewed interest in active matter concerns, perhaps most obviously, the material properties and structures themselves, as is currently evident in the numerous emerging approaches to design utilizing organic materials: fungi, algae, bacteria, cellulose, etc. The understanding of active matter can also be seen as an initiative against the constant passivation of matter caused, controlled, and exploited by modernist design, technology, and industry. In many ways, industrial methods of infrastructuring and construction have in the past worked against, rather than with, the inherent activity of matter, exhausting “natural resources” to the limit. Understanding matter’s intrinsic dynamic and vibrancy could therefore contribute to a fundamentally different understanding of the inseparability of nature and culture.

However, the distinction of matter into active and passive is by no means limited to construction methods or design principles, but also has a political and ethical dimension – for passivation goes hand in hand with objectification. Passivation turns active matter into mere things – lifeless, inert, passive objects. Passivation is part of what Raj Patel and Jason Moore (2018) have called the capitalist regime of the “cheap things,” according to which capitalism is built on and sustained by artificially cheapened resources such as nature, money, labor, care, food, energy, and life. Moreover, passivation of matter affects not only the handling of “natural resources” and the use of organic materials, but human life itself. Passivation means, as human geographer Kathryn Yusoff convincingly argued, a division of life into active and passive, human and inhuman, based on racial ideologies and policies of oppression. Racialization, she says, “belongs to a material categorization of the division of matter (corporeal and mineralogical) into active and inert” – both natural resources and enslaved people have been treated as passive material “through the [...] extraction of their inhuman properties” (Yusoff 2018, 2–3).

The theme of material trajectories and designing with care is thus far from being limited to questions of material science, architecture, and design, but has far-reaching geopolitical and biopolitical consequences: it is about material politics and material legacies, and the violence of commodification and exploitation. Digital technologies could even reinforce this logic of passive matter by combining digital code with completely passive materials to produce functional devices and machines: transport, communication and industrial production become digitally controlled activities that consume a lot of energy and produce large amounts of waste. However, despite all the energy invested in digital technologies, they often remain poor and passive in terms of their contribution to an adequate representation of society and the inclusion of cultural diversity.

We believe that design, despite its ambivalent and often unsustainable past, has now perhaps more than ever a crucial role to play in rethinking and reshaping material culture and material becomings. Design still offers practices and ways of knowing that are deeply intertwined with socio-material making and thinking with and through materials. And yet, the future of design will not only be about problem-solving and “smart” technical solutions. Rather, the attempt to understand the complicated and contested trajectories and legacies of matter will be accompanied by an urgent question: "Who or what actually designs?" This is a question that we raised almost a decade ago in a previous edited volume for the DGTF, together with Gesche Joost, with a focus on human stakeholders (Mareis, Held, and Joost 2013).

Today, however, the question of human-centered design has shifted to eco-centered and more-than-human design. Thus, in a way, the two conferences and the resulting volumes provide a parenthesis for our work as board members of the DGTF and also show how the design discourse has changed over the years. Designing with care, which is at stake here, requires critical self-examination and a constant attempt to problematize ethical presuppositions, dominant styles, reference systems, working methods, knowledge cultures, and circulating objects. And yet the question of care is, as Léa Perraudin and Clemens Winkler show in their introduction, one that itself requires interrogation and critique. We believe that addressing these questions and issues is particularly important for design as a discipline and field of research, and we are very grateful to the DGTF and its outstanding community for helping to prepare the ground.

We would like to take this opportunity to thank all those who have supported us in the preparation of this publication: The German Society for Design Theory and Research (DGTF), the German Research Foundation (DFG) and the Cluster of Excellence "Matters of Activity. Image Space Material" as well as the Swiss National Science Foundation (SNSF). We would like to thank Christiane Sauer for co-organizing the conference from which many of the contributions to this volume originated. Our sincere thanks go to Amanda Winberg for her valuable contributions as an editorial assistant and to Philipp Bräuner and Ursula Klammer, who supported us in completing this manuscript. We thank Benjamin Carter for the translation of Sénamé Koffi Agbodjinou's contribution into English. We would also like to thank all authors for their substantial contributions and for their patience during the editing process. We thank our partners at meson press, namely Marcus Burkhardt and Inga Luchs, who accompanied the publishing process with their expertise and patience, as well as Torsten Köchlin for the graphic design and Selena Class for the copy-editing. And finally, our special thanks go to Léa Perraudin and Clemens Winkler for their committed and expert performance in the making of this volume.

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Designing with Care? A Pending Question

Léa Perraudin and Clemens Winkler

What Design? How to Care?

Designing with care refers to the process of creating something with a high level of attention, consideration, and intention. It means approaching a design project with a focus on creating something functional, aesthetically pleasing, and user-friendly, while also taking into account any potential social, cultural, or environmental impact. Additionally, designing with care often means considering the needs and perspectives of all stakeholders involved in the design process, including users, clients, and other design team members. (ChatGPT 2023)[1]

1 Text generated by ChatGPT, January 04, 2023, OpenAI, https://chat.openai.com. This output was generated with version 3.5. On March 14, 2023, version 4 was released, which is able to produce more nuanced output.

This is the output of an OpenAI ChatGPT chatbot on “Designing with Care” in January 2023, which, on the one hand, summarizes from a variety of sources what can be considered of importance for designers, namely the significance of user and client, and on the other hand, as an intermediary, maintains communication between different actors and scales (including material and capital flows). By taking care of an operation that can be read as an attempt at approximating data and practice, at merging ethos and factual constraints, GPT might also point towards the methodological as well as material struggles and challenges design research is facing. So, what does this algorithmically rendered definition prompt back to us as designers, as scholars, as practitioners in the field?

As an assembly of descriptors and buzzwords that circulate about design, GPT suggests how care and caring could be easily fed into this equation. But what is at stake beyond the reassuring and backslapping tone of such seemingly self-evident statements when claiming care as a mandate for/in design? Who is the assumed client in a design practice that attempts to be careful? How do the societal realities of care as oftentimes invisibilized, unpaid labor and perpetual effort in various domestic and institutional contexts alike – public and private, material and symbolic – relate to such a mandate? Does this exceed or even undermine the notion of said "stakeholders" placing an emphasis on environmental relations, ways of worldmaking, institutional and material legacies, and microscalar attunements? How does this affect the prevailing transactional logics of design and their often economically motivated techniques and executed paradigms of making? In the face of system failures and states of emergency on a global level, it seems worthwhile to ask once again if the designated task of design is just problem-solving, innovating, or optimizing. Yet if we take alternative modes of engagement and co-creation into account, in particular the operations of complicating, scrutinizing, and queering materials, they urge us to "stay [...] with the unsolved tensions and relations," as Maria Puig de la Bellacasa (Puig de la Bellacasa 2017, 5) reiterates what Donna Haraway famously claimed as "staying with the trouble" (Haraway 2016) of the planetary condition. Consequently, ideas of constructability, ingenuity, and the "how-to" logic of design remain in an ongoing process of negotiation and interpretation towards matters of care.

In the most general sense, caring is about attention and concern, as brought forth by feminist scholars rooted in ethics and moral reasoning (Gilligan 1982; Held 1993). Recent critical feminist scholarship has taken up these questions by emphasizing resonance and interdependence but also the fragile and frictional qualities of any care practice: caring, as a material engagement and non-normative form of ethical obligation (Puig de la Bellacasa 2017), is a matter of attentive experimentation and practical tinkering (Mol, Moser, and Pols 2010) and can therefore be understood as a situated practice of interweaving in what Joan Tronto described as a complex life-sustaining web (Tronto 1993). It entails acknowledging our complicity in the status quo but also the possibility of embracing unruliness, vulnerabilities, and impurities as forms of aspirational solidarity in a more-than-human world (Shotwell 2016; The Care Collective 2020; Caison and Perraudin 2022).

One could say then that design is always simultaneously caring and not caring for itself and/or something else, depending on the perspective and position of those involved. A large neural network learns, decides, and synthesizes based on quantities and consistencies and therefore neglects knowledge of marginalized languages and thus cultural knowledge and practices. The above query on caring in design by algorithms in a large neural network training engine, such as those of Microsoft's OpenAI ChatGPT engine, releases 3–4 times more CO_2e (carbon dioxide equivalent) than a Google search. In a superimposition of helping and hurting what surrounds us, we are creating a contradictory, yet undeniable, physical imprint of digital activity on planetary environmental realities. The possibility condition of connectivity unequivocally binds us to the materiality, and therefore the activity, of technological infrastructures and the prolongation of fossil capitalism (Malm 2016) – even though these ties have been historically and strategically dispersed in cultural rhetorics of abundance, placelessness, and immateriality (Hu 2015; Perraudin 2019; Winkler 2020).

Material Trajectories

As a provisional inquiry, one could claim that design is intrinsically and deeply engaged with materials. Yet the attempt to make sense of the properties, composition, and behavior of said materials, artifacts, and built infrastructures is accompanied by a pressing question: "Who is in fact designing?" (Mareis, Held, and Joost 2013). As engineering techniques in fields like biomedicine, information technology or aerospace develop further, the possibilities – and challenges – of designing (with) materials and their activity become apparent. Simultaneously, matters of existential urgency, such as anthropogenic climate change, extractive capitalism, planetary threats to multispecies livability and the quest for resilience, call for a critical and careful response. Spanning from environmental politics to everyday practices (Alaimo 2016; Tsing and Bubandt 2017), as well as indigenous ecological knowledge (Kimmerer 2013; Watson 2019) and the ongoing toxic legacies of settler colonialism (Liboiron 2021), they relate to the multiple worldmakings of design (Escobar 2018). They demand a grounding in the material itself as a practice of care in order to identify means, develop modes, and foster motives for livable and more just futures.

In recent years, discourse in the humanities, natural sciences, arts, and design alike has witnessed a renewed devotion to matter and material cultures, as well as an engagement with the legacies of old and new materialisms and their respective ontologies (e.g., Barad 2007; Bennett 2010; Fratzl et al. 2022; Grote 2019; Deacon 2011; Stakemeier and Witzgall 2014). Design as a practice and knowledge culture seems to be a nexus of this highly entangled dynamic as it not only addresses and analyzes these questions but contextualizes and synthesizes them through open-ended processes of making (Mareis 2011; Mareis, Joost, and Kimpel 2010). The fundamental role of materials in design, whether fabricated or organic, from the nanoscale to the planetary, signals towards the significance and scope of design research in the Anthropocene (see Schäffner in this volume). By shedding light on the modes of production in their scientific and cultural evolvement, the various practices of speculating, informing, dismantling, and reassembling also allow for a critical portfolio of contemporary environment–human relationships. Cycles and sites of extraction, production, consumption, obsolescence, disposal, and/or recycling must be conceived as the scaffolding of mass material culture and therefore are formative for every design process. Thus, these structural conditions for a design process are also negotiated through material-driven research that attends to the aesthetic and semantic markers in the designed object itself (see Bulling in this volume).

Caring for a physical material, whether through tacit and embodied knowledge or explicitly through a conscious choice, is informed by its metabolic activities and environmental relationalities (Winkler 2024; see Kirschner in this volume). It requires a continuous correspondence with what we are designing with – whether that is bacteria, fungi, recycled plastics, textiles, or the ever-present and inevitable elemental conditions themselves. The latter also applies to remediating toxic and contaminated sites, landfills, or greenhouse gasses in such a way that the repair activity acknowledges its potentially invasive character (Papadopoulos, Puig de la Bellacasa, and Tacchetti 2023; see De Visscher in this volume). Due to the demands of such activities as acts of co-planning and support, the designer/architect quickly turns from being an engineer to a gardener, kitchen worker, therapist, or caretaker. If the material is treated with such attention and proximity, it makes the oftentimes implicit reciprocity of such activity unequivocally apparent. Yet, this reciprocal dynamic carries and potentially reinforces asymmetries among the involved actants and their status within their surroundings (Perraudin 2024).

If the activity of matter is taken seriously, design itself has to be conceived as a highly entangled process of co-creation. This collaborative endeavor is not only negotiated between human actants but also a vast variety of more-than-human agencies and their respective relations. The notion of sympoiesis (Haraway 2016) provides a novel understanding of design processes by emphasizing the ways agencies and environments emerge and affect each other: every task and every event in the workshop, in the lab, at the desk, on the computer screen, the outdoors, etc. presents itself as a becoming-with and making-with of highly heterogeneous agencies. Complicating such questions of representation, response-ability (Haraway 2008; Barad 2014), translation, visibility, and (the limits of) scale (Tsing 2012) are at the heart of performing and understanding these processes of co-creation: they require refined modes to account for our work as designers and scholars (see Witzgall; Peluso, both in this volume).

Situating Care: Collective Practices and Questions of Li(v)ability

What constitutes caretaking and when does caring become an objectified service that can be delegated and allocated to a system, a program, or any other pursuit of manageability? Boris Groys comes to terms with the implications of such a philosophy of care by claiming: "Where religion once was, design has emerged" (Groys 2022, 125). What are we avoiding here when it comes to designing with care? If we slightly outsource our responsibility for decision-making, we may lose track of the prospects for building self-determination and self-care in a sustainable way. From a social perspective, it is likely to be more about solidarity and coalition-building on this issue. So, how do collective practices of sharing through modes of caring and compassion (see Kundoo in this volume) connect self-care with community care? Designing care might be about creating accessible means and spaces for collective action across a broader population or a specific group. In that sense, the deliberate act of designing becomes an intricate part of meaning-making processes through social negotiation (see Ahrensfeld in this volume). But how do we create appropriate spaces for debates on these individual and collective concerns in times of rapid social and ecological change (see Boehnert in this volume)? This could also be resonating in an ethics of inhabiting as "a way of being in the world" and therefore strongly indicating the communal *and* cosmological dimension of architecture itself (see Agbodjinou in this volume).

Will there be an economic equation for rationing and shrinking while taking care of others and ourselves, not just in socio-material terms? What does the shift from a spiraling capitalism towards a circular design model entail (see Wenig; Schmidt, both in this volume)? Consequently, how do we move through technological progress in design to other forms of growth, such as green growth or less growth? Technological progress operates at a distinct pace and is closely attached to the matters of interest it seeks to advance, their modes of worldmaking and objectives of execution, their authorities, and their problem-solving means. Technological fixes are flawed exercises to counteract problems by applying the very same engineering mechanisms that are themselves the causal agents of what needs to be "fixed" in the first place (Huesemann and Huesemann 2011; Kolbert 2021). They reveal an engineering-driven and teleological understanding of care (see Müller and Tikka in this volume). So far, achieving carbon neutrality through carbon capture and storage technology seems to be a failed attempt at geo-engineering on a planetary scale – it simply takes too long and is too expensive. Instead, we need to focus on storage technologies such as green hydrogen or existing biological structures, even if they are complex and costly to deploy (Carbon Aesthetics Group 2022).

The narrative of sustainable development is based on the normative idea of shaping a civilization in political, social, ecological, and economic equilibrium without limiting the opportunities for future generations. Intrinsically linked to this is the belief that growth and economies can be reconciled with the potentially conflicting demands of ecology (Boehnert 2018). Design has taken up these challenges by proposing lasting and ecologically viable applications through, for example, novel biomaterials and more environmentally conscious fabrication techniques (see Kretzer in this volume). Accompanied by the diagnostics of the Anthropocene, the term resilience has gained popularity to describe adaptive capacities and survival strategies (in materials, organisms, and societies) to endure crises (Grove 2018; see Waldhör and Schneider in this volume). While resilience is referred to as the attempt to partially replace an optimistic notion of progress, it seems to embody an opportunistic stance towards the manageability of crises (Halpern 2017). Are sustainability and resilience opposites, subsets, or complementaries? Regarding materials, artifacts, and entire socio-economic systems, design is challenged to respond to these complexities without resorting to the convenient assertion of mere rhetoric (Lee 2016; Cowley et al. 2018).

Temporalities and Intensities of Care

Caring, like the concepts of repair and healing, are charged terms that can express different ways of being. They range from grief to ecstasy, from ancient, indigenous, and passed on modes on what it means to keep active, involved, and asking, as temporal matters of committed concern, to new forms of empathy, ad hoc engagement, and resonance. Care can involve attempts at healing and repair, and healing and repair are careful processes. Yet, they bear different temporal dynamics and intensities. As healing is often perceived through the absence, distance or detachment of a stressor, or through a process that is subsequent to a wound and allows for prospective protection (e.g., scar tissue), the very act of healing points beyond its restorative capacities. Healing is potentially accompanied by striving for (material) integrity, and simultaneously healing can be about letting go. Repair seems to be closely tied to the assumption that things can be "fixed" and put back into a functioning condition prior to failure. However, repair always entails adding, detouring, compromising, and reclaiming. The Latin origin *reparare* signals at something being made ready (*parare*) again; it employs its necessarily generative characteristic through repetition, as the "again" that also reveals an ongoing act of engagement towards practices of maintenance (Baraitser 2022, 21). In dispersed cultures of repair, narratives of productivity and efficiency are being continuously resisted and appropriated through modes of tinkering, DIY, and resourceful repurposing.

In that sense, both repair and healing are confrontations with the status quo. In their doing, they urge for critique of the prevailing discourse that remains indifferent to or ignorant of the structural conditions of worldmaking through design. The prevailing paradigms of making in engineering, architecture, and design are a testament to passivation, invasive practices, hegemonic action, and their biased logic of replaceability. They carry a complicated legacy regarding the place and function of repair and (the need for) reparation, care, and healing. Research in the field has taken up these notions and their ties to materiality in quite different ways. Material-driven, large-scale innovations in engineering work with the concept of healing to address the flaws *and* sustainable potentials of existing built structures (e.g., by employing the self-healing capacities of concrete; Seymour et al. 2023). Architecture attends to the politics of "The Great Repair" in that it encompasses an assignment for both architectural practice and theory on a damaged planet (ARCH+ 2022). Formative work in decolonial design research and practice confronts the discipline to acknowledge its historical and ongoing role as a "powerful ontological tool" (Tlostanova 2007, 51) in the material systems of extractivist colonial violence and to work actively towards their dismantling (Abdulla et al. 2019; Tunstall 2023).

As durational activities of maintenance through labor, practices of caring for the material-infrastructural and socio-political fabric of design are linked to processes of slow violence (Nixon 2011; Parikka 2016). In their emphasis on the supra-individual and potentially human lifespan-exceeding characteristics of these processes, they also spell out that care remains a vulnerable practice that points towards an ongoing attempt and a re-evaluation of what exercising criticism could effectively entail (Mareis, Greiner-Petter, and Renner 2022). The intensities and temporalities of such activities are in themselves primed by normative concepts and socially approved effectuations: caretaking as a practice and form of reproductive labor is oftentimes used synonymously with committed consanguineal or affinity forms of kinship, as in nurturing, parenting, domestic health care, and cultivation (or forms of wage labor that externalize these tasks). However, caring stretches well beyond biologically rooted and committed concepts of responsibility and trust. Recent critical scholarship has emphasized the elusive couplings, ad hoc proximities, and chosen forms of kinship that radically expand and multiply care towards "promiscuous care" (The Care Collective 2020, 40) and "fleeting interactions" (Ensor 2017, 163). They work against its strategic placement in heteronormative societal discourse and are often vital for support, safety, and survival (Hamilton, Zettel, and Neimanis 2021). Recognizing these nuanced modes of intensity and temporality of care is key to grasping its lived reality as a political practice and collective motive.

Complicating Care in Design

Ultimately, accepting care as an academically valued concept and approach of interest in design must mean coming to terms with its complicity in the material-industrial complex. Care can easily be appropriated towards optimization, functionality, and a neoliberal understanding of a sustainable and well-cared-for relationship between all contributing parts. As care is at risk of becoming a mere "design strategy," design as an academic discipline and practice-based research culture needs to acknowledge its part in reproducing and prolonging hegemonic systems of oppression, injustice, and exploitation ruled by capital. Capitalism itself *takes care* of maintaining the universal principle of asymmetrical transactional logic in societies at large, and is therefore also the causal agent of the injustice and environmental depletion that stabilizes the order we live in (Haraway 2015; Moore 2015). "Design struggles" with its deeply enmeshed ties to eurocentric modernist thinking and industrial and colonial power – it is in need of intersectional and environmentally conscious practices (Mareis and Paim 2021) and should come to terms with their material politics by means of situating themselves (see Büsse in this volume).

So, what is at stake in design when it comes to care? The uptake of care as a practice, a motive, a commitment, and ultimately a pending question in design research needs to be contextualized through its pitfalls. As Bonaventure Soh Bejeng Ndikung demonstrates by invoking the delusions of care, care itself as a benevolent concept is strategically set in place to reaffirm existing power relations and the prolongation of neocolonial violence in favor of the capitalist supremacist establishment (Ndikung 2021). Cherrypye and Nina Paim point out the carelessness of discursive “lip service” in design and design research. They insist that care as a relational figure of thought simultaneously bears intricacies that cannot be taken into account regardless of the privilege that grants access to, and *Gestaltungsmacht* of, crucial political, economic, and scientific processes of decision-making (Cherrypye and Paim 2021).

Writing about care – and therefore theorizing it – and, on the other hand, practicing care, responding to an urge, in creating a bond, maintaining, or potentially letting go of it, have one thing in common: they require attention and attunement that won’t remain and never were neutral. This volume brings together new forms of caretaking through a variety of material-driven design processes and discursive relocations of techno-scientific trajectories and material futurities that are of concern in the extended field of design research and critical humanities scholarship, as well as ecocritical approaches in the field. *Material Trajectories: Designing with Care?* responds to the aforementioned dynamics through five thematic sections.

Material Revisions

The contributions to the first section *Material Revisions* reassess the status quo of Design and Architecture as material practices. Wolfgang Schäffner opens up design as *Gestaltung* in its crucial role as a process that incorporates scientific and practice-based approaches across scales. In his sequel, “Design Turn Revisited: A Revolution of Design in the Spirit of Active Matter,” he refers to planetary modes of crisis to show the fundamental change needed to enable a different, careful design. By proposing an adaptive program in six inversions, he presents design as a process of symbiotic, adaptive, and collaborative interaction in which deviations from the imagined outcome should not be eliminated as disturbances. Anupama Kundoo critically attends to the growing and economically motivated disconnect between building and living through technological advancement and standardized industrial processes in architectural practices. Built around 12 principles, her essay “Re-thinking Urban Materiality in the Age of Climate Change” encourages us to reconsider our understanding of and foundational contribution to the built environment in urban spaces in terms of resourceful practices, participatory construction, or the willingness to think and learn with our hands.

Positioning Care

Positioning Care gathers contributions that provide outlines for a nuanced reading of the worldmaking processes of design and architecture. As Joanna Boehnert points out, the political economies and knowledge systems of design are creating and reproducing unsustainable conditions on a planetary scale. Her essay "Design Politics in the Anthropocene" proposes five strategies for politicized design that span from transdisciplinary knowledge and collaboration to ecological thought and intersectional feminist and antiracist practices, while giving an outlook on the relational ways of knowing in the Ecocene that seek to redesign and co-create worlds anew. In her essay, "'Critical Standpoints That Are Careful': Anthropological Relocations for a Performative Study of Design," Michaela Büsse makes a plea for design to not resort to universality and abstraction but instead to commit to a situated engagement with its socio-material processes. From Büsse's perspective, this entails rethinking how to frame design by seeking out openings that allow for speculative commitments and ways of disentangling the politics of material transformation as a differentiated critical, and therefore careful, task for the discipline. By arguing for solidarity, kinship, and transversal ethics as foundational for vernacular architecture, Sénamé Koffi Agbodjinou introduces the community approach as an integral quality of the building in Africa. As community itself remains resistant to any kind of programmed obsolescence, Agbodjinou's "Principles of a 'Cosmoarchitecture'" proposes a way of being in the world – a new contract of kinship and a politics of taking care that largely exceed the domain of housing.

Technoscientific Trajectories

The contributions to *Technoscientific Trajectories* seek to complicate questions of livability and cooperation to expand the realm of design. Emilia Tikka and Martin Müller problematize an engineering-driven understanding of care that they discern in the invasive worldmaking strategies of synthetic biology and geo-engineering, which are installed to counteract escalating climate crises and the extinction of entire species. As these anthropogenic threats particularly affect the vulnerable ecosystems of the Arctic, their essay "Mammoths and Reindeer: Speculative Design Imaginaries and Technoscientific Care in the Arctic" portrays the living relations in the Finnish Sápmi herding cultures that are on the verge of vanishing. By emphasizing care as the cultivation of independence, Tikka's collaborative speculative design inquiry proposes alternative techno-science futures in the Arctic by means of epigenetic ways of belonging. In "Biocompatible Radiations – Designing for the Living," Emile De Visscher gives a report on his experimental research endeavor to generate microvascular networks in biocompatible materials that he – coming from engineering and design – collaboratively effectuates with experts from the fields of surgery and biochemistry. His *design for life* simultaneously addresses the intricacies of bio design, the charged concept of healing, and how design can potentially unravel disciplines and technologies. Cutting is caring. In her essay "A Critical Cut Through a Designed Thing: A Short Study on Oblique Matters of Design," Viola S. Ahrensfeld first detaches from a merely user-centered design perspective on prosthetics in order to look towards their re-attachment: the co-shaping of designed things and their users as social actors that bear relational frictions. For Ahrensfeld, finding and fostering mutual practices across different communities, such as for both users of hearing aids and users of hearables, also allows for new forms of mediation as an auspicious aspect of design processes.

Sympoietic Futurities

Sympoietic Futurities presents positions that shed light on the manifold acts of making-with and collaboration by directing them towards (and potentially beyond) the ecological conditions of the Anthropocene. The contribution "Sympoietic Design as an Ethical Project" by Susanne Witzgall draws attention to the variable and intensive affects of materials, which are also, as she insists, carefully weighed and responsible practices of boundary making. As her exemplary investigation into craft-based art projects that respond to the complicated colonial legacy of the invasive shrub plant *Lantana camara* demonstrates, indigenous, scientific, and artistic forms of knowledge and experience share common ground in a sympoietic approach to design. Roman Kirschner puts the emphasis on metabolic relationality through an investigation into its energetic and material embeddedness in experimental art and design projects. His essay "When Mirrors Metabolize: Towards a Metabolic Perspective in Art and Design" addresses this by complicating questions of reduction, passivation, and control. Through mirroring existing experimental practices at the intersection of art and biology, Kirschner proposes design methods and frameworks for material-metabolic care scenarios. Through a DIY approach to sympoietic design with living organisms, the contribution "Design for Future Coexistences" by bio-artist and speculative designer Fara Peluso questions the relationships we intend to build with non-human agencies. Peluso presents the contemporary urge of bio-art practices to bring forth situated proposals that operate as fulcrum between premonitory and hopeful scenarios towards a post-anthropocene world – as an attempt to educate, to critique, and change the prevailing human practices that rely on resource extraction and the exploitation of natural habitats.

Careful Practices

The contributions to *Careful Practices* provide an insight into recent practice-based and material-driven approaches in the field. In her essay "Stop Mixing Materials: Mono-Material and Variety," design researcher Lea Schmidt takes up the promise of mono-materiality as a claim in pursuing circularity. In her "culture of mono," Schmidt pleads for a reduction of material complexity in favor of unexpected variety in the design process. By critically contextualizing her approach with invasive monocultures (e.g., in plantation cropping systems), she introduces her practice-based research on 3D printing techniques for a potential circular use of textiles made from polyethylene. Maxie Schneider and Ebba Fransén Waldhör present their material-driven design process on "Designing Performative Surfaces – a Textile Approach to Active Architectural Facades" as the quest for material actuation in response to temperature changes. In an interdisciplinary process, they proceed from the adaptability of textile materials to employ movement sequences of metal alloys as prototypes for a shading system. Accordingly, their aim to develop adaptable designs leads to further questions on biologically integrative material systems, for example in terms of sunlight, wind, and heat. Stemming from practice-led material design research, Jessica Bulling's essay "Leather as a Carrier of Meaning" raises questions about substitution, imitation, and acceptance. In response to the demand for ethically and ecologically conscious material choices, Bulling's investigation focuses on plant-based leather substitutes, so-called *plant skin.* By examining their aesthetic affordances and cultural meaning, her contribution builds on material semantics to propose acceptance models for a growing domain of material substitutes in the design field. "On Materiablity" presents an overview of the vision of ecologically viable design applications in an open community approach focused on education, research, and development. As founder of the Materiability Research Group, Manuel Kretzer provides insight into recent research and student projects that apply 3D-printed bio foam, compostable textiles made from lignin, or adaptive sound installations. As a material research platform, Materiability allows for the accessibility of these resources through a growing network of interdisciplinary collaboration partners. Charlett Wenig's practice-led research on "Designing With Biomaterials: A New Form of Material Understanding" introduces the versatile utilization of European tree bark as a waste product from the timber industry. In Wenig's approach, knowledge from both materials science and design is carefully employed to facilitate bark as a narrative for material circulation and an opportunity to rethink its potential in various contexts (from woven structures in fashion prototypes to glazing porcelain with material residues like bark ash).

Care is always *in actu* and it is exactly this attribute that addresses these practices of decision-making, their response-abilities and commitments, as well as asymmetries, as a matter of concern. Thus, designing with care necessitates a continual effort to question and challenge the prevailing systems of reference, styles, working methods, forms of knowledge, and object cultures as they circulate. Nurturing these commitments is of particular importance for design research and the differentiation of design as a scientific discipline. Intrinsically linked to this ambition is the adherence to a responsive culture of promoting emergent researchers and facilitating institutional structures to do so in sustainable (Held 2018), careful, and even playful ways. This is what care in design needs to spell out as well: nurture in the literal sense, care for the discipline by design, and those who will carry it in the future. Ultimately, this entails encouragement, trust, and providing the means to conduct practice-based research and engage in design theory as a feasible trajectory in design education and as a profession in the academic field.

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Material Revisions

ESSAY

The Design Turn Revisited: A Revolution of Design in the Spirit of Active Matter

Wolfgang Schäffner

The fundamental crisis of the modern societies has reached a decisive turning point. Is it still possible to get out of the planetary catastrophe and provide a livable future, or is the catastrophe inevitable? The proposed Design Turn refers to an ongoing revolution of the sciences that shift from analyzing to designing nature. However, this shift involves two opposed strategies of design, one of which prolongs the technical control of nature, while only the other represents a fundamental change in strategy. This adaptive design inspired by active biological matter makes necessary a revision of the Design Turn. Such a design strategy can be seen as a special revolution of design. Therefore, a proposal for an adaptive program is presented that, based on six essential inversions, also includes a turn in perspective that no longer privileges the often-implicit northern view-point.

Keywords: Design Turn, active materials, invasive and adaptive design, South

Our damaged planet needs a fundamental cultural change. Above all, since industrialization, human intervention achieved a destructive level on a planetary scale, and today global destruction is moving towards the collapse of our living conditions. There is thus an urgent need to shift this kind of human impact towards a different mode of interaction and symbiosis between humans and the planetary environment (Haraway 2016). In recent years design has been addressed as a kind of cautious change and activity (Latour 2009). In the following I will refer to design in its broadest sense as *Gestaltung* of earthly living conditions, and its growing fundamental role as a process that includes scientific and practical approaches. It is a necessary turn towards design for developing new possibilities, forms and ways of change towards desirable futures. Within this context, the notion "Design Turn" refers to processes or research about and with design. From an academic point of view, there is an increasing awareness of *Gestaltung* and design processes, which are not limited to the realm of design, art and architecture, but become relevant for any kind of discipline. *Gestaltung* also plays an important role in politics (e.g., the New European Bauhaus [European Union, 2021]), and can be considered not only as an essential procedure for any cultural production, but also as something relevant within nature.

My concern, however, starts within the academic field: in the following I will deal with 1) the role of *Gestaltung* in the natural sciences, and 2) the transformation of the Design Turn into research structures. Revisiting the Design Turn is insisting on moving the turn on according to the following perspectives: 3) two opposing strategies within design processes; and 4) redesign of global circulation and transmission of materials and artifacts. Finally, I will outline an adaptive Design Turn program based on fundamental inversions.

The Design Turn: A Revolution of the Sciences

During the past decades, the natural sciences shifted in a fundamental way from the analysis of nature to the design of the physical world. In the context of materials science and so-called nanotechnology such a shift created the historic opportunity for a new convergence of various disciplines "in the spirit" of design. This shift from the analysis of chemical, physical and biological elements to the construction and design of new worlds manifested itself, not coincidentally, in a vocabulary drawn from architecture, design, and engineering. These new micro-scale architectures of nature had fundamental consequences for the relationship between the natural sciences, engineering, humanities, and design disciplines.

Since bio-sciences are shifting towards bio-technology, they enter the field of design and engineering, where biological materials had barely been worked on. Nevertheless, since the time of cybernetics (Wiener 1961; Pias 2003) a large field of naturalizing technology and technicizing nature had developed (Tamborini 2022). When biological processes are increasingly characterized as machines, such as pumps for fluid exchange in membranes (Grote 2019), or as "architectured materials" (Estrin et al. 2019), nature is obviously conceived as a world where the difference between natural object and artifact or machines – after centuries of having been a sharply disputed distinction – has disappeared.

This new situation required the natural sciences to become aware of their own turn to design and to confront the different strategies existing in the fields of engineering, architecture, and design. Correspondingly, the humanities – my own disciplinary home base – can coherently complete their path from the analysis to the co-design of practices, in a sense that they no longer limit themselves to a historical and theoretical analysis of practices but participate in the design processes themselves.

Architecture and design, however, also change in a fundamental way in relation to this turn of the sciences. There is an increasing need for design research, transforming design into an integrative procedure of interdisciplinary knowledge production. The design disciplines should no longer be taught and developed separately from the other disciplines in special art schools, but in close connection with all other research disciplines. This type of diagnosis and program of a Design Turn was developed together with colleagues from the design disciplines and natural sciences from the perspective of the Southern hemisphere, at the Faculty of Architecture and Design, in close collaboration with the Faculty of Exact and Natural Sciences, at the Universidad de Buenos Aires since 2003. It started with a kind of rethinking of Bauhaus and Ulm from outside Europe by integrating design, natural sciences, humanities, and the local pluricultural practices and knowledge production of Latin America. Within the context of the Latin American Bicentennials of Independence around 2010[1] this approach included the analysis of the history of asymmetric transmission of technology between Europe and Latin America. Within this context a new integrative relevance of design provided the basis for an explicit program aimed at

1 In Argentina, Bolivia, Chile, Colombia, Ecuador, Peru, Mexico, and Venezuela.

translating this unique opportunity to readjust design so that it became an essential mode of interdisciplinary and intercultural research strategies (Schäffner 2010).

Transforming the Design Turn Into Interdisciplinary Research Strategies

By focusing on design disciplines, which had been largely excluded from classical university basic research, design can be seen as an integrative combination of heterogeneous methods. Its material- and practice-oriented approach provided a working method with a model character: project thinking incorporates all kinds of disciplinary knowledge. In close collaboration with the natural sciences, engineering and the humanities, interdisciplinary research that had previously hardly seemed feasible has become possible.

The aim of the Design Turn from the viewpoint of the humanities was to broaden the traditional focus as a critical, theoretical and historical – and therefore retrospective – analysis by including modes of experimental, cross-cultural, and design epistemologies. Generally, the humanities are directed to research on, but not with, other disciplines – completely disconnected from the fields of “application.” Only in this way can the humanities become a fundamental actor in future-oriented design processes and lose the status of analytical and consequence-free knowledge.

As a result, practice- and material-based design methods, experimental and theoretical procedures, as well as culture- and nature-oriented practices, closely merged within an interdisciplinary research field. This novel combination of diverse disciplines benefits from other forms of convergence that cross very different sciences in parallel. For example, there are the medical research clusters and material sciences that can be characterized as new nodes of convergence (Sharp et al. 2011), but also – seen from a broader epistemological perspective – the new materialism (Coole and Frost 2010; Dolphjin and van der Tuin 2012) and the new structuralism (Oxman 2010).

These convergent research strategies go beyond mere analysis and attempt to establish the conditions for drawing consequences and producing the necessary change. It is not surprising that at the core of these convergence approaches design processes are highly productive for integrating all the relevant knowledge: research procedures made new design processes possible, and vice versa. In this way, design theory has expanded from its disciplinary context into a horizon of debates spanning different disciplines. This is an essentially new position of design.

During the past 10 years, the process of establishing interdisciplinary structures was accompanied by a growing experience of crisis. While crisis has been a permanent condition, for example in Latin America, for decades, these colonial and postcolonial asymmetric entanglements today increasingly affect the entire global culture in a negative way, even within the seemingly more stable structures of Europe. The resulting urgency further emphasizes the indispensable need for fundamental change.

Transferring this approach to design to Humboldt-Universität zu Berlin there was the opportunity to transform it into a large research project: the Cluster of Excellence “Image Knowledge Gestaltung: An interdisciplinary laboratory” (TIB 2020). With researchers from more than 30 disciplines we set out to transform design from separate specialized disciplines into an interdisciplinary and collaborative process of *Gestaltung*: the integrative strategy inherent in design procedures was paralleled by the humanities’ transversal approach of focusing on images, structures and spaces as fundamental ways of knowledge production. The humanities thus obtained a complementary integrative role within the interdisciplinary collaboration.

We also analyzed and tried to design new collaborative procedures within a laboratory space used as an experimental zone, in which the integration of various disciplines became a proper object of design research: interaction design, product design and architecture analyzed and designed our own interdisciplinary research processes (Marguin, Rabe, and Schmidgall 2019). Experimentation became essential in this process, allowing *Gestaltung* to be closely linked to the experimental practices of the natural sciences, which were already marked and determined by the new relevance of design procedures (Marguin et al. 2019). The Cluster “Image Knowledge Gestaltung” has given rise to a second currently ongoing Cluster of Excellence at Humboldt-Universität, “Matters of Activity” (2019–25).

Interdisciplinary design also makes a different education of young researchers necessary. The joint Master Program *Open Design—Diseño abierto para la innovación* of the Humboldt-Universität and the Universidad de Buenos Aires, which builds a bridge from the South America to Europe, pursues the integration of interdisciplinary and intercultural forms of research by training students in novel processes for project development.[2] The modes of interdisciplinary collaboration were extended to transdisciplinary structures through interactive exhibitions (Doll, Bredekamp, and Schäffner 2016) and the *Humboldt Lab* of the Humboldt Forum at Berlin, the new cultural center dedicated to Non-European Clutures, where we started to design research processes for a close exchange with society.[3]

2 https://www.matters-of-activity.de/en/promotion/38/master-open-design.

3 https://www.humboldt-labor.de/en.

Two Opposed Strategies of Design

The turn to design, which was diagnosed over a decade ago as a fundamental shift, has evolved considerably since then. In the natural sciences there is a growing awareness of design: synthetic biology is a highly controversial field. Since the invention of CRISPR, genetic material can be cut and tailored in any desired way. In 2016 the editorial of the journal *Fungal Genetics and Biology* for a special issue on "The Synthetic Biology Era of Yeast and Filamentous Fungi" was published with the title "The Art of Design." The editors explain:

> The most common definition of synthetic biology refers to both (i) the design and construction of new biological parts, devices, and systems and (ii) the re-design of existing natural biological systems for useful purposes. (Meyer, Nevoigt, and Wiemann 2016)

What does design mean in this context? Is it a highly invasive strategy to transform the natural environment into controllable cultural structures, as has been the case since modernity?[4] Is there a fundamental difference between biologization of technology and technization of biology (Tamborini 2022)? It becomes obvious that within the natural sciences the Design Turn can be associated with two completely opposite strategies: invasive design and adaptive design.

4 A historical analysis on the genealogy of synthetic biology can show an escalating process of technisizing nature (Müller 2022).

On the one hand, design can be considered the production, manipulation, and control of things, and as such it is representing human mastery and domination over nature. Design in this sense has been expanding since the 19th century at an ever-increasing pace, turning the natural physical world into a mere substrate or passive support for the production of a cultural and technological world. Our objects are manufactured from preconceived ideas implemented in physical reality as artificial foreign bodies. For this reason, malleable materials such as metals, concrete and plastics have been developed and are used for producing artifacts because, as passive materials, they allow very flexible and controllable shaping. Thus, they became an integral part of all classical technical artifacts, planning processes, and project structures.

These strategies continue to be implemented in our physical and social environment all over the planet. They had a massive impact on nature and became a crucial driver of the Anthropocene catastrophe. And at present, that kind of destructive implementation of human intelligence is in its most radical phase. The idea of programmable matter, which dominates much of materials research, is being translated into our physical world as Industry 4.0 (or synthetic biology) with regard to molecular life. This is all part of the shift towards design in materials science.

The destructive effects of these strategies have become increasingly evident over the past decade. There is a growing social awareness of the global threat, and COVID-19 clearly showed how difficult it is for our societies to react flexibly and quickly and to leave behind habitual routines. However, the daily changing strategies represented an unprecedented adaptation process that tried to directly respond to ever-changing circumstances. In this respect, the pandemic revealed what fundamental change is needed to make a profound shift to a different careful design possible. This would also require abandoning invasive forms of design, and pursuing an opposite strategy as a different way of responding to critical situations.

This challenge is the starting point for the second design strategy: a procedure of symbiotic and collaborative interaction with nature, a process of adaptation and permanent feedback with the natural environment. The distinction between these two basic paradigms – invasive design and adaptive design – is of crucial importance. Within materials science, design processes emerge that are different from invasive design strategies. These take biological materials as a model for bio-inspired technology that acts with and through nature instead of fighting against it. They constitute a decisive basis for revisiting the Design Turn as a general transformation of the natural sciences, which is a necessary response to current urgencies.

Even if it is a project-oriented procedure, design should no longer try to anticipate its process and to prefigure its precise outcome, as is the case with the principle of prescriptive codes or form-oriented procedures. Instead, design can enable unpredictable solutions to emerge, and as such it is a process in which deviations from the imagined outcome don’t have to be eliminated as disturbances; rather, they form a source of fundamental information about everything that cannot be anticipated or foreseen within the design process.

Accordingly, materials no longer have to obey human ideas as mere "docile materials," but become, in the terms of Manuel de Landa, "active participants in the genesis of form" (de Landa 2001). They are no longer passive carriers of technical implementations, but complex active structures whose synergistic use makes an adaptive design process possible. This can be clearly seen today in the analysis of biological materials from bacteria, fungi, plants, or animals. By delving deeper into these materials, complex structural worlds are revealed that are not passive, but characterized by their intrinsic activity (Fratzl et al. 2021). They are active processes based on composite fiber structures and hierarchically structured architectures, and they are particularly light, elastic and sensitive to the environment. They also use water as an essential component of their activity, which is an important adaption to the humid planet Earth.

Turn of Perspective in Circulations and Transmissions
While these nature-inspired modes of experience disappeared in industrialized societies, the activity of objects and materials constitutes essential knowledge within traditional cultures. In this sense, the turn to design in the spirit of active materials does not invent a new strategy, but rather corresponds to the fundamental shifts in perspective that have long existed in the cosmologies of traditional cultures. The ontologies of such communities invert the modern subject–object relationship: animals, plants and objects can be experienced as embodied actors whose essence is that of the human being, and not an unknown adverse nature. This "perspectivism" has been described by anthropologists such as Eduardo Viveiros de Castro (Viveiros de Castro 1996). In Latin America, the Andes constitute one of the great reservoirs of traditional practices that include the activity of plant and animal fibers in their processes, from spinning to weaving techniques. In this context, even textiles become active beings, thus widening the change of perspective towards natural-cultural objects (Arnold and Espejo 2013; 2019). These are adaptive practices and forms of knowledge interacting with their natural environment by involving the activity of materials, plants, and animals (see Müller and Tikka in this volume).

In the 2008 *National Constitution of Ecuador*, in Chapter 7 the "Rights of Nature" are fixed parallel to the rights of people (Asemblea Nacional Republica del Ecuador 2008). This means that nature and humans are no longer separated but symmetrically related. Even in national parks that are mostly used for the conservation of nature, there is an essential interaction between indigenous communities and the natural environment. Also in 2008, in Colombia the Chiribiquete National Park was inscribed in the World Heritage List as a mixed – both cultural and natural – site (Castaño Uribe 2019). It is one of the most famous areas of petroglyphs painted more than 20.000 years ago by indigenous people, thus proving a millennia-old practice that survives today. In the vast areas of tropical rainforests and the highlands of the Puna there are still communities that have no contact with the modern world.

These kinds of traditional knowledge practices can be found everywhere, but there is cultural and technological heterogeneity, and a contemporaneity of different historical and cultural layers, that coexist full of conflicts (García Canglini 1990). This is why the traditional practices, as well as the languages and communities associated with them that survived 500 years of colonialism, are in danger of disappearing after being exposed to the normative effects of the extensive hegemonic cultures. The number of examples is endless: in the early 1990s the Argentinean anthropologist Gustavo Politis visited the Nukak, a nomadic community of hunters, in the Colombian Amazonia. The motto expressed in his book, “It’s not that I want that they remain as they are, I just want them to remain independent,” was wishful thinking that has not been fulfilled (Politis 1996): 30 years later, the Nukak are destroyed as an independent culture.

The Anthropocene is not only inscribing itself in geological dimensions, but also dissolving such elaborate cultural-natural adaptive assemblages. These practices were highly adapted to the natural materials whose inherent activity they integrated. At the same time, they were able to store and transmit these practices by stable and inherited operations over very long periods of time.

These alternative interactions between people and their natural environment can obtain a similar status as essential components for new design processes to the active structures discovered in biomaterials. In this sense, to move away from the domination of nature means also to move away from the disdain of traditional cultures and thus develop a new type of symmetrical intercultural exchange. But taking the field of biomaterials and traditional cultures as important sources for adaptive design processes, a basic question is how to access these “sources” and how to “use” them without reproducing old forms of extraction and asymmetry. Reconsidering the knowledge of traditional cultures can give rise to new forms of asymmetric “infocognitive extraction” (Ramirez Gallegos and

Minteguiaga 2020). What new types of exchange have to be established in focusing on these new modes of design?

The material basis of design processes makes it necessary to examine the whole chain of procedures and supplies necessary to produce artifacts. Taking the relationship between Latin America and Europe as a basic constellation that shaped the design of artifacts on both sides of the Atlantic during past centuries, it is not only during the colonial period that there was a tremendous impact. Since the post-colonial period at the beginning of the 19th century, and precisely the span of the bicentennial of the so-called independence, the asymmetry of interaction has increased even more intensely. There are long-lasting mining processes started in the 16th century that continue until today. Places like the city of Potosí still show similar structures that are in use and can serve as a paradigm for capitalist extraction (HKW 2010). The famous Cerro Rico, which was one of the richest silver mining sites for centuries, is still an active mining site today, mainly focused on tin and zinc. At the beginning of the 17th century Potosí was one of the biggest cities in the world, with about 150,000 inhabitants – only comparable to Paris or London – and more than 13,000 mine workers. Today the town still has the same number of inhabitants, and mining procedures are still based on mainly unhealthy manual labor by miners; the mountain is a landscape devastated by mining.

The same is true wherever massive extractions such as open-pit mining, oil extraction, etc. take place. The transport of raw materials to the Northern hemisphere, accompanied by the products of massive agricultural planting, was answered by a different transmission of technical and industrial artifacts to the South. Since the first industrial revolution did not really take place in South America, almost everything related to modern technology had to be imported from the North.[5] This supply chain installed a strong dependency on many levels: any kind of product was imported, from bathroom equipment to cars, trains, instruments or whole technical infrastructures of telegraphy, telephony, transportation, electrical energy, construction, and mining. The growing European demand for materials for modern technology also gave rise to extraction infrastructures that were installed everywhere and made it possible to continuously supply production processes in Europe. These trajectories of materials from the place of their collection or extraction, and the working conditions involved, through the modes of land and sea transport to storage, distribution and final use, form an essential part of the conditions for the design of an artifact. The extraction process

5 The transmission of instruments, technology and knowhow from Europe to Latin America since the 19th century was the focus of the DAAD research project "Transmisiones" (2005–2009) at the Walter-Gropius-Chair at the University of Buenos Aires (Podgorny et al. 2008).

and the transmission of artifacts are further accompanied by the process of externalization (Lessenich 2019) of garbage towards the South.

These activities show that the whole process of designing an artifact reaches a planetary scale: great efforts and long transport distances for even small items is the very opposite of sustainable production. Changing this fundamental heritage of colonial and post-colonial asymmetry is a necessary requirement of the Design Turn. The challenge for Latin America will be to minimize long-distance transportation and encourage the use of local skills and materials in the design of sustainable artifacts. Instead of educating people to become consumers of industrial products, the strategy of "social design" is oriented to the application of knowledge for production based on local materials and practices.[6] Complementary with these necessary changes for Latin America will be the even more difficult shift for Europe towards a non-extracting and non-externalizing culture which will fundamentally challenge the entire established European way of life.

6 This implies above all the shift from a consumer society to a creative society that can develop sustainable modes of design (Galan 2015).

Adaptive Program

These changes in perspective call for new design strategies, a certain permanent revisiting that responds to the urgency of our current situation. There is a need for a design practice that is not aiming at prescriptive procedures in the sense of modern project logic and that will not anticipate processes and expected results. Rather, it is a critical and adaptive elaboration that includes both practical and epistemic experimentation into open-ended processes. This strategy of the Design Turn process is based on at least five essential inversions:

Inversion 1: Adaptive Process

Radically transdisciplinary design aims to establish an open-ended *adaptive process* modeled on biological growth and evolution. Adaptive design does not use rigid prefabricated components, nor a fixed program or a programmable objective, but enables a process open to unpredictable circumstances and environments. In this sense, the optimum of such processes cannot be radically anticipated.

Inversion 2: Material Activity

The analysis of internal mechanics and architectures of materials will allow the deployment of their intrinsic *material activity* and transform it into new design strategies for any type of sustainable artifact or building.

Inversion 3: Beyond Extractivism

Sustainable design has to cut off supply chains based on unidirectional extraction processes that always lead to waste and trash in landfills and dumps or, even worse, scattered all over the planet as myriad wastes. Avoiding the use of metals, concrete or oil is not yet a step *beyond extractivism* and does not prevent other types of extraction and long-distance circulation.

Inversion 4: Naturalizing Culture

The new adaptive interaction between cultural procedures and natural processes means moving from culturizing nature to *naturalizing culture*. Therefore, symmetrical intercultural collaboration is of fundamental importance for the Design Turn. Reversals of habits, technologies, behaviors and social routines are fundamental and necessary, as industrialized culture is on the verge of collapse. These design guidelines require a variety of knowledge, from biology to materials research, to make possible a new world of artifacts that no longer manipulate and control nature, and facilitate an adaptive, non-destructive design process.

Inversion 5: Social Design of Knowledge

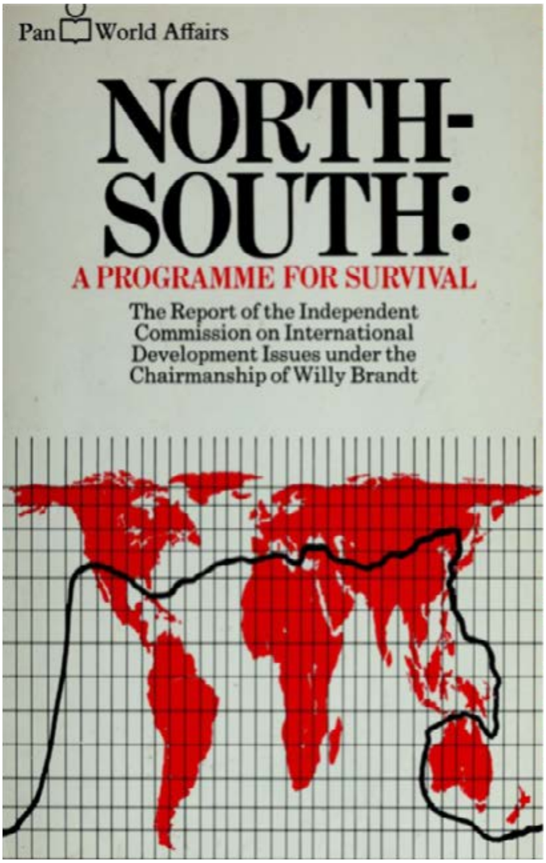
Designing knowledge needs all kinds of experience and disciplines and results in an integrative procedure to incorporate as much knowledge as possible. The academic space must be enriched in a transdisciplinary way with other knowledge, for example *traditional practices and social urgencies*. We need open laboratories to include all these actors and requirements. In this way, design becomes a social process. Social design of knowledge is another name for politics considered as an open, inclusive and creative process that we need for all our concerns.

Inversion 6: Sur o No Sur

Taking these inversions into account, it is evident that the Design Turn has to occur, at any scale. The fundamental change implicit within these further turns of the Design Turn can be exemplified by turning from the hegemony of the Northern hemisphere – which is in deep crisis – towards a new notion of the South.

The focus on a Design Turn from and towards the South tries to avoid the North–South antagonism, on which the famous Brandt Line report of 1980 was based, since "'North' and 'South' are broadly synonymous with 'rich' and 'poor'" (Brandt 1980). Or, to use the classic phrase of Eduardo Galeano, "The division of labor among nations is that some specialize in winning and others in losing" (Galeano 1971).

1 Brandt Line 1980 (Brandt 1980)



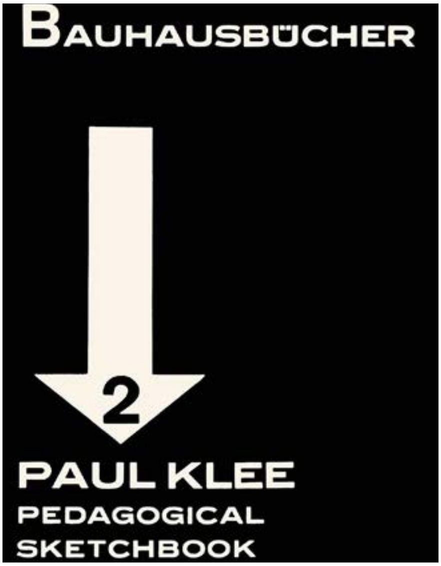
7 "The South is rather a metaphor for the human suffering caused by capitalism and colonialism on the global level, as well as for the resistance to overcoming or minimising such suffering." (de Sousa Santos 2016, 18)

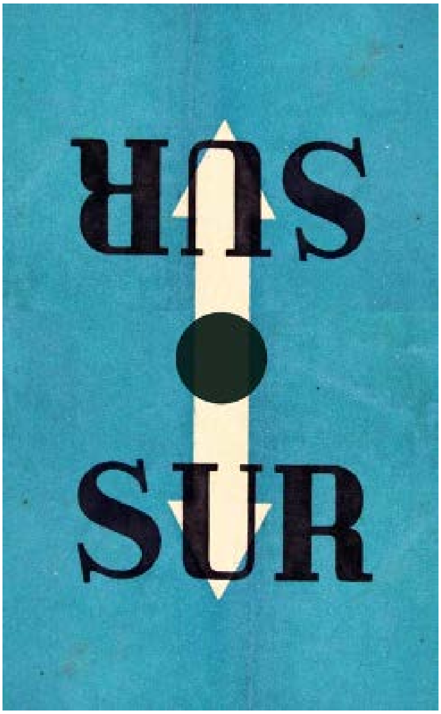
8 The Workshop "Sur o No Sur" held at the Universidad de Buenos Aires in August 2018 focused on the development of guidelines to put an end to the idea of peripheries and to start rethinking the South as having specific and essential spatial-cultural values in the sense of Kevin Johansen's seminal song "Sur o no Sur."

This negative antagonism is still essential in the notion of the "Global South."[7] Going beyond identifying the South as periphery and victim, the permanent revision of the Design Turn has to include the inversion of this difference in the moment when the industrialized nations of the North suffer incurable damage.

The new notion of the South also has to go beyond the classical relationship that was exemplified by the famous journal *Sur*, founded by the Argentinean writer Victoria Ocampo in 1931 (Ocampo 1931). The title already highlighted a different symbolic order, a fundamental dissymmetry with the Northern hemisphere, but still dependent on the culturally guiding example of the North. The cover of the journal reflects not by chance the Bauhaus design – it included a text of Walter Gropius – showing the "Sur" icon with an arrow from the North. It is time to invert this beyond any new antagonism. This turn that includes all changes could be called "Sur o No Sur,"[8]

2 Dessau 1925 (Klee 1925)
3 Buenos Aires 1931 (Ocampo 1931)
4 Sur o no Sur 2018 (Martin y Schäffner 2018)





which sounds in Spanish quite similar to Shakespeare's "To be or not to be" – "Ser o no ser."

We need a both radical and careful way to set in motion a fundamental change, in teaching,[9] in conducting research, and in changing the destructive processes on all levels. But the real challenge is the urgency of our current situation, which requires this Design Turn to advance much faster than traditional or natural processes. Only then will the much-needed design revolution arrive in time.

9 This is an agenda within the future field of science, technology and society (STS) studies in Latin America (Schäffner 2022).

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ESSAY

Re-thinking Urban Materiality in the Age of Climate Change

Anupama Kundoo

The built environment, once a collective effort, is now dominated by specialized professionals, which cause social and environmental instability. “Ordinary” human beings lose their ability to participate in shaping their surroundings, resulting in a decline in skills and engagement. Additionally, unsustainable consumption of natural resources, coupled with standardized industrial processes, often pose conflicts between social and environmental values. This paper presents a principled approach to address these issues. By re-examining industrial habits, embracing local materials, known technologies and building methods, the built environment can become more sustainable and inclusive. Implementation of initiatives like human-scale design, creative material use, waste reduction, and integration of artisanal practices in building processes promote more affordable housing, reduced environmental impact, and community engagement, ultimately benefiting both society and the environment.

Keywords: Human-scale design, vernacular architecture, local technology, waste reduction, energy consumption

Introduction

Architecture is the stage on which all human stories are lived out. Where once the stage was constructed by everyone, the stage today is almost exclusively constructed by professionals, virtually all of whom specialize in one trade or another. The growing, economically motivated separation between professional builders on the one hand, and users of the built environment on the other, is socially and environmentally destabilizing.

“Ordinary” human beings are losing their ability to participate in the construction of society’s largest undertaking – the built environment. That loss is leading to a slow erosion of human skill, social and physical engagement, and individuality.

Since the beginning of the Industrial Revolution, the construction and operation of the built environment has consumed natural resources at a rate that has exceeded global population growth. In too many cases these resources have been wasted only to create urban ugliness. Technological advancement, standardized industrial processes, and our own unexamined belief systems and habits – especially those that have been promoted as saving time, reducing costs, or offering more comfort and amenities in our built environment – have delivered uneven benefits.

Except in a handful of countries, construction projects across the world don’t move any quicker than they used to 50 years ago. Homes and commercial real estate are becoming more expensive and are increasingly out of reach for the majority. Cities around the world are shedding their identities; modern buildings across various cities in the world are practically indistinguishable despite the diverse climatic and cultural contexts. The loss of aesthetic diversity is also a reduction – as if all human stories are the same.

Why have the purported gains from technological advancement not resulted in housing that is more broadly accessible? What should we do about the conflict between our desire to improve living conditions for all of humanity versus the unsustainable trends in resource consumption? And what of the largest losses of all – our skills, our capacity to think, and our sense of purpose and belonging?

A Principled Approach

The answers to these questions may lie in re-examining those habits of mind and body that humanity has adopted during the long process of industrialization. Foremost among these are the notions of time and its scarcity. If time is perceived to be scarce, then it follows that rational professionals would prefer to specify pre-designed, standardized materials and components and outsource to experts those tasks they believe they are not qualified to handle.

That preference, once it becomes a reflexive habit, has pernicious effects on the choice of form and materials. These effects are a consequence of the growing and unquestioned disconnect between what might have been possible with a bit more thought versus what ends up happening when design decisions are effectively outsourced to someone with a standardized product or preferred solution.

The point is simple: we think we don't have time, so we don't take the time to think. That mindset has avoidable consequences. This article is about how to avoid that mindset and its consequences. Just as athletes seeking to develop strength and endurance spend countless hours practicing and all their energy on exercise, so also should we, seeking more engaged and purposeful lives, look to spend (not save!) more time in deliberately creating the built environment of the future.

Our time is not an "expense" to be minimized. Rather, it is a wasting resource that we should be eager to employ. It is the misguided disuse of our time (and therefore our intelligence) that leads to wasteful overconsumption of finite natural resources and a lower quality of life. The idea is to imaginatively and purposefully use our time to create an abundance that can benefit all.

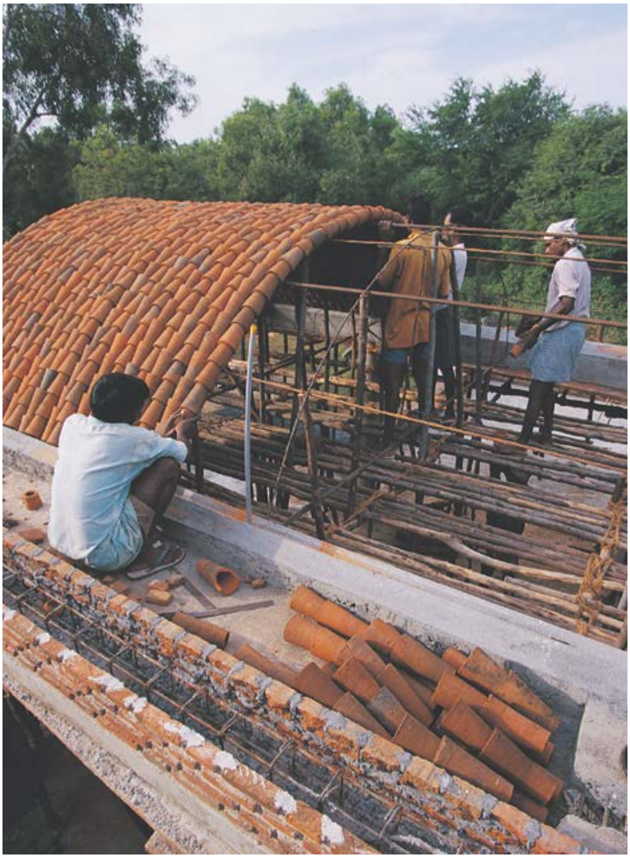
The strategies discussed below can help thoughtful design professionals achieve multiple objectives at once – reduce a building's environmental footprint, extend finite resources, house more people, develop human capital by teaching building trades and skills, and support local economies.

The most important principle guiding any effort to alter mindsets and practices surrounding urban materiality is this: the emergent built environment must facilitate better lives for all of humanity.

Material Is Best Treated as a Local Matter

If we only ever buy berries at the supermarket, it isn't easy to identify edible berries in the wild. Once we get used to sourcing materials and components from catalogues and industrial-scale suppliers, local materials fade into and look like part of the landscape. Yet, throughout history humans have built great structures by using stone, clay, wood, and other

1 Samskara: Made in India (hand-levelling of granite slabs in Tamil Nadu) (photography by Vimal Bhojraj, 2014)
2 Wall House construction process (photography by Andreas Deffner, 2000)



materials they could find at or near the building site. Think of how often field stone at a site is dug out and discarded only to make way for purchased building materials with similar properties!

An important advantage of using local materials is that it usually improves employment prospects for local craftsmen, who are more familiar with those very materials. And, of course, it saves on transportation costs and emissions too.

Example: *"Samskara: Made in India" (New Delhi in 2017) was an exhibition of high-end, hand-crafted contemporary products. Granite from a local quarry was used to emphasize local stonecutters' craftsmanship—making thick white slabs look like delicate flying ribbons. The ribbons served both as the exhibition hall floor and as the stage for the products. Between the ribbons, 2–3 inch streaks of crushed darker granite provided visual relief. Their more important (and unnoticed) role was to absorb the inevitable dimensional variances between working drawings and the actual site.*

Known Materials and Technologies Have Uses We Have Yet to Discover: Experiment Boldly

If you see an object simply as a clay pot then all you will see is that you can use it to fetch and store water, or cook food in. If, on the other hand, you can see it as an object with a convex surface made of a sturdy material, then you can conceive other uses for it. For example, you could use it as lost formwork for a coffered ceiling. By removing concrete from that portion of the slab experiencing tension, we make the slab stronger, lighter, and cheaper to produce.

Baked in situ mud houses, which look a lot like traditional housing, are a novel way of recombining a known material (mud) and a known process (kiln firing). This novel approach does away with the need for cement (one way to reduce embodied energy, more on which later) since the bricks that make up the house are fused together during firing. Of course, the finished bricks require no (energy for) transportation since they are fired in place. Additionally, the house works as a kiln to bake other clay goods with marketable value (capturing heat energy that would otherwise go to waste).

In summary, treat your project as a laboratory in which you encourage risk-taking to discover new ways to reduce the overuse of finite natural resources.

Example: *"Wall House" (Auroville in 1996) was a living laboratory that housed a decade of building technology experiments and prototyping. From one-inch thick, pre-industrial achikal bricks, to vaulted brick and terracotta roofs, to coffered/filler concrete slabs, to innovative spaces and volumes, the Wall House has explored a range of building technologies using common materials and products (not typically used in building construction) in unexpected ways. The laboratory helped train a community of craftsmen who have since gone on to build commercially thriving construction ventures.*

Old Can Be Gold
What one person thinks of as old-fashioned, another might consider a classic. Perceptions matter.

Around the world there are a plethora of time-tested, traditional building methods and styles (so-called vernacular) that offer important lessons and inexpensive alternatives to modern modes.

However, they do not attract the research and marketing funds that routinely flow to industrial technologies and products. The creators of the latter self-servingly (and incorrectly) presume that traditional systems are fossilized in time. Modern building codes therefore come to emphasize standardized industrial products and systems while extinguishing traditional methods that could offer equivalent benefits at a lower environmental cost.

Many traditional methods have been found to be cheaper, less wasteful, and better for local craftsmen and economies. By using them whenever practical, we can improve their odds of equal representation in regional and national building codes.

Example: *Earth construction is a common example of an age-old residential construction technology that is, unfortunately, no longer permissible under most building codes. Yet, the method is inexpensive and more than adequate (structurally and climatically)—especially when you consider the unmet needs of hundreds of millions of people.*

Design So Anyone Can Build
Not all construction activity requires highly skilled or experienced talent. Around the world there is an abundant pool of enthusiastic (if inexperienced) people able and eager to augment their income or contribute "sweat equity" for a chance to be able to afford a modest dwelling.

From hanging doors, to painting walls, to handling and organizing construction materials, there is a lot of work on a construction site that anyone can do. With modest changes to design details and the very choice of building technologies, we can expand the scope of such anyone-can-do-it activities and so encourage broader participation in the construction of our built environment.

Empirical observation and hard data confirm that this approach – encouraging broader participation in construction – reduces total construction costs, broadens affordability, and increases community engagement and skillsets, which pays off handsomely via improved employment prospects.

Example: *"Creativity" (Auroville in 2003) is a 3,250-square meter urban eco-community focused on reducing costs by sharing spaces and resources and by enabling future residents to contribute labor. Construction details were simplified to allow even inexperienced individuals to participate and gain knowledge and expertise by doing so. Clay excavated from an on-site wastewater treatment plant was used in cement-stabilized rammed earth walls which, because they require little more than brute force to construct, are a good way to conserve resources and invite the inexperienced to participate.*

Build So Everyone Can Grow

Most people think that solid construction requires skilled and experienced personnel. Such talents being neither cheap nor plentiful, homes and other structures are becoming increasingly expensive. In response to any immediate shortage of experienced personnel, the construction industry – which is cyclical – finds it uneconomical to invest in training people for skills that are unlikely to pay off by the end of the then prevailing construction cycle.

In the short term, it is cheaper to modify processes and technologies to allow more standardization and even mechanization. In the long term, standardization and mechanization reduce employment prospects within the construction industry and thus deplete hard-won skills and experience. The unintended effect is the economic impoverishment and demoralization of entire communities. The irony is that the process of "efficiently" constructing our built environment is inexorably dismantling the very society we are building it for.

When we invite broader (inexperienced) participation we are effectively recruiting for "attitude, not aptitude." The approach yields a cohort of people who gain knowledge and experience

3 Creativity cohousing (photography by Javier Callejas, 2003)

that they otherwise would have no way of obtaining. Along the way some may discover that they have a knack for the work and that it brings them joy, which leads to better economic prospects for themselves and a broader and deeper pool of construction skills in the community. One adjacent benefit of enabling the inexperienced to participate is that it develops project management skills, which, of course, are broadly transferable.

By integrating “participatory construction” with local materials and craftsmanship one can reverse regional economic declines and gain a structural cost advantage over wasteful mechanized solutions.

Example: *“Volontariat Homes for Homeless Children” (Tuttipakkam in 2008) is a 500-square meter cluster of whimsical dwellings offering refuge to homeless children of all ages. The clusters of catenary domes made of sundried earth bricks with earth mortar were fired in situ to stabilize them into water-resistant ceramic structures. Most of the budget went into labor, with very little cost attributed to materials.*

Waste Less Embodied Energy

Concrete is the second most widely used material on the planet, with an annual consumption exceeding 10 cubic kilometres. High in embodied energy, it accounts for 5% of anthropogenic carbon dioxide emissions.

Ferrocement is a low-embodied-energy variant of reinforced concrete. It consists of simple chicken-wire mesh, sometimes augmented by a frame of quarter-inch steel rebar, with the whole assembly encased in cement plaster (as opposed to concrete, which contains coarse aggregate). No more than an inch thick, it has superior strength-to-weight properties and conserves materials (cement, steel, aggregate) that are high in embodied energy. So, material conservation yields direct economic and environmental benefits.

Ferrocement is highly durable, offers better seismic force resistance (it bends where reinforced concrete would crack), and is exceptionally easy to maintain.

It is well suited to off-site production, where curing and other processes are easier to control. This, in turn, further improves its strength-to-weight performance and ensures higher durability. When produced in the backyards of masons’ houses, ferrocement components offer a secondary source of income – more equitably distributed – with minimal capital outlay.

Example: *"Full Fill Homes" (modular in 2015) are a rapid and inexpensive housing solution with a far lower environmental impact than conventional methods. The design and the building technology (ferrocement) address three crucial and inter-related issues: affordable housing, decentralized economic opportunity, and environmental impact. Built from engineered, prefabricated ferrocement components, these modular homes can be assembled on site within a week (including foundation work) and are roughly 50% cheaper than conventionally produced housing with similar amenities. In addition to the basic structure, windows, doors, and other components are also made from ferrocement. Specialty pigments embedded in the cement slurry save on painting costs and give the smooth cement surfaces a waxed, waterproof finish. The folded and box-shaped components, designed to conserve and concentrate material where it is optimal (in webs and fins), double up as storage for clothes, books, kitchen utensils, and household effects. The approach saves on furniture and yields more living space.*

Another way to reduce waste is to use materials in their lowest possible energy state – which is to say one should minimize processing and transportation. Raw materials are much cheaper than, and often work just as well as, highly processed items. For example, level slabs of unpolished granite can be had for a fraction of the cost of polished granite tiles. Granite slabs are stronger than tiles and can serve as floor and substructure at the same time.

Similarly, a small diameter de-barked tree trunk is much cheaper than, and offers as good or better strength than, a square post sawed from a larger trunk.

Example: *"Hut in Petite Ferme" (Auroville in 1990) was the first output from a life-long quest for building systems that deliver a great deal with very little. Built from coconut thatch, thin casuarina trunks (debarked but unseasoned), coconut rope, and rough-hewn granite, it involved merely the dry assembly of lightly processed and unprocessed materials. The modesty of upfront capital investment did entail greater spending on periodic maintenance, since elements like rope and thatch wear out more easily than more solid materials—a necessary and even welcome trade-off for people who have no access to*

4 “Volontariat Homes for Homeless Children” construction process (photography by Javier Callejas, 2008)

5 FullFill Home in Chennai (photography by Javier Callejas, 2015)
6 Hut in Petite Ferme (photography by Andreas Deffner, 1991)

credit but who, through work, can accumulate enough savings to manage small repairs over time.

All things being equal, the less we handle any material, the cheaper it will be for us and for the environment.

Trash is Unimagined Treasure
Resource wastage in modern economies is a crisis that offers a substantial opportunity for re-thinking both how we design and how we use and maintain our buildings. Old books and newspapers, glass bottles, and car tyres are examples of unconventional materials that can occasionally be repurposed as building materials or even formwork.

Example: *"Unbound: The Library of Lost Books" (Barcelona in 2014) was a temporary pavilion of three "trees" with canopies made from obsolete city library books designated for destruction. Repurposing the books as foliage, the pavilion served as a place for reflection, rest, and a chance to re-think old constructs. The "trees" were later removed and re-assembled and found new life at a nearby public school, where they remain to this day.*

Another common example of resource wastage is dishwater or bathwater. If we think of it as "dirty" then we treat it as waste. If we think of it as a fluid that (with a little treatment) helps plants grow, then we end up with a functional gray water system that saves money in the long run.

Example*: "Auroville Town Hall Complex" (Auroville in 2005) is a cluster of buildings connected by flying walkways, bridges, and ramps. Rain harvested on the roofs is treated to drinking standards and piped to the cafeteria. Wastewater from toilets is treated and reused for irrigation.*

(Do the Math and You'll See That) Good Enough Is Perfect
Engineering firms are not usually invited early enough in the conceptual phase of a project to make a meaningful difference to material selection or the quantities consumed. Nor are they asked to offer solutions that result in the least possible material usage to get the job done. Rather, they are usually asked to weigh in after critical design decisions are made, and so they tend to focus on ensuring that a given design is safely engineered.

The process is recognized by architects and engineers alike as a short-sighted one in that it precludes critical thinking and instead defaults to codes and norms that can be quickly applied to a given situation to yield a safe, if over-designed, structure.

Rampant standardization nudges us to accept over-designed norms as the correct solution. But the norm has a factor of safety built in that is excessive or entirely unnecessary in many a specific context. In practice this means that some percentage of concrete slabs cast every day are over-designed and thicker than they need to be. It means that everything from spatial dimensions to steel beams to floor tiles are, at least in some cases, larger than they reasonably need to be. The implications for material usage and environmental impact are… well, material.

Aside from the higher purchase cost, using more material than a situation warrants has multiple indirect consequences. Beams, columns, and foundations become costlier; transportation costs increase; and the amount of finishing (painting) required tends to be higher too.

Example: *"Sri Aurobindo World Centre for Human Unity" (Auroville in 2000) is a 300-square meter covered community space defined by eight inward-leaning concrete pillars supporting a circular concrete roof. The pitch and profile of the pillars (and other aspects of the design) were iterated several times to reduce structural spans and lighten the roof. The structure consumed only 75 cubic meters of concrete instead of the originally budgeted 125 cubic meters.*

Think to Learn With Your Hands

One troubling corollary of skill specialization in modern economies is that society is cleaving into two camps: people who work with their heads and people who work with their hands. This divergence is socially problematic, of course, but it also leaves everyone intellectually worse off.

For architects and architects-in-training there is no better way to learn – to navigate the gap between the elegance of theory and the rough reality of the world – than to work in the field and get one's hands dirty. Climbing a long flight of stairs with the sun blazing overhead informs us about scale and place very differently than representing the same stairs inside a DWG file. Pour concrete and you understand the weight and workability of the material in a way that no numeric description can replicate. Sometimes we think and learn better with our hands (and on our feet!), and that sort of thinking takes time.

An even greater benefit of "thinking and learning with our hands" is that it allows us to establish a closer connection with the craftsmen and women who give physical form to our ideas. In turn, that connection has the power to make us aware of how even a small design or sourcing decision helps or hurts a real person. This is engagement with a purpose, and it works.

Student design-build examples:

- *Watch tower at Auroville's Botanical Garden (2006) built by students from the AA School of Architecture using rope-tied round wood construction and coconut thatch.*
- *"Liquid Wall" backdrop constructed at a public space in Mexico City using discarded Tetra Pak containers refilled with sand or water.*
- *"Wall House" (2012) reconstructed in full scale at Venice Architecture Biennale by students from the University of Queensland, Brisbane and Università Iuav di Venezia.*

Avail of the Human Scale
We know scale confers benefits. But we also instinctively know that just because something is good, it does not mean that industrial-scale quantities of it must be better. The tyranny of monotony is an affront to the human scale, which is about intimacy and uniqueness. It is craftsmanship – which is about producing a specific object for a specific person or situation – that more easily honors the human scale even as it reduces the waste that accompanies over-designed standardized products. The issue of scale applies not only to what is built but also to how we design and build.

Developer-driven construction projects are principally concerned with the most cost-effective (and therefore most profitable) production of marketable space. Qualitative design intangibles do not readily feature in these calculations.

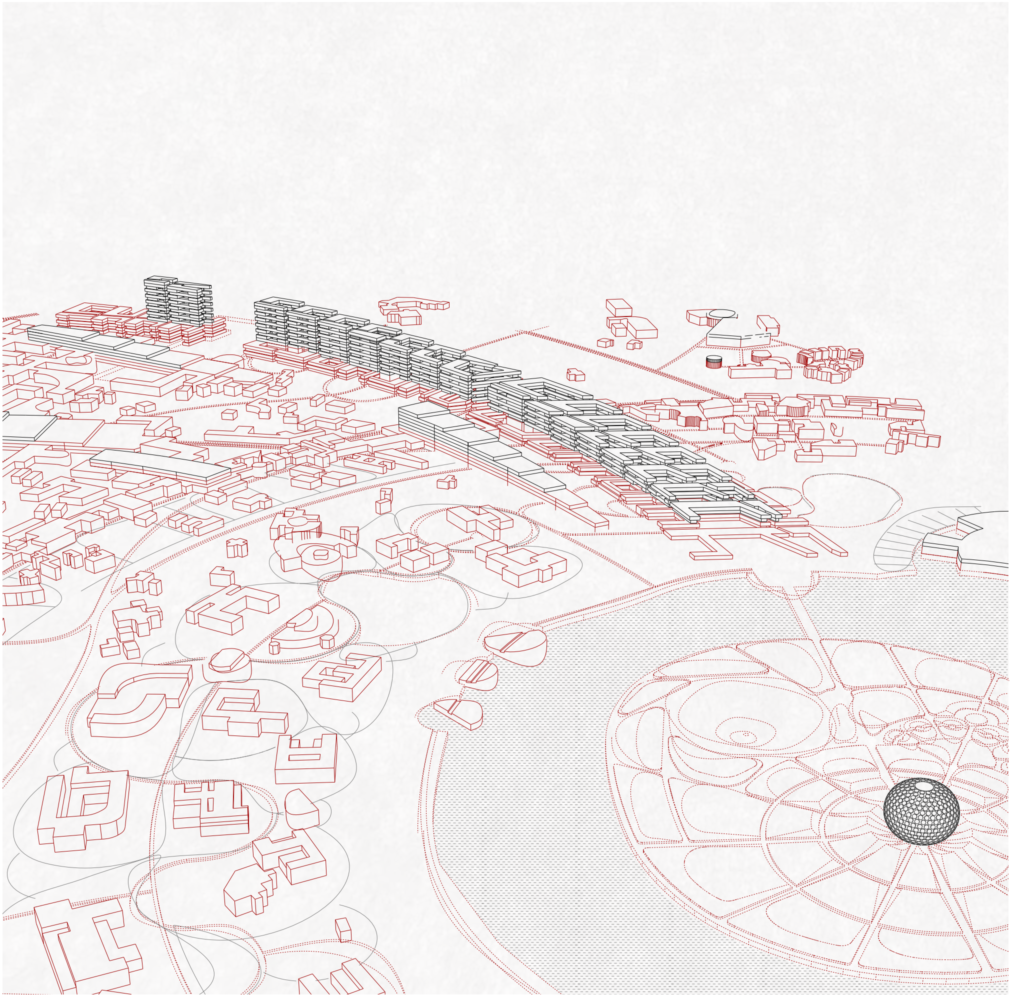
Regardless of typology and project scale, then, artisanal design practices – traditionally focused on the very intangibles that are difficult to measure – are increasingly excluded from consideration. But when projects are awarded to and delivered by large teams – complete with hierarchies and narrowly focused specialists – critical attributes like care and holistic attention may go missing.

Freed of administrative burdens and empowered to contribute all they can, small teams with members wearing, as it were, multiple hats may deliver much more at a lower total cost.

7 Library of Lost Books (photography by Javier Callejas, 2014)

8 Sri Aurobindo World Centre for Human Unity (photography by Javier Callejas, 2000)

9 Line of Goodwill by AKA, 2020



Develop What Is Plentiful and It Will Extend What Is Finite

Discussions of natural resources are pointedly silent on the one natural resource that is not only renewable but that grows and gets better over time – human resourcefulness.

Because our current economic system does not account for the full environmental and social costs associated with the extraction and use of natural resources (and the energy required for the same) it is easy to see why a machine powered by the energy equivalent of hundreds of humans[1] will be cheaper to operate than hiring a human being.

1 The energy contained in a barrel of oil approximates the work output of 2,200 humans (https://www.vhemt.org/humanenergy.htm).

The downside of the modern predilection for over-mechanization is that it diminishes our engagement with the built environment, reduces the potential for skill acquisition and intellectual and spiritual growth, and increases our propensity to accept the choices of "experts" and, indeed, accept an entire way of life that is alien to our needs and our natural condition.

This is a case where a bit of faith in human ingenuity – backed by only modest investments in time taken to think and experiment – could yield substantial savings and a lighter environmental footprint. Repeated a million times, these sorts of small decisions can greatly develop the human potential to create compounded economic, environmental, and social benefits.

Influence to Amplify

Although it seems obvious, it still bears mentioning that policy and design choices made on an urban scale can have a disproportionate impact on the single site one is focused on. To maximize their environmental and economic impact, architects and urban designers could step outside the confines of their site and consider the bigger picture.

It helps to prioritize options that help neighbors and other stakeholders achieve their objectives. The approach opens the door to reciprocity and influence and can enable solutions (rainwater harvesting, wastewater treatment, shared gardens, reciprocal easements) that are difficult within a small project, but which may be undertaken co-operatively.

Cities are unique organisms that tend to promote and preclude specific development options. The form, scale, and layout of urban infrastructure defines the reasonable range of possibilities for design strategies at individual sites within the city. Influencing the core decisions, then, is a way to amplify the adoption of design strategies that can make a difference.

Example: *"Line of Goodwill" (Auroville, current) is a high-rise mixed-use project designed for 8,000 inhabitants. It is one of several dense conglomerations envisioned by Roger Anger in a larger city plan for Auroville. Set in the context of a car-free future city in which there is no private ownership of land, the project offers high-density collective living consisting of co-housing clusters with different experimental sharing structures. It rethinks the urban tower (where the human scale is otherwise lost after eight stories) by introducing several expansive horizontal walkways and public use layers. The gently descending cluster of buildings stretches over 800 meters, resembling a hill that starts at the entrance to the city and culminates at the edge of the lake in the city centre. The project features integrated water and wastewater systems, renewable energy sources, in-structure urban farming, and smart mobility.*

Conclusion

Of course, we can achieve big things by adopting small strategies and spreading awareness of their success. But even bigger successes await those of us willing to ask questions and take on problems and paradigms that lie beyond our immediate concerns. How can we expand human potential so that our economic assumption shifts from scarcity to abundance? How can we encourage economic systems that reduce the wasteful consumption of finite natural resources? How do we go about constructing an economy that sees unused time as the greatest waste of all?

Positioning Care

ESSAY

Design Politics in the Anthropocene

Joanna Boehnert

The Ecocene is a vision for design in response to Anthropocene planetary conditions. Progressive movements are challenging defuturing norms in design. Whether appropriate responses will happen on a scale that will make substantive mitigation and adaptation to climate change and other ecological crises effective depends, in part, on human abilities to design and enact massive change. As a practice that helps create the material conditions for everyday life with artifacts, services, spaces, and systems that enable future ways of living, design will play a role in the development of more sustainable and more equitable worlds. This essay highlights five design movements supporting radical and adaptive responses to environmental crises. The feminist design ecologies embedded in the Ecocene proposal are a foundation for the redesign and co-creation of worlds anew.

Keywords: Feminist design ecologies, regenerative design, transitions, design politics, Ecocene

We have yet to create a world where designers create ways of living to meet human needs and desires without undermining the climate system and contributing to the sixth extinction event. While many designers aspire to work in sustainable and just ways, the design industry is not yet responding on an adequate scale to environmental concerns. Instead, with the artifacts, buildings, communications, systems, and services we create, designers continue to play a central role in creating and reproducing types of human activity that are currently destabilizing the climate system and other Earth systems. The collective impact of human activity has resulted in geological changes scientists describe as indicators of a new geological epoch: the Anthropocene. The significance and risks associated with the Anthropocene diagnosis have yet to be integrated into normative design theory, education, and practice.

Design is implicated in creating and reproducing unsustainable conditions in the Anthropocene. Design skills are typically harnessed to generate economic value with insufficient or no regard for the unsustainable ecological consequences and social harms that are reproduced and often accelerated in the process. Designers create new objects, services, and places that produce increasingly fragile ways of living in a degraded and destabilized ecological context. While design sits in a pivotal sense-making and change-making space to potentially help facilitate ecological transitions, much of the design industry continues to be involved with the development of unsustainable products, processes, systems, and spaces. Despite the risks associated with delayed responses to environmental imperatives, design typically remains inadequately engaged with its political and economic context. This civilization has not yet created design economies or forms of governance in design institutions that enable responsible design on a scale that will prevent escalating ecological disasters.

Over the past half century, environmental scholars have argued that a paradigm shift in understanding the human relationship with our ecological context is a necessary part of an effective response to the dynamics that drive climate breakdown and destabilize planetary boundaries. The erasure of the ecological in the Western mindset has been described as a part of an “epistemological error” (Bateson 1972, 493–495) that results in gaps in knowledge and ways of knowing that have environmentally destructive consequences. These errors have manifested across disciplines and domains. Knowledge systems have been built on assumptions that deny or simply dismiss the ecological. These knowledge systems reproduce and entrench errors. Fields that help reproduce the material circumstances of human existence are at the crux of the problem as they give material form to this erroneous way of knowing—with unsustainable, supposedly unintended, consequences. These fields are also key to any potential solutions. Design is one such discipline.

Part of the process of creating more sustainable and just future societies is creating politicized design knowledge and practices. In the context of deeply unsustainable and unequitable norms, change on a scale that will make a difference requires politically engaged design practice. A first step is an understanding of the role of design in contemporary structures of unsustainability and the need for contra-innovation against pervasive design defuturing (Perera and Fry 2022). Design transitions for sustainability depend on deconstructing the assumptions that have allowed design to perpetuate so much harm to ecosystems and unserved communities alike. For example, the Anthropocene concept itself needs to be critically interrogated.

Against the Anthropocene: Reproducing the Unsustainable
The Anthropocene concept was popularized by atmospheric scientist Paul Crutzen and biologist Eugene Stoermer in a 2000 report describing environmental changes in the current era as indicators of a new epoch (Crutzen and Stoermer 2000). The Anthropocene follows the Holocene, an epoch that lasted for 11,700 years. It signals dramatic changes in Earth systems due to human activities and the end of the relative ecological stability that made civilization possible. The Anthropocene concept has helped the scientific community draw attention to environmental change, destabilizations of Earth systems, and ecological disasters. It communicates the urgency of the consequential decisions facing humanity with the intent of provoking responsive actions within complacent institutional contexts committed to business as usual. The concept has been mobilized to attempt to catalyze substantive responses to environmental problems. The idea has helped generate transdisciplinary debates in conferences, new journals, and books across the physical sciences, social sciences, and humanities. And yet, more than two decades after its introduction, the dangerous trajectory of Earth system destabilization accelerates.

The social sciences and the humanities have responded to the Anthropocene concept with their own descriptions and analyses of intersecting eco-social crises—including an interrogation of the Anthropocene concept itself. The term has been critiqued as an idea that works in counterproductive ways by limiting the scope of social transformations (Moore 2015; Haraway 2015; Latour 2017; Demos 2017). This position holds that the Anthropocene concept does counterproductive work by implying that "Anthropos" (humans) – as a generalized category – are responsible for climate change and other planetary crises. Environmental historian Jason Moore explains that: "conceptualisations of a problem and efforts to resolve that problem are always tightly connected. So too are the ways we think about the origins of a problem and how we think through possible solutions" (Moore 2015, 169). Moore proposes the "Capitalocene" as a useful descriptor of an epoch in which Earth systems crises are a result of specific things that humans do, since there are specific ways of organizing social relations that create unsustainable conditions. This politicized position has been expanded in the realm of aesthetics by T. J. Demos, who argues that the Anthropocene rhetoric:

> [...] frequently acts as a mechanism of universalization, albeit completely mediated and distributed among various agents, which allows the military-state-corporate apparatus to disavow responsibility for the differentiated impacts of climate change, effectively obscuring the accountability behind the mounting eco-catastrophe and inadvertently making us all complicit in its destructive project. (Demos 2017, 19)

This universalizing discourse allocates agency to generic "human activities" and thereby avoids "the politicization of ecology that could otherwise lead to the practice of climate justice, which demands the politics of equality, human rights, and historical responsibility be taken into account" (Demos 2017, 21). This critique is important for design because challenging norms as embedded as the interests served by design practice is a fundamentally political process. For example, how is ecological context accounted and catered for in human-centered design practices? Shifting the focus of design practice to consider ecological harms is all too often a politicized process.

The scientific community's call to action in response to the converging planetary crises of the Anthropocene requires both critical socio-political analysis and regenerative design responses. Designers can play a role in shifting the current trajectory, but this will not happen without a major realignment of design priorities and practice to include wider sets of interests in our ecological context. The Ecocene proposal describes a vision for this transition work.

Toward the Ecocene: Regenerative Design Futures
There are alternatives. Design is a practice that can help make another world not only possible but desirable. Faced with climate breakdown, constrained resources, and widening inequalities, new strategies and pathways are needed. The Ecocene is an alternative vision for design. Design theorist Rachel Armstrong describes it as an emerging ecological epoch in which:

> [...] the side effects of industrialization, with its relentless consumption of natural resources and fouling of our environments, set up feedback loops that destabilize the very systems that sustain us, the hyper complexity, and nonlinear character of the biosphere evades our ambitions to bring these runaway consequences back under our control through the tools of modern synthesis. [...] Yet, the harder we try to “solve” the unfolding ecological catastrophe, the more it evades our attempts at resolution. Currently, we are reaching the limits of modern technology to address the challenges of “wayward” nature and are faced with the daunting prospect of reimagining our position within the world and the way we construct the idea of value in the Ecocene. (Armstrong 2017, 188)

Ecological knowledge is integrated in new forms of regenerative design. Design can respond to “flux, uncertainty, diversity and instability, by shaping the values on which our decisions are founded” (Armstrong 2017, 1). A politico-ontological shift in design is emergent. This transition can be accelerated with deliberative strategies.

The formulation of the Ecocene presented here describes design practice built on ecologically coherent, politically engaged, and socially liberatory premises. This vision of feminist design ecologies requires dramatic shifts in normative Western social relationships, modes of governance, and institutions. These transition strategies are already emerging in the following design movements:

1. *Transdisciplinary and systemic design*
2. *Critical ecological design thinking*
3. *Intersectional feminist: linking the “isms”*
4. *Redirected political economies of design*
5. *Expanded, regenerative, and pluriversal design*

These approaches redirect designers’ priorities and practices to influence the future worlds designers help create. The Ecocene proposal describes how emergent politicized ecological knowledge can enable new types of design practice. In remediating defuturing assumptions, approaches, and practices in design, these movements attempt to address the challenges of the Anthropocene.

Transdisciplinary and Systemic Design

As design expands its remit, transdisciplinary and systemic engagements are a foundation for the more accurate interpretation, analysis, and framing of the design problems under investigation. Hybrid knowledges are generated in which the sustainability sciences are integrated with design thinking, design methods, and design skills. The Anthropocene concept itself is a good example of how different knowledge traditions inform the design context, as a prerequisite to effective contemporary framing of design questions. The Anthropocene is a scientific concept that provides a fundamental overview of ecological circumstances created by human activities, including breached planetary boundaries (Steffen et al. 2018). As we have seen, the politicized Capitalocene concept was proposed by social scientists (Moore 2015; Haraway 2015; Latour 2017) as a description of the specific structural drivers and social conditions that have generated these physical impacts on Earth systems. The Ecocene concept proposed by design theorists (Armstrong 2009, 2017; Boehnert 2018a) provides a vision for transformative social, political, cultural, and technological change.

Critique opens space for alternatives. When Donna Haraway stresses that the Anthropocene must be "as short/thin as possible" (Haraway 2015, 160),[1] she describes a situation where we must move past the assumptions that created Anthropocene conditions in the first place. This perspective creates space for ecologically grounded and socially liberatory responses. The epoch in which humans are destabilizing Earth's systems must come to an end. Armstrong stresses: "there is no advantage to us to bring the Anthropocene into the future [...] the mythos of the Anthropocene does not help us [...] we must re-imagine our world and enable the Ecocene" (Armstrong 2009). The Ecocene calls for dramatic reconfigurations across disciplines.

1 The full quote is worth including here. Haraway wrote: "The Anthropocene marks severe discontinuities; what comes after will not be like what came before. I think our job is to make the Anthropocene as short/thin as possible and to cultivate with each other in every way imaginable epochs to come that can replenish refuge" (2015, 160).

Science is only one of various arbiters that need to participate in the naming and framing of this epoch. The social sciences contribute to analytic frameworks that describe exactly why particular types of societies have generated so much ecological destruction over such a relatively short period of time. Design and the arts and humanities more broadly help envision and generate new ways of seeing and being. Critical, social, and generative hybrid knowledges are all needed to understand, critique, re-imagine, re-design, and re-make new ways of living.

Transition work depends on these hybrid knowledges and systemic understanding of complex problems to enable behavioral change—and the even more difficult work of social, cultural, institutional, political, and structural change. This inherently transdisciplinary work can be facilitated with systemic design, a design practice that combines system thinking with design thinking and methods (Jones 2017; Sevaldson and Jones 2019). Design must expand its remit. This expansive work aligns with other progressive ecologically and politically engaged movements in design research, including Design for Sustainability (Ceschin and Gaziulusoy 2019) and Transition Design (Irwin, Tonkinwise, and Kossoff 2013). Transdisciplinary, hybrid, and systemic knowledges support the competencies, mindsets, and skills needed to engage carefully and critically with eco-social problems. Design practices can be used to help social and physical scientists collaborate and to generate new tools, services, and systems. Critical feminist design ecologies have theoretical contributions that are relevant across disciplines.

Critical Ecological Design Thinking

The existential threat facing humanity is not only converging planetary crises but also human inability to respond effectively with knowledge traditions that have denied ecological context—and social institutions and system structures designed based on these premises. Addressing ecological breakdown depends on unlearning ways of knowing that have systemically dismissed the ecological. This foundational shift is key to the transformation of institutions and technologies created with erroneous assumptions. The error in knowledge systems that deny the ecological has wide-reaching implications. Anti-ecological ways of knowing and doing reproduce exploitative and extractive economic priorities, technologies, social practices, and behaviors. These are all manifested and reproduced by unsustainable and defuturing design (Fry 2009). In responses to these problems, ecological knowledge creates a foundation for new strategies of regenerative, sustainable, and systemic design.

Over the past 50 years, ecological theorists and sustainability scholars have described ecologically engaged epistemologies, ontologies, and ethics with increasing sophistication. In 1972 Gregory Bateson described a fundamental epistemological error in the erasure of the ecological in his groundbreaking *Steps to an Ecology of Mind* (1972, 493–495). More than five decades later, there remains significant work to be done to embed an ecological lens in intellectual traditions. Ways of thinking that embrace the ecological are emergent in the Western tradition as environmental scholars, practitioners, and activists transform outdated paradigms and frameworks.

Ecological knowledge and relational ways of knowing are being integrated into design theory, practice, and education.

This is happening in regenerative design and in design theory with concepts such as post-human, multispecies, more than human, etc. that help decenter the human and “greatly expands our understandings of the multiple agencies, dependencies, entanglements, and relations that make up our world” (Forlano 2017, 17). Ecological ways of knowing and doing design are relational, situated, and embedded. Relational design draws on the cross-disciplinary relational turn that acknowledges interdependencies and social dynamics (Nielsen and Bjerck 2022, 1061). While it is not explicitly drawing on ecological thought, the Social Design Institute emphasizes “situational, situated, and situating” design research (Kaszynska, Kimbell, and Bailey 2022). This turn towards context is mirrored in a newly emphasized positionality in design (Motti Ader et al. 2023). Explicit focus on position supports learning to recognize exclusion (Noel and Paiva 2021). The historic and ongoing exclusion of the ecological in design (Boehnert 2018a) can also be addressed with these positioning strategies. The notion of *embedded ecologies* formulated by Vijaya Rettakudi Nagarajan describes “implicit and embodied ways of seeing and relating to the natural world” that are “contested, historicised, and culturally specific” (Nagarajan 1998; cited in Kannabiran and Søndergaard 2023). The embedded ecologies concept encourages situated and contextualized engagements in ways that also reflect feminist concerns and theories.

Intersectional Feminist: Linking the “isms”

Ecofeminist, environmental justice, and decolonizing movements have emphasized how global systems of domination such as patriarchy, race, and colonialism intersect with ecocide (Plumwood 1993; Dumbuya and Solanki 2021; Tunstall 2023). Exploitative and extractive relationships are reproduced and accelerated by designed artefacts, services, and systems (Costanza-Chock 2020; Tunstall 2023). These discriminatory relationships must be challenged not only because of the harms associated with these injustices, but also because all viable pathways to sustainable and socially just futures depend on cooperation. Hierarchies and monopolies of knowledge and power must be transformed because collaboration is an essential part of ecological transitions that are not authoritarian. As an alternative, design researchers have developed new means of participation with collaborative and commoning practices (Balamir 2021; Botero et al. 2020). Design is a practice that can help implement these transitions.

As the climate and ecological crises accelerate, social and political tensions escalate. This is evident in the rise of far-right movements. With the setback of reproductive rights in the USA, for example, decades' worth of social progress is destroyed. New right-wing environmental movements are emergent. In this context, environmental movements that are not explicitly collaborative, intersectional, and justice-oriented default to politics that have authoritarian characteristics. Tensions will continue to escalate if intersectional solidarities are not deeply embedded into environmental movements and the institutions responsible for sustainable transitions. Intersectional solidarity and cooperation are foundational for sustainability because cooperation within and across communities depends on trust, and trust cannot be built in spaces where injustices are not addressed. The way to preserve freedoms for all is to be explicit in the work confronting and repairing past injustices. Movements such as decolonization in higher education, and truth and reconciliation with indigenous and racialized peoples around the world, are examples of attempts to do this vital work.

Ecofeminists have described the conceptual intersections and parallels between the disregard and disrespect faced by women and other historically oppressed groups—and the ways in which humans have dismissed and denied the interests and needs of the natural world (Plumwood 1993; Frazier 2016; Kannabiran and Søndergaard 2023). This dismissal of the ecological often extends to a disregard for individual environmental activists—evident in the bullying, criminalization, and violence that is directed at environmental activists. Ecological and social injustices emerge from the same pattern of "othering"—as a fundamental absence of care at the intersection of all oppressions. Exploitative relations of all types undermine our collective survival and potential flourishing.

Climate change and other ecological crises create new social injustices which then continue to amplify unjust power relations. The people least responsible for greenhouse gases (GHG) in the atmosphere are at the front line of climate impacts. These harms are the responsibility of corporations and countries that have benefited from historic GHG emissions. These companies and nations have a responsibility to address the harms created by historic GHG emissions (along with other ecological harms). Design must commit to global responsibility—and negotiate the dangers of strategic ignorance in (McGoey 2012), and epistemic erasure (Bacevic 2021), by those who would avoid inconvenient historical and contemporary facts. Acknowledging historic and contemporary harms is a foundation for reparative and generative social and ecological transitions.

Redirected Political Economies of Design

The political economy of design refers to the ways economics shapes priorities in the design industry and thereby determines the roles that design plays in society. The political economy governs the function and form of design along with the "unintended consequences"[2] of processes of production, shipping, use, and disposal. It determines whose interests are considered by designers and how "costs and benefits are distributed within society and across generations" (Orr 2018, 7–8). Since economic structures influence and even determine the priorities of the design industry, and these priorities impact the sustainability agenda, the political economy of design is of central importance for design transitions to sustainability (Nardi 2019; Boehnert 2018a, 2018b). Unsustainable design is currently a structural feature of the design industry.

2 The very notion of unintended consequences should be interrogated as a "failure of design and design education to engage and adapt suitable strategies to avoid producing ecological and social harms" (Boehnert, Sinclair, and Dewberry 2022, 22).

Net Zero and other sustainability transitions all depend on redirected design economies that engage with (rather than deny) the complexity of the ecological context, the risks of unsustainable practice, and the urgent need for new priorities. The political economy of design determines the nature and form of the technosphere, i.e., the material output of the human enterprise (Zalasiewicz et al. 2017). Furthermore, the internal dynamics of the political economy and associated technological systems come to have their own emergent "design" goals that limit human agency (Haff 2014). Design economies intersect with both physical laws and socially constructed laws in ways that influence what design can and cannot do. The values of designers and design users and audiences are often not supported by the design economies that emerge from dangerously outdated political and economic structures and assumptions.

Neoclassical capitalism generates economies that reproduce extractive and polluting activities following the ecology-denying premises that these economic systems were built upon. These economic models also systemically devalue the labor of particular groups, starting with women's and racialized people's work and including other groups historically denied equal access to capital. The natural world is subject to a similar devaluation.[3] This dynamic creates increasingly fragile societies, economies, and ecosystems on various scales. The historic dismissal of the interdependence between the economic and the physical in economic theory and practice (Daly 1991; Jackson 2009; D'Alisa, Demaria, and Kallis 2014) has obscured the various ways economics directs design practice toward unsustainable ends (Boehnert 2018a, 38–48).

3 Note that "valuing" nature does not imply that ecological spaces and species should be brought into the capitalist economic system (Boehnert 2016, 2018b).

The development of sustainable ways of living depends on redirected design economies and reconstructed political economies to serve wider sets of interests.

Expanded, Regenerative, and Pluriversal Design

The focus on the political economy – and the political struggles associated with redirecting economic activity to address ecological crises – can make it seem as if individual designers have little power. But because design is a practice that plays a powerful role in reproducing the ways we live (by creating artefacts, services, and systems that enable our daily life), there is latent power in design that is not being utilized due to social norms being uncritically reproduced by designers. Priorities, values, frames of reference, and ontologies are embedded and reproduced by design as new world-shaping artifacts in ways that can reproduce or transform our ways of living and being (Escobar 2018; Willis 2006). With more widespread understanding of the world-creating capacities of design, more radical transformations become possible.

Designers already facilitate change with design strategies that influence human subjectivity and direct social relations in ways that impact the environment. Typically, designers reproduce the subjective grip of the dominant order. Normative design makes capitalism seductive. With the shape, look, and feel of a font, a brand, a product, a service, a building, etc., designers make new worlds to serve the interests of those with disposal income, i.e., "customers" or "users" – according to the logic and modes of governance generated by what is valued by economic structures and processes. Habitually, designers work to create ideas, items, services, and spaces that are appealing to future users according to capitalism's extractive logics, which reproduce and accelerate eco-social crises.

Ecologically responsible options will be generated by inspiring and establishing new priorities based on pluriversal knowledges, values, and practices. Pluriversality "refers to the human power to build worlds differently and envision different models for inhabiting the planet" (Leitão 2023, 17). Pluriversal design proposes "another design imagination, this time more radical and constructive [...] transition towards plural ways of making the world" (Escobar 2018, 7). It draws on traditions from the Global South with "relational creative practice focused on nurturing new models of life and reweaving our reality, not on destroying the old" (Leitão 2023, 17). Renata Leitão emphasizes the exclusionary premises and harms associated with the supposed universality of modernity (ibid.,

18) – and the need, in response, for "pluriversal worlding" to enable new types of future-making design practice.

Design researchers are already developing these strategies with collaborative, critical, systemic, and ecologically engaged mindsets, methods, and approaches. Sustainability theorists and design theorists have created a foundation for regenerative (Wahl 2016), redirected (Fry 2009), transition (Irwin, Tonkinwise, and Kossoff 2013), distributed (Raworth 2017), pluriversal (Escobar 2018; Leitão 2023), systemic (Sevaldson and Jones 2019), justice-oriented (Costanza-Chock 2020), and decolonizing (Tunstall 2023; Ansari 2021) design[4] primed to enable the creation of transitions and new ways of living. Effective responses to eco-social challenges depend on the ability of designers to reposition themselves in response to the complexity of converging eco-social problems and to re-orient design practice to support socially distributive and ecologically regenerative processes.

4 A partial list of emergent design practices with radical potential.

Conclusion

The Ecocene is a vision for design in response to Anthropocene planetary conditions. Feminist design ecologies in the Ecocene proposal support new capacities for sustainable transition based on expanded, redirected, redistributive, and regenerative design transitions. The trends described above are already happening around the world. This essay highlights these politicized movements and their relevance for design. The first premise commits to transdisciplinary collaboration. The second describes a contemporary design praxis emerging from critically engaged ecological thought. The third commits to intersectional feminist and antiracist practice. The fourth focuses on political economies of design, technology, and science with a redirection of incentives towards human and planetary health and well-being. The fifth describes how these premises can be combined within expanded pluriversal design.

These movements support adaptive responses to crises unfolding around the world. Whether appropriate responses will happen on a scale that will make mitigation and adaptation to climate change and other ecological crises possible depends, in part, on human abilities to design and enact massive change. As a practice that helps create the material conditions for everyday life with artifacts, services, and systems that enable future ways of living, design will play a role in the development of more sustainable and more equitable worlds. The emergence of ecological, relational, and situated ways of knowing, embedded in the Ecocene proposal, are a foundation for the redesign and co-creation of worlds anew.

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ESSAY

“Critical Standpoints that are Careful”: Anthropological Relocations for a Performative Study of Design

Michaela Büsse

This paper makes a plea for design practices and theories to situate themselves, historically and empirically, and attend to their material politics. It responds to recent works in the field which state that the discipline and practice of design are in crisis (Mareis and Paim 2021; Fry and Nocek 2020) and suggests unsettling abstraction in favor of specificity. Following María Puig de la Bellacasa’s concept of “critique as care” (2017), I suggest a reading of design that encompasses both extractive and alternate practices.

Keywords: Critical anthropology of design, material politics, critique as care

Design is in crisis mode, state design theorists Tony Fry and Adam Nocek (Fry and Nocek 2020) in their book with the same title, *Design in Crisis: New Worlds, Philosophies and Practices*. On the one hand, as a practice, design is faced with environmental, political, and social crises, which it tries to address via designated approaches, such as design for social innovation (Manzini 2015), transformation design (Jonas, Zerwas, and von Anshelm 2015), or transition design (Irwin, Kossoff, and Tonkinwise 2015). On the other hand, as they continue to argue, it is not so much a re-orientation of design as material practice that is at stake, but its ontological foundation – that is to say, the exploitation of people and the environment, as well as the flattening of histories and epistemologies into *one* hegemonic design paradigm. Accordingly, labeling design as eco-friendly or sustainable is only "window dressing" (Fry and Nocek 2020, 2); the core issue is that design, in its current state, is part and parcel of the problem. "(M)odern design is at the ontological root of the universalisms responsible for the asymmetrical forms of violence that human and non-human life are facing today and in the future" (Fry and Nocek 2020, 2). Design, Fry and Nocek assert, needs to redesign itself.

In a similar manner, design scholar Claudia Mareis and curator and activist Nina Paim propose that "design today struggles to confront this modernist and post-war heritage, which rests on colonialist and imperialist foundations" (Mareis and Paim 2021, 15). In the edited volume *Design Struggles: Intersecting Histories, Pedagogies, and Perspectives* they make a plea for design to become an intersectional practice, wary of essentializing or universalizing claims about the nature of design. In line with Fry and Nocek, they note: "Design cannot change anything before it changes itself" (Mareis and Paim 2021, 19). But what is design to begin with?

Design has been called many things. It is considered to be formative of both the human and the environment (Colomina and Wigley 2016; Fry 2012; Willis 2006), complicit with neoliberalism (Julier 2017) and colonialism (Schultz et al. 2018), yet transformative and re-directive (Fry 2012; Irwin, Kossoff, and Tonkinwise 2015; Jonas, Zerwas, and von Anshelm 2015; Yaneva 2017). While each definition sheds light on a particular aspect of design, it is their simultaneity that requires our attention. In this article, I suggest deferring any abstract definition of design and instead shifting the focus to its performative qualities. Because design, as a socio-material practice, is context-, place-, and time-specific. As such there is no singular definition of design – design is always already plural (Escobar 2018).

As design theorist Guy Julier has pointed out, every attempt at defining design is necessarily reductive and transports a particular worldview that requires scrutiny:

> Design is far too variegated in its practices, far too widely deployed and far too diverse in how it is understood and used for us to be able to express a singular definition for it. Instead, we have to take into account the different temporalities and territories that it operates in. We have to understand its various and, sometimes, conflicting purposes. We must recognise the many formats it appears in and the conjunctions of objects within these and between them. No object is an island. No one definition of design is enough. (Julier 2017, 2)

If the aforementioned authors call for a redesign of design, they are referring to a particular understanding of design as a systematic problem-solving and planning activity, not limited to crafting an object but capable of tackling any sort of problem at any scale (Simon 1968). But what if, instead of reasserting the universality of design as a burden to overcome through improved design, we were to attune ourselves to the actual material practices that constitute our built environment and continue to remake it on an everyday basis? What if, instead of starting from one dominant mode of design, we were to acknowledge its multiplicity, which encompasses extractive, transformative, and minoritarian practices alike? How could a situated analysis of material transformation complicate abstract definitions of design and destabilize unilateral power dynamics?

By engaging critique as a mode of care, science and technology studies scholar María Puig de la Bellacasa prompts us to pay attention to that which gets neglected when focusing only on oppressive dynamics (Puig de la Bellacasa 2017). Instead, and in the spirit of feminist thought, she encourages us to employ a speculative commitment to also imagining how things could be otherwise. A caring and careful engagement with our more-than-human surroundings, she argues, makes us aware not just of power imbalances but helps us rethink our own relationship with the world. Against the often-deconstructive tendencies of critique, that is, uncovering the pervasiveness of power relations, Bellacasa suggests adding more layers to reality, complicating the picture, and embracing the unruly edges we encounter. Such an active and additive mode of critique is not coercive but engages with the messiness of the world.

> A commitment to show how forms of domination affect the construction of things and lead to exclusions is not necessarily directed to the

> disarticulation of the world, or to the negation of the reality of matters of fact and the materiality of technologies, nor even to a reinstating of humanist questions at the center of more than human arrangements. Rather, it is a specific way to add to their reality, an urge to getting further involved with their material-semiotic becoming: the coming to matter and ongoing mattering of things. (Puig de la Bellacasa 2017, 61)

If we are to take seriously Bellacasa's call for care while relating it to Julier's observation that design evades any definition, it is necessary to recognize that the urgent call to redo design as expressed in *Design in Crisis* (Fry and Nocek 2020) and *Design Struggles* (Mareis and Paim 2021) cannot be confronted on a theoretical level. Rather, it requires "critical standpoints that are careful" (Puig de la Bellacasa 2017, 60) – a situated engagement with socio-material processes and a differentiated analysis that does not do away with power imbalances, yet does not let them define what is or *could be* either. Such a "critical study of design" (Suchman 2011) reflects on the constructedness of design methods, the context they exist within, and the relationships they articulate. It allows for a shift of focus away from the output of design and towards its material politics, offering a critique that is both careful and productive.[1]

Who designs, on whose behalf, and to what end? These questions are latent in many critical readings of design, along with the calls to redo design, but nonetheless seem to have become more urgent in recent years. It may not come as a surprise that this happens at a time when agency itself has become a contested concept. The material turn and its emphasis on the activity of matter challenge the intentionality of both form-making and meaning-making processes (Ingold 2013). Ultimately, considering the activity of matter or the agency of natural processes is not about generating flat ontologies that erase pre-existing power imbalances, nor is it about finding new ways to engage non-humans more actively in design processes. Rather, it is about the involvement of humans and non-humans with particular configurations, their specific inequalities, and therefore unique ways of restoring justice and building alliances (Papadopoulos 2010).

Disentangling the politics of material transformation therefore necessitates challenging apparently universal concepts, such as human, material, and design. Anthropologist Arturo Escobar, when stating the need for critical studies of design to be formed, posits that rethinking design is part of a bigger project of disentangling dominant modes of knowledge production:

1 The work of feminist science and technology studies scholar Lucy Suchman is instructive for how to read design against its context. As an embedded ethnographer at Xerox in California, Suchman participated not only in designing user-friendly technologies but in observing the hidden workings thereof, that is, their affordances and limitations, as well as the ideologies they are implicated with. Based on her multi-year research experience, she calls for design to attend to its specific (dis)articulations and acknowledges both its limits and potentials (Suchman 2011). See also Suchman 2007.

Not only is there still a dearth of critical analyses of the relation between design practice and capitalism, gender, race, development, and modernity, but the limits of Western social theory's ability to generate the questions, let alone answers, needed to face the unprecedented unraveling of modern and most other forms of human life on the planet at present are becoming patently clear. (Escobar 2018, 46)

In his comprehensive analysis of the field, he suggests that a closer engagement with "anthropology, development studies, political ecology, and feminist theory" might lead to an advancement of the discourse (Escobar 2018, 51). In fact, in the aftermath of his influential publication, research on the material politics of design (Keshavarz 2019) and decolonial directions within design (Schultz et al. 2018; Abdulla et al. 2019; Ansari 2020) have gained more visibility and urgency.[2] However, resource extraction and material transformation have not been the focus of these contributions.

2 Ahmed Ansari critically reflects on the popularity of decolonization discourses and practices in design. He points out how many so-called decolonizing designs are in fact a kind of supervised resistance in which designers facilitate participation by marginalized groups. For Western scholars to become engaged in decolonizing work, he argues, it requires "a careful attentiveness to one's own subject position" (Ahmed 2020).

Future research in, about, and with design needs to attend to the reciprocity of dominant forms and alternatives without essentializing social, material, economic, or political processes, but point towards their contingencies. The question then is not so much whether design is in crisis but what the notion of crisis does to design, practically and theoretically. Relocating design, both historically and empirically, shows how certain notions of design are bound with material and epistemological violence, and how they continue to proliferate, but also where openings occur that allow us to rethink how to frame design.

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Principles of a "Cosmoarchitecture"

Sénamé Koffi Agbodjinou

The traditional African house is the projection on the ground of complex social structures and systems of thought in the form of a renewed tangle of principles – remarkably ordered ones realizing a true "vernacular algorithm!" The fundamental ethic that this seems to support has been shaken up at the same time as the building by invasions and their systematic razing of particularisms and all devices allowing mobilization. But colonization was only the first movement of imperialism and the privileged ground for its prototyping; it thrives on the relay of industrial lobbies locked on the international style.
With the aim of restoring the vernacular, I have summarized those principles of organization that similarly structure the ancient installations and Black African communities into eight concepts. The cosmoarchitecture will be a new contract of kinship proceeding from an anthropocentrism not split from totality. Thus, it weaves with its environment. Foreshadowed by traditional society, cosmoarchitecture is a modality of the "World System" that opposes the "modern" civilizational approach to human installations. Ideally, cosmoarchitecture would thus engage, by its means, the concept of "living together" in its most contemporary acuity.

Keywords: Cosmoarchitecture, kinship, vernacular architecture, habitability, community

Man is insofar as he dwells.
— Martin Heidegger[1]

1 **“[L]’homme *est* pour autant qu’il *habite* […]” (Heidegger 1951, 173).**

It is customary in African societies to speak of the house as belonging also to those whom one has not yet met. In this way we speak of those to come. Is that not in fact the best definition to give to the concept of sustainability?

An Old Meaning of Sustainability

Let’s look at this approach to sustainability, which would see it as a kind of intergenerational contract according to which the actions we take today must not jeopardize the lives of subsequent generations. Following on from this, let’s attempt to isolate and examine in traditional architecture the interconnected seeds of a new ethics of sustainability whose potential may be to regenerate, starting from Africa, the contemporary debate around the challenges of living together and the habitability of our planet.

The idea of an exclusive right of use, the very notion of property, and any exacerbated sense of ownership are, as we know, remarkably muted in the African cognitive apparatus. Hence, in traditional societies, things are thought to belong vaguely to everyone – the house in particular, whose construction (with a good helping of millet beer) would often have mobilized the whole village.

If the time spent in a place of initiation can give to a whole year group the sense of belonging to the same community, the construction of a new house has the task – as do the numerous rites that punctuate our time on this planet – of reactivating and reinforcing this bond. The communal dimension of architecture is therefore the first proof of its sustainability.

If the African house, whose erection would have been initiated by the husband, is generally the responsibility of the woman, the doors must remain permanently open to all comers. The house, then, represents the principal node of a complex system: the interweaving of collective obligations and mutual responsibilities, which incidentally performs its relative permanence.

Thus, extraordinarily, the house crystallizes the very first performative system developed by humanity: man augmented… by man.

The Link as Technology

Indeed, the adding of man to man, the constitution for the sake of efficiency of groups, of the community, of the tribe required levels of sophistication that would never be achieved again. The social structure can be considered as the first known technology. Moreover, one can safely say that there is complexity in the social structure and only complexification at the source of all subsequent technologies: from rudimentary tools to the logics of auxiliaries right up to digital technologies.

The community approach to the construction site proves to be a fundamental quality of the building in Africa since it mobilizes a technology that will never be eroded by its use. In fact, the more one uses it, the stronger the social structure becomes. This is what distinguishes the link from all other forms of technology. Community is resistant to every kind of programmed obsolescence; it can be used as often as one wishes. An organic society implies a transversal community of the known and the unknown and an integral kinship that admits and even requires the non-human living world—but, above all, it is open to future generations. In this sense, the entire African world finds itself caught in an inclusive panoptics.

A Transversal and Intertwined Ethics

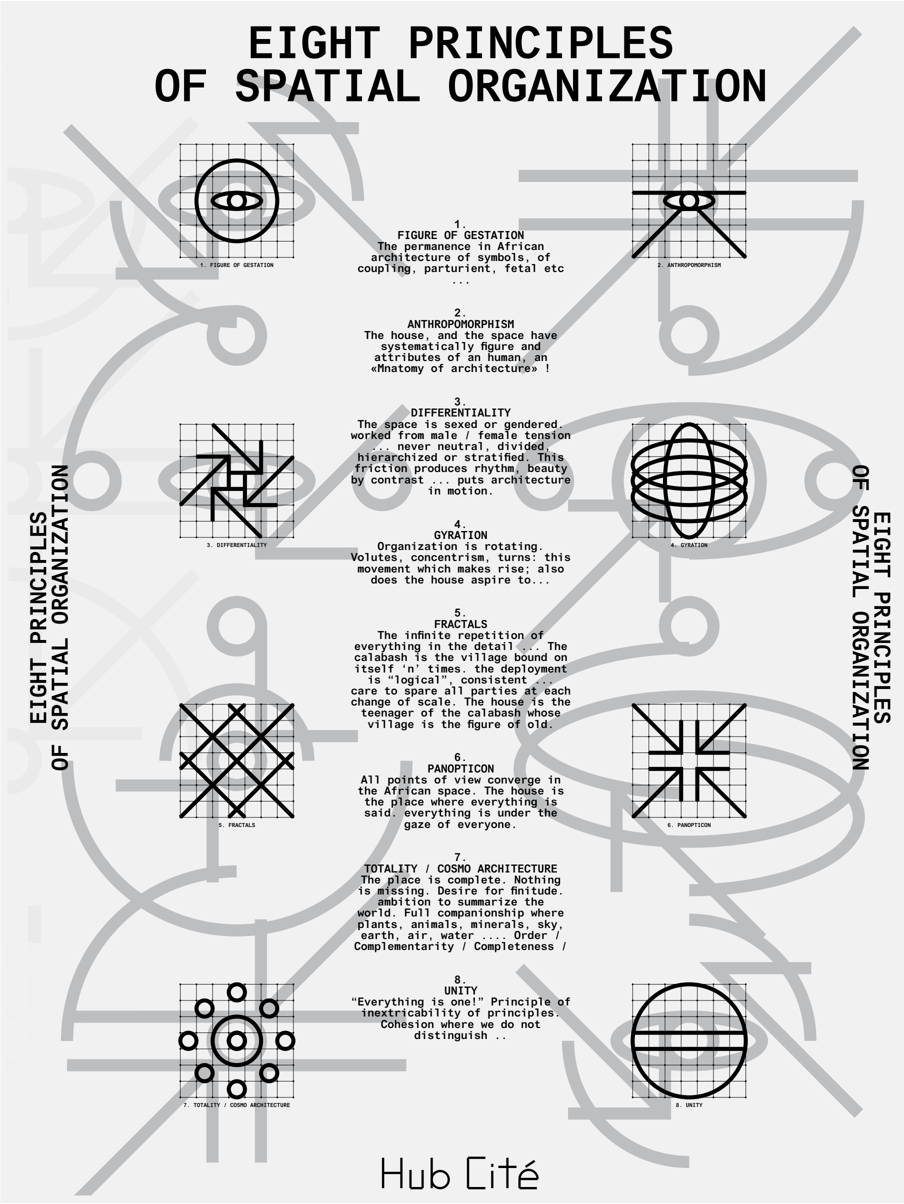
The original house is the projection onto the ground of these expanded social structures in the form of a renewed web of principles, whose purpose is to translate complex systems of thought. These principles, rigorously the same, remarkably ordered, give rise to what might be understood as a veritable vernacular algorithm!

Accordingly, we have been able to show that the traditional house and installation are rigorously structured by eight principles:

1. The permanence of figures of gestation;
2. the pedagogical anthropomorphism of the means;
3. a fundamental differentiality;
4. and 5. Movement and order in revolution and fractals;
6. accountability in panoptics;
7. and 8. the desire for totality and unity

Whether one is interested in the housing of the Batammariba of Togo and Benin, in that of the Dogon in Mali, or of the Kassena in Burkina Faso, this imbrication of the same preoccupations, combined differently in relation to e site, can be seen clearly and with perfect consistency—which seems to speak to their dependence. Indeed, the concepts are intimately

1 **Sénamé Koffi Agbodjinou, Eight Principles of Spatial Organization, symbols for the installation HubCités Africaines, developed by Manuel Bürger, ZKM Karlsruhe (DE), 2018.**



linked; they are reciprocal supports and means that mutually complement one another: intimacy and unity being ultimately the credo of earthen architecture.

Traditional architecture’s obsession with summarizing the world (the desire for totality), for example, is often sated by “figure and creation” (anthropomorphism); hence, the African house always has a human figure: as the most complete being in all creation, the human being illustrates the world. This synthesizing obsession is also evident in the multiplication of the figurations of “creation” (gestation), that is, in the permanence of motifs of the embryo, allusions to procreation, coupling, birth, etc.

The total architecture, having a human figure and soul, thus tends to indicate the status of the human being in the universe. The woman, being more completely “human” – to the extent that she holds the secret to life – eclipses the male. And here again it is necessary to extract the ecological dimension of this system of thought, which, while ordering space, wants it to be “woman.”

Among the Kassena, for example, as Jean-Paul Bourdier and Trinh T. Minh-ha (2011) point out, “the image of the house as a womb translates into the fetal forms of the dia-diyu (bedroom-kitchen) couple of the unity of the woman.” Figures of childbirth, embryonic forms (often in the form of figure of eight) are thus secretly introduced into the traditional ground plan. The status of the mother here, as in all traditional societies, is transcendent. This unity of bedroom-kitchen, which also hosts the labors and rites of childbirth, is canonical in West Africa.

The set of values that thus emerges in these reflections on vernacular architecture suggests a kind of meta-value in the African world that derives from the inextricability of the principles mobilized.

Above, briefly sketched, is an attempt to shed light on the elements of what might constitute an African “canon.” Nevertheless, it is still necessary to show how this might conceptualize a viable response to contemporary challenges.

A Return to Responsible Architecture

If we follow Heidegger’s point of view, then, rather than Le Corbusier’s “A house is a machine for living in,” the traditional African house becomes a machine to learn to inhabit. It conceptualizes more than it models “responsible habitation.”

A correspondence can be established between the principles presented above and the challenges of our times: gestation = sustainability; anthropomorphism = responsibility; differentiality

= equality; gyration = balance; the fractal = democracy; panoptics = solidarity; totality = inclusion; unity = cohesion.

Following the ideal of intertwinement, sustainability could participate – as in the African spirit – along with "responsibility," "equality," "balance," "democracy," "solidarity," "inclusion" and "cohesion," in a single movement, of which habitation would be the modality. In 2005 we proposed a system with this specific aim: an eight-part grid that enables us to envisage the horizon of a modern cosmoarchitecture.

A cosmoarchitecture is an architecture that claims to be "world" – that is, together, an ethics and politics of taking care by way of the same gesture of building and inhabiting it prescribes: the communality of the living, the different scales, the unity of the spectrum, and balance. Cosmoarchitecture thus sets out to establish a new contract of kinship proceeding from an anthropocentrism that is not split from the totality. It is also closely tied up with its environment. The entire living world is sheltered there. From one side to the other, it is traversed by the idea of a solidarity extending beyond generations, and by the idea that actions taken today must leave room for the future... It does not introduce a rupture in the habitation of the world – not even that, in modernity, of existence (in the sense of our time here on Earth) with the mother's breast and the grave. In a sense, it invites a more general and fundamental consideration of habitation: a way of being in the world that largely exceeds the domain of housing while remaining aware that the conditions of the latter's installation and functional logic prefigure it. Moreover, building is from the outset caught in a complex set of relations and responsibilities that, in order in places to become alternately tied and untied, often mobilizes ritual. Prefigured by traditional society, cosmoarchitecture is a modality of the "system of the world," which is opposed to the "modern" civilizational approach to human installations.

Hence, with its own means, cosmoarchitecture would ideally be a response to the "living together" in its most acute contemporary form. There would necessarily be a relation between its ethics and the material.

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Technoscientific Trajectories

ESSAY

Mammoths and Reindeer: Speculative Design Imaginaries and Technoscientific Care in the Arctic

Martin Müller and Emilia Tikka

The future of the Arctic is highly contested. How to care for its fragile ecosystems suffering from escalating climate crisis, extinction of species, and vanishing of cultures? This article discusses and contrasts two cases of design-driven technoscientific speculations on Arctic futures. The first part of the article addresses and problematizes contemporary synthetic biology, where design is understood as engineering: to protect Arctic ecosystems, the mammoth and other extinct species are to be “resurrected” with genome editing. The second part introduces an Arctic design collaboration situated in a reindeer herding culture in the Finnish Sápmi. The project aims to counter the hegemonic technocratic imaginaries, where nature is seen as inert matter for human design: alternative technoscience futures are materialized as other stories where the *living relation* to the land and reindeer is central.

Keywords: Arctic futures, synthetic biology, technoscientific care in the Anthropocene, speculative design, human–nature–technology relations

In the discourse of the escalating climate crisis, the Arctic region has received special attention. Global warming is occurring here four times as fast as the global average (Rantanen et al. 2022). Not only the Arctic glaciers are melting; nature, biological life, and ancient cultures and practices are in the process of dissolving at an alarming rate. Here, what the rest of the world will be threatened with is already becoming visible: the eschatology of the Anthropocene. Thus, the Arctic becomes the site of technoscientific action for climate rescue approaches and struggles over interpretation about what to do in the imminent crisis (Müller 2023, N4). Our article will contrast two projects that deal with the same question: How to care for Arctic futures? What kind of role can design play in this endeavor?

One predominant answer leads into the field of synthetic biology, where design is understood as the engineering of living entities. The first part of our article will discuss a project of "radical design" (Smith et al. 2020) in times of ecological mass extinction: the so-called resurrection biology of the woolly mammoth. In this case particularly, care appears to be a rather hylomorphic relation of active form-giving (bioengineering) and passive form-receiving (nature). Biotechnological making and designing is, for the most part, an expression of classical engineering in modernity, set in motion in the 19th century and increasingly advanced ever since – as the production, manipulation, and control of "natural things" (Schäffner 2022, 186). Synthetic biology denotes human domination over nature, which must bend to the will of the engineer. Care (and design) appears here as an anthropomorphic, universalist and teleological dispositive of a technological fix, in which the preconceived idea of the engineering object is implemented into the artifact and material worlds. The ecological crisis, brought about by the technical-industrial culture of modernity, is to be combated using even more technology. The promethean program is obvious: mastery of nature from atom to atmosphere (Müller 2022, 164–168).

The second part of the article introduces a different ontological approach to technoscientific care in the Arctic, aiming to move beyond the tragic dichotomy of pristine nature and technocratic progress. It focuses on a case study that is situated within the realm of vanishing reindeer herding cultures in the Finnish Arctic, where technological applications are rapidly replacing ancestral nomadic practices. It shows how speculative design is used to collaboratively explore technoscientific futures based on alternative ontologies of care and nature. The project fosters a contrasting position to synthetic biology's hylomorphic approach to design. In the reindeer worlds, the land and the animals are not perceived as inert or passive *res extensa*, but as interdependent and living. Films and objects are part of the process of co-speculating and imagining alternative concepts of belonging, which draw from the idea of the *living relation* to the land and latest research on epigenetics. This fusion of knowledge systems and ontologies marks the possibility of different kinds of futures in the Arctic.

De-extinction

In the Arctic, anthropogenic climate warming can be observed at a breathtaking rate. Besides the eroding glaciers, the permafrost soils are losing their millennia-old layer of ice. Christian Frei's documentary *Genesis 2.0* (2018) shows not only the novel landscapes that are emerging, but also the traffic and business that is now starting in the Anthropocene Arctic. In the milder cold, its inhabitants traverse the swampy landscapes, navigate their boats on newly formed lakes, climb and dig into crevices that are now open. In Frei's portrayal, men in camouflage gear are searching for and sometimes finding the bones of long-extinct animals. The human-sized teeth of a mammoth are being transported away on snowmobiles. This new extractivism breaks with an old tradition: "To many Siberian indigenous groups, the mammoth is a sacred beast and mustn't be disturbed – to do so could mean death" (Wrigley 2020). The buyers of these remains from the last Ice Age are not only museums and collectors. Among the most important customers are the departments of biological engineering. The phrase new "white gold" is equally applicable to the Arctic tusk diggers and the global bioeconomy.

Synthetic biology has chosen a thoroughly mythopoetic genre in which almost unrestricted feasibility and thinking of all-constructibility is embodied: in Cambridge, Massachusetts – and in other labs around the world – scientists are working on the "resurrection" of the woolly mammoth. "George Church's lab at Harvard University's Wyss Institute reported their first successes in editing living elephant cells so that they contain gene sequences from the elephant's recently extinct relative, the woolly mammoth." As evolutionary biologist Beth Shapiro writes in the December issue of the prestigious journal Genome Biology, "Using CRISPR [...], Church's team replaced 14 loci in the elephant genome with the mammoth version of those sequences" (Shapiro 2015, 1). Previously, the mostly intact DNA of the Ice Age animal had been found in the Arctic. In comparison with its genome data, the genetic material of an elephant is to be processed in such a way that, after artificial insemination, a mammoth embryo produced from it can be carried by an elephant cow – a distant relative of *Mammuthus primigenius*, which has been extinct for thousands of years. The goal of the project, made possible by the methods of synthetic biology, is a merely climatological affair: the plan is to bring the majestic woolly mammoths, should the experiment succeed, from the Harvard laboratories to the North Pole, where they will then circle in their hundreds to protect the endangered Arctic ecosystem. A program whose motivation is described as follows:

> [C]limate change, much of it driven by anthropogenic factors, is reshaping the distribution of habitats too quickly to allow species to adapt to the changes. As populations decline, species are increasingly threatened by secondary drivers of extinction, including disease and inbreeding. Genome engineering enables the reintroduction of lost genetic diversity, or the introduction of traits that evolved in related species, into species that are struggling to survive. (ibid., 2)

Despite, or perhaps because of, its vague program, resurrection biology and its figurations of necrofauna have attracted considerable interest, not only from the popular press, but also in the field of environmental ethics. The woolly mammoth is not the only animal in the de-extinction program: also of note would be the migratory pigeon (*Ectopistes migratorius*), the Australian dodo (*Raphus cucullatus*), the Pyrenean ibex (*Capra pyrenaica pyrenaica*), and the southern stomach-breeding frog (*Rheobatrachus silus Liem*). In 2013, the so-called Lazarus Project was established at the University of New South Wales in Australia, where de-extinction has progressed the furthest. There, they had accomplished what was the next step for the mammoth. The research team had enucleated the eggs of a related frog species and infused the nuclei from the frozen tissue cells of the gastric hatchery frogs into the "empty" eggs. Embryos of the extinct species grew; however, they survived only a few days. Nevertheless, this was regarded as an engineering proof of principle, according to which the approach of resurrection biology was technically possible and quite promising (Preston 2018, 81–104).

In her critical analysis, historian of science Sophia Roosth has rightly argued that, especially regarding the woolly mammoth project, these are mythopoetic fantasies built on an aporia: for an eventual "making" of "wholly synthetic creatures that will stand-in counterintuitively as resemblances of untouched nature, a latter-day garden of Eden seemingly unsullied by human hands, albeit generated by the most recent bioengineering technologies" (Roosth 2017, 170). We share this assessment and criticism, because bioengineers want to turn nature back into a pristine and untouched state, which *de facto* never existed. The means for this are supposed to be those computer-designed beings that are as similar as possible to the primordial animals. These beings are then supposed to protect an environment in which they never lived. Precisely for this reason or despite it, the projects of the "resurrection of extinct species" are to be seen as "fantasies of ultimate biological control" (ibid.) with the means of engineering and design.

Universal Constructors

Synthetic biology's concept of design is fundamentally based on an explicit understanding of the genome's textual form and molecular performativity. As George Church and Edward Regis write, "[B]iological organisms could be viewed as a kind of high technology, as nature's own versatile engines of creation" (Church and Regis 2012, 4). In this technoscientific narrative, DNA-based life appears as an aeonian, non-human technology and is described as a billion-year-old machine of creation. The conceptual figuration of life as high technology advances thereby to the core of a design theory of synthetic biology. The technoscientific notion of the genome becomes obvious when the idea of genetic programmability comes into play: "Just as computers were universal machines in the sense that given the appropriate programming they could simulate the activities of any other machine, so biological organisms approached the condition of being universal constructors in the sense that with appropriate changes to their genetic programming, they could be made to produce practically any imaginable artifact" (ibid., 49). Church and Regis declare an organism's genome to be a universal production technology, whose material output is controlled by an inherent genetic program: "A living organism, after all, was a ready-made, prefabricated production system that, like a computer, was governed by a program, its genome" (ibid., 50). Design of genomes starts with code engineering. In the grand narrative of biological engineering, life no longer appears as a limited resource but rather as a medium of production for the unmitigated materialization of human projects. Church's discourse is by no means limited to the realm of technological imagination. Instead, under his direction concrete engineering practices are being developed for the purposes of "radical redesign." In April 2019 his team presented a new CRISPR process that can perform more than 13,000 programming actions at once in a single cell. Today, this Blumenbergian "readability of the world" is followed by the attempt at a biotechnical "writability and programmability of nature" as a consequent application of genome editing, which now appears more and more clearly as the master discourse. In the words of the co-inventor of CRISPR, Jennifer Doudna:

> Using powerful biotechnology tools to tinker with DNA inside living cells, scientists can now manipulate and rationally modify the genetic code that defines every species on the planet [...] As long as the genetic code for a particular trait is known, scientists can use CRISPR to insert, edit, or delete the associated gene in virtually any living plant's or animal's genome. [...] Practically overnight, we have found ourselves on the cusp of a new age in genetic engineering and biological mastery [...]. (Doudna and Sternberg 2017, xiii)

This asymmetrical human–nature relationship of design-invasive ecomodernism is evident in the long list of contemporary projects of genome editing such as plant design, germline editing, etc. This hylo- and anthropomorphic world-making after the "end of Holocene nature" can be further problematized in the following example.

Ecological Machines and the Total Industrialization of Nature

The artist and designer Alexandra Daisy Ginsberg has done speculative design on synthetic biology. She has brought the visions of the synthetic biologists into the visual image and ontological articulation through the means of speculative design: *Mobile Bioremediation Unit*, *Autonomous Seed Disperser* and *Self-Inflating Antipathogenic Membrane Pump* – these are the names of the speculative life forms in her multimedia artwork, which combines and, as it were, embodies the subjects of ecological crisis and biotechnological futures. As a pivotal work at the intersection of Bioart and speculative design, it is entitled *Designing for the Sixth Extinction* (2015). The formula of the sixth extinction of species is not speculative, but owes much to prosaic empiricism, according to which the extinction of species and the heating of the Earth's climate are reciprocally dependent: at this point in time, more than one million of the planet's approximately eight million species are on the brink of immediate extinction. The warming of the climate caused by humans is fueling mass extinction, and the extinction itself is in turn accelerating the collapse of more and more ecosystems, which can no longer regenerate without the contribution of the extinct species. "The average abundance of native species in most major land-based habitats has fallen by at least 20%, mostly since 1900," a recent UN report on the subject concludes, "More than 40% of amphibian species, almost 33% of reef-forming corals and more than a third of all marine mammals are threatened. The picture is less clear for insect species, but available evidence

1 Detox for soils and trees, while other biotechnical "helpers" spread the seeds in the forest. Image shows a "Self-Inflating Antipathogenic Membrane Pump" from the work *Designing for the Sixth Extinction* (2015) by Alexandra Daisy Ginsberg.

supports a tentative estimate of 10% being threatened" (United Nations 2019). On the other hand, the number of people has more than doubled since the 1970s, rising from 3.7 to 8 billion. Against this backdrop, the question arises: How many planets have enough resources to support the nine billion people projected to live on Earth by 2050? In this "accumulation of the present" (Horn 2018), the images of a doomed world, which circulate in daily reporting as apocalyptic, are emerging. It is becoming increasingly difficult to distinguish between actual events and probable scenarios: the Gulf Stream is drying up, Arctic glaciers are about to melt completely, soon large parts of Southeast Asia and Oceania could become uninhabitable due to scorching heat and rising water levels. There is even talk of a possible reversal of the poles.

In view of these thoroughly eschatological discourses of a dying and eroding nature in the Anthropocene, Ginsberg brings the speculative element of design into play: where the natural species have disappeared, where nature can no longer regulate and regenerate itself, that is where man-made, synthetic species take up their work: “In this version of the future,” the British artist explains, “novel companion species are designed by synthetic biologists to support endangered natural species and ecosystems” (Ginsberg 2015). Designed in the lab and with the tools of bioinformatics, then produced in large numbers, they are released into the dying ecosystems. There they function as actors in an Anthropocene future, in which the consequences of the anthropogenic climate catastrophe, with these very anthropogenic “ecological machines” (ibid.), are to be kept in check. Yet the idea of these machines has a thoroughly early modern sound to it. It is almost reminiscent of the mechanistic visions of Bacon or Descartes. The machines of the future do nothing but filter, clean and pump in the ruins of the natural world (Bacon 1626).

In this speculation, the possible ecological machines appear as eschatological machines that only form the soft surface of a much harder engineering logic. Ginsberg touches on this “hard core” in an explanation of her own work. The question she poses there can be understood as the central vanishing point of a theory of the present that we would like to develop in this contribution: “If nature is totally industrialized for the benefit of society – which for some is the logical endpoint of synthetic biology – will nature still exist for us to save?” (ibid.). The total industrialization of nature is indeed the logical endpoint of engineering biology, pushing the opaque idea of “repairing” the damaged planet almost into the unthinkable (Müller 2023b, 185–200).

Practices of Care in the Reindeer Worlds: *Living Relations*
Following the critique of Arctic care projects based on molecular engineering of the living, we argue for a need to imagine different kinds of technoscience futures. What ultimately should be re-imagined is the underlying human–nature–technology relation, where nature appears as inert matter and *res extensa,* waiting to be appropriated and redesigned by technology and engineering. This chapter introduces an example of how human–nature–technology relationships are renegotiated collaboratively through an alternative approach to care. After the problematization of the described synthetic biology project in the Arctic, the woolly mammoth, the following paragraphs develop an alternative position through discussion of a speculative design and film project entitled *Mnemonia.* Here the artwork serves as a kind of contrasting foil to the engineering-driven care concepts of the synthetic biologists and creates a collaborative approach of designing with care through reindeer ontologies. The

collaboration project took place during 2020–2022 between one of the authors of this article, the designer and researcher Emilia Tikka, and a reindeer herder, Oula A. Valkeapää, and his artist-researcher partner Leena Valkeapää. The collaborative artwork is situated in the most north-western part of Finland, in the area of Sápmi, where Valkeapää is following his family's ancestral tradition of reindeer herding based on nomadism.

Technoscience is an imminent part of contemporary herding in this area. Ancient practices and ontologies exist simultaneously with drones, snowmobiles, and GPS tracking. In these worlds, where in many ways "multiple natures" are intertwined, binary divisions between "pristine" or "modern" are not useful to make. However these technologies are not developed from the cosmological perspectives of nomadic herding, and therefore they ontologically shift the practice. For example walking or skiing *in* the landscape creates a different awareness of it, as when moving fast *through* it with snowmobiles. In this way the technoscience ontologically "redesigns" (Willis 2006) the practices and ways of being in reindeer worlds.

The nomadic practice of reindeer herding is on the verge of vanishing in Sápmi in the Finnish Arctic. Some of the complex reasons include climate warming, but also politics of borders and infrastructure development projects. In the ancient nomadic reindeer herding cultures, humans migrate by following the seasonal rhythm of reindeer. The distances between pastures are often hundreds of kilometers. Migration is seen as "nature's way" to maintain balance in ecosystems regarding resources. When a herd of thousands of reindeer is grazing, the balance comes from changing pastures between seasons, giving the land an opportunity to rest and regenerate. However, this has been made difficult for the herders in Finland, where the fenced herding areas are not following the natural migration rhythm of the reindeer (Reinert et al. 2009). Some recent studies suggest that reindeer grazing would actually hinder climate warming (Beer et al. 2020). Furthermore, migrating with reindeer has a deeper dimension of cultural and social meaning to the herders. Sámi author Johan Turi has compared reindeer to migrating birds (Turi 1979, 73). Science and technology studies scholar Marianne Mäkelin interprets Turi: "For the birds, home is in this circular leaving and returning. A migrating bird does not belong to a place but to the movement that follows seasonal variations" (Mäkelin 2022, 12). Migrating does not only bind humans to the seasonal rhythms of reindeer, ecosystems and landscapes, but is also the actual home of the herders. "Home" for them is not about living in one place, one building, but rather dwelling *in* the landscape.

Care in human worlds is often understood as a physically close activity of *taking care* of someone, as a human takes care of their child or cattle by feeding them. Care in nomadic reindeer herding cultures means something rather different (Reinert 2014). It firstly means to foster the animal's freedom to migrate according to their seasonal rhythm and secondly to respect their ability to fend for themselves in order to survive without becoming too dependent on humans. Environmental humanities scholar Hugo Reinert writes about how care manifests within Norwegian Sámi reindeer herding communities: "Distance was managed here, and cultured, as an element of moral obligation toward certain nonhuman others: in other words, as an attribute of moral responsibility, and as a practice of care in itself" (ibid., 52). In this practice, care is different from domestication and making the animal fully dependent on the humans. Instead, care means to cultivate interdependency. This is because by losing their ability to find food from nature, the animals would lose their agency and therefore become more separate from the ecosystem. Also, Maria Puig de la Bellacasa argues similarly: "Care is not about fusion; it can be about the right distance" (Puig de la Bellacasa 2017, 5). The underlying concept of care here is based on perceiving the animals themselves and the human relation to them with agency. This relation between humans and reindeer is part of the tacit knowing in reindeer worlds and we call it here *living relation*. This term is a translation of a word that Oula A. Valkeapää and Leena Valkeapää have used in their dialogues on human–reindeer relations with Tikka. The *living relation* itself constitutes the flourishing of the ecosystem. It is based on an exchange, a symmetric relation between humans, reindeer, and land. Letting the reindeer follow their natural migration rhythm, and being part of it as humans, is the core of keeping this relationship alive. Therefore, it is the dwelling in the landscape, following the ancestral paths and continuing the practices, that ultimately binds the humans in the *web of life* (Haraway 2016, 216). When migrating with the seasonal rhythm of the reindeer becomes impossible, the *living* ancestral relation to the land and reindeer vanishes.

***Mnemonia*, Stories of Hope in the Ruins**

This fading *living relation* between reindeer herder, the reindeer and land is the focus of the artwork *Mnemonia*. The aim was to co-speculate alternative technoscience worlds and futures through the reindeer ontologies of care and the *living relation*. The work is a result of a dialogue-through-making between the partners, in which speculation functioned as a mode where different ways of knowing and cosmo-ontological positions were equally valued as factual (Meskus and Tikka 2022). The installation includes three parts: two short films and a set of speculative objects. The first part is a film called *Bottažat* (Sámi for Short Moments), directed and shot by Oula A. Valkeapää. It was important for the partners that the work started with a story of the contemporary reindeer worlds, told and "seen" by Valkeapää. He was filming the material with a GoPro camera when he was living with his herd during the summer of 2021. The autobiographical story takes place in contemporary reindeer herding practice, where technological change is visible as motorized vehicles and the use of drones. However, the practical rituals of making fire, setting up the lávvu (temporary dwelling) and living in the landscape are ways of keeping the traces of the nomadic past alive. These are the cultural techniques that connect the herder to the *reindeer time* and to the living worlds of the landscape. As long as these rituals are continued, the *living relation* between the species is alive. The end of the film shows haunting images of a summer home of the Valkeapää's family that now lies beyond borders in the area where migrating is no longer possible. The film is a kind of a swansong to the deep ancestral connection between humans, reindeer, and landscape, slowly fading away when the ancestral nomadic practice becomes impossible.

The second part is a film called *Lauman Muistot* (Finnish for Memories of the Herd), directed by Tikka and written with Oula A. Valkeapää. This is a collaborative storytelling, where different ontological positions are present simultaneously. The story, in the form of magical realism, takes place in the year 2102. As a result of an escalation of global warming the Gulf Stream has collapsed (Boers 2021). The movie starts at a post-apocalyptic beach by the Arctic Ocean, where snow falls for the first time after decades without winter. In this world, nomadic reindeer herding has faded away. The film tells a story of a bioscientist, who has traveled from afar to find traces of her ancestors. She spends years wandering alone in the landscape, looking for material traces of the nomadic past. The story takes a new turn when she finds a deceased reindeer that carries the epigenetic memories of her ancestors in its bones. The film is a story of hope in the ruins (Tsing et al. 2017), where the toxic soils and the bones of deceased reindeer still carry epigenetic memories of past migrations. "Landscapes, as well as the bodies dwelling in them, carry signs of what has been. These can often be felt only indirectly, as eerie presences or absences, as traces [...]. Or, as ways of inhabiting landscapes and temporalities that become possible

2 A screenshot from *Bottažat*. (image credit by Oula A. Valkeapää 2022)

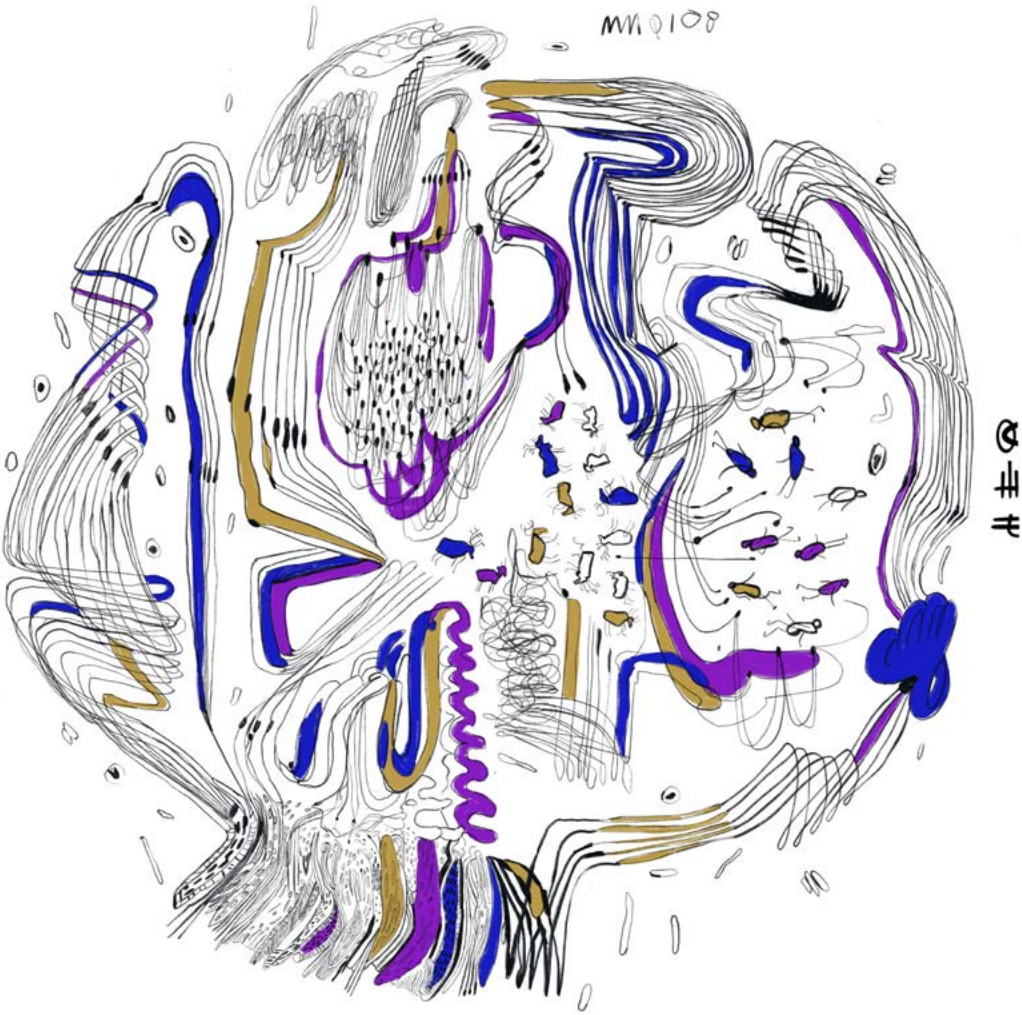
3 A screenshot from *Memories of the Herd* (photo credit Emilia Tikka 2022)

or impossible with the changing world" (Mäkelin 2022, 12). The memories here are not meant as subjective images of past events stored in the synapses of the human brain – rather, they are understood as embodied traces of the living worlds, which can be enfolded and re-remembered with the right sensitivities and practices.

Genes connect human bodies to past generations through the transmission of DNA. This has been the central grand narrative of heredity in Western science. Yet, epigenetics proposes another perspective, making the questions of genetic heredity messier, reaching beyond human bodies. Epigenetics is the study of heritable changes in expression of genes that are not caused by changes in DNA (Gibney and Nolan 2010). New studies in biosciences suggest that lived embodied experiences such as traumas or hunger can be inherited transgenerationally through epigenetics (Painter et al. 2008). Some scientists suggest that epigenetic particles may even move between bodies of different species (Chen and Rechavi 2022). How this process of transmission takes place is still unclear, but evidence suggests that bodies are porous and alternative ways of bioscientific belonging may be plausible. In *Mnemonia* new bioscientific relations are imagined through a lens of reindeer ontologies. The tacit knowledge of the *living relation* between humans, reindeer and the land is taken as being as much of a fact as the latest bioscience research. In this way the stories don't separate the tacit and bioscientific knowledge, but rather aim to weave them into new narratives of interspecies ancestry and sharing of embodied memories.

The third part of *Mnemonia* carries the story deeper into the future, in the year 2152, when nomadic reindeer herding cultures flourish. The newly established *living relation* between toxic landscapes, rewilded reindeer and herders leads to new kinds of nomadic cultures and technoscientific futures. The objects of *Designs for Nomadic Futures* are everyday items of a speculative culture where technological development is following the reindeer seasonal migration rhythm. One of the speculative design objects, a circular *Book of Mnemonic Biosciences,* tells the imaginary history of a new kind of bioscience that recognizes the ancestral connection between species. The drawing of a *Post-Genetic Family Tree* illustrates the ancestral connections between humans, reindeer, and the land. The *Biometric Visitor Visa* refers to an alternative border system that now allows humans and animals with the *living relation* to the landscape to migrate freely. These objects do not only embody a hopeful future for the vanishing nomadic culture, but they also materialize a society where technological

4 A page from the circular *Book of Mnemonic Biosciences*, illustrating *Post-Genetic Interspecies Family Tree* (image credit Emilia Tikka 2022)



development is based on ontologies and ethics of care of the reindeer worlds.

The Possibility of Other Worlds

One cannot accuse synthetic biologists of not being interested in ecological issues. On the contrary, they promise to take care of ecological problems with technological means, with "radical design." They invent, imagine, and project ecological futures. However, the idea of living beings as instruments becomes a thoroughly problematic matter. The worldmaking strategy of synthetic biology with regard to the extinct mammoth is speculative design in the true sense. However, the speculation is based on a precarious nature ontology. Synthetic biology's understanding of materials and nature culminates in Oron Catts and Ionat Zurr's ironic statement: "[L]ife is becoming bio-matter, waiting to be engineered" (Catts and Zurr 2017). This approach separates subject and engineering practices on the one hand and between a passivated and quasi-inert nature on the other. It is not surprising that this separation determines the design process, as ideal human imagination is inscribed in the passive material nature. (For a critical perspective: Petruschat 2022, 80–84; Schäffner in this volume.) Behind the spectacular promises and projects stands a thus antiquated concept of making. Here the promise of synthetic biology as an ecological take on care is failing due to the carelessness of design ontological questions: of the domination of form over material – as a classic hylomorphism of 19th century engineering. It is the outmoded conception of a thoroughly mythopoeic hylomorphism: as a separation of (metaphysical) form and (passive) substance. In antiquity, according to the well-known image from Aristotle's Metaphysics, the sculptor recognized the idea of the figure, which was already laid out in the marble. In the now dawning Anthropocene, the genome becomes a kind of quarry for the techno-scientific figures and natures of an "evolution from human hands." But can Homo faber be affirmed as Homo creator without further ado? One notices an ethos of *tabula rasa* and all-constructability that wants to build concrete bridges and redesign genomes (Müller 2019). The *will to engineer* aims at nothing less than the total industrialization of nature. In this narrative, living beings are smart machines, only tools, perhaps, that are the basis for the production of more machines for dying worlds. Daisy Ginsberg's scenes and scenarios are without people, yet they show the universal division of labor between engineers and soft machines, between master and servant. Donna Haraway criticized the universalist "view from nowhere" of modern science as "the god trick" (Haraway 1988, 581). Arguably, an "engineering from nowhere" applies to contemporary synthetic biology. But for whom are these worlds made – who, or what, is supposed to inhabit them?

The Arctic care in *Mnemonia* is imagined with and designed for real people whose ancestors have lived and survived in the Arctic for centuries. However, they are not representatives of pristine nature–culture relations. Even if reindeer ontologies and worldviews can be distinguished from the scientific worldview of Western modernity, both have been shaped by technology and technoscience. Whereas the mammoth project promises the return of a "pristine" nature, *Mnemonia* stems from the ongoing collision of modern technology and ancient *living relations* to the more-than-human worlds. It does not repeat the master discourse of a technological fix, but it makes visible the open process of a permanent negotiation of an always fragile relationship between culture and nature, humans and animals, technology and traditions – between ancient pasts and possible futures.

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ESSAY

Biocompatible Radiations: Designing for the Living

Emile De Visscher

What role can designers play in the production of new technologies in interdisciplinary scientific contexts? What makes them distinctive? This article outlines a research project that combines experimental surgery, nuclear physics and design, with the ultimate aim of finding ways to produce microvascular networks. Such geometries are present in numerous biological systems, and their production is key to the support and remediation of many life forms. By detailing this project, the following article highlights a possible role of design: to bring the traditions and logics of different disciplines into dialogue, and ultimately to fragment the ineluctability of present-day scenarios by imagining alternative technological futures.

Keywords: Design research, bio-design, electron irradiation, design anthropology

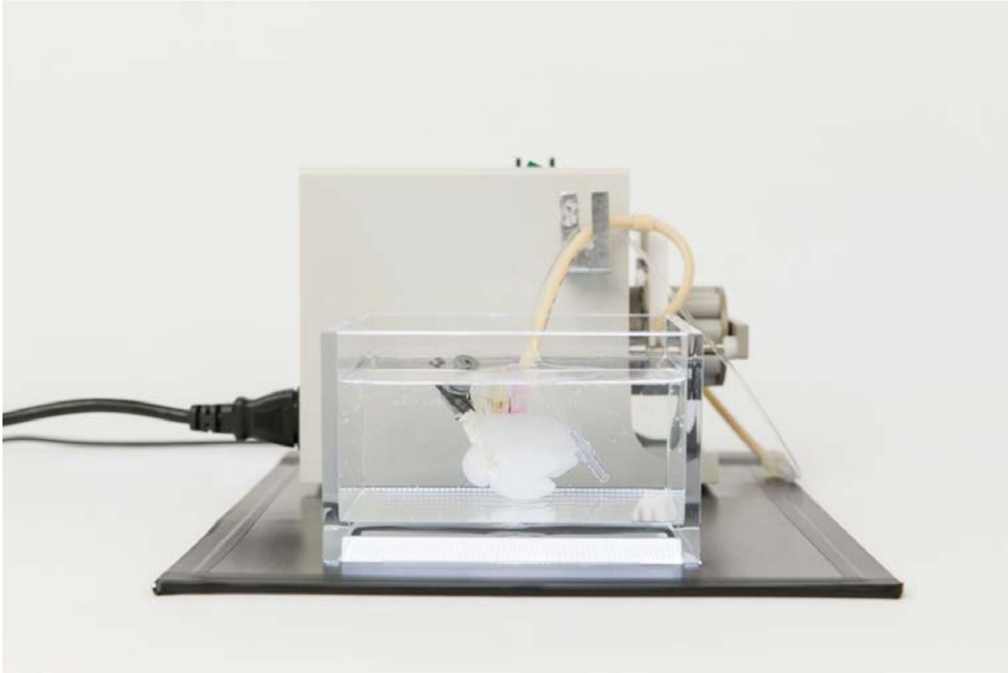
As designers, the entanglements of our field with the current ecological crisis and obsessive consumerism raise the following central question: Why still design and produce functional objects, which will always imply extracting materials, using energy, and creating garbage? How can we approach our profession so that it supports ecological cycles, biodiversity and life forms rather than destroying them eventually? “Bio-design” has been for nearly 20 years now an answer to this question, as it advocates for the use of biomaterials and bio-organisms rather than passive and energy-intensive plastics, metals, or ceramics. It explores logics of growth and care instead of extraction and control. Nevertheless, many of the projects encountered in the “bio-design” movement are showing another kind of exploitation. Whether it is new packaging based on bacterial cellulose, insulation made of stabilized mycelia, or clothing built by microbes, the use (and killing) of bio-organisms for human needs still exhibits an exploitation with problematic ethical implications.

This article accounts for a quest to see how one could literally *design for life* rather than *design with life* — trying to unveil strategies for creating conditions for the living and eventually to explore what a “design for non-humans” could be. To do so, my first step was to team up with the profession that is most involved in *keeping things alive*: surgery. From this collaboration, I understood that many vital biological entities rely on specific geometrical typologies, one being the microvascular structure. Finally, I found a way to reproduce these biological forms with a technology coming from a totally different environment: electron irradiation. The result is a project that is truly “monstrous,” in the sense that it combines knowledge, machines and experiences from surgery, nuclear research, craft and design to produce architectures for the proliferation of living organisms. This research provides some possible responses regarding how designers position themselves in a research framework — and how they can facilitate exchanges between actors and techniques that surround them to open alternative technological futures.

The Story of Organs

When I met Igor Sauer, surgeon and director of the Experimental Surgery Lab at Charité Hospital in Berlin, I was seduced by the sense of necessity and urgency his profession was dealing with. Doing research in a hospital means immediately being confronted with situations of deep need, as eventually, a surgeon’s objective is to *keep things alive*, in the most concrete sense. At the same time, experimenting with the living and exploring how the body can be improved and saved from

1 De-cellularization of a rat liver, Experimental Surgery Lab, Charité Hospital (Source: Michelle Mantel, 2019)

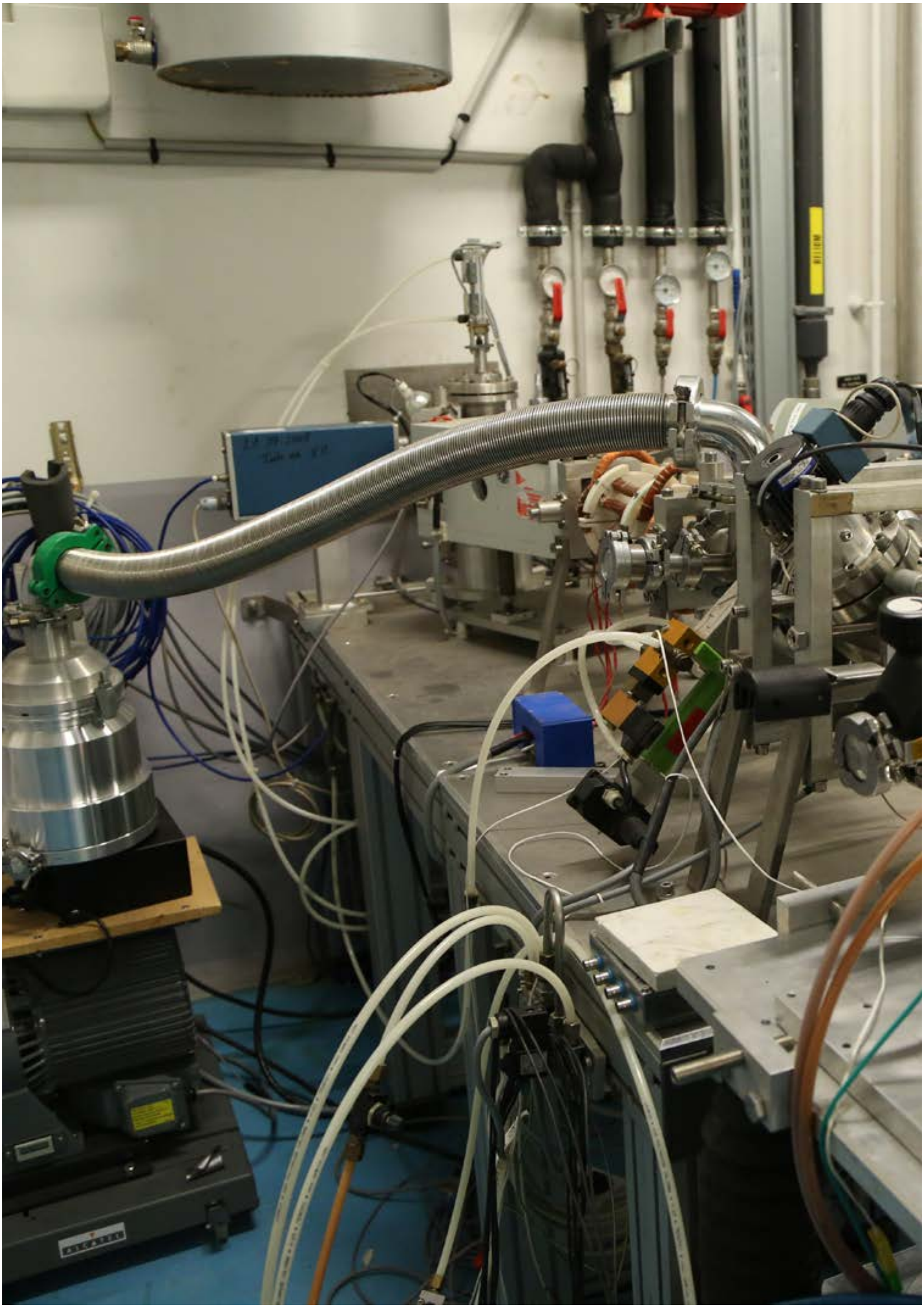


decay and death raised fundamental ethical questions. As I began to learn about his profession and visit his laboratory, I discovered how surgery is an art more than a precise science. Like cabinetmakers, surgeons learn their techniques from a master, work in an empirical manner, in dialogue with active materials that respond. I must admit the disgust I endured at the sight and smell of living organs, disemboweled mice and cut up hearts, but I felt a great respect for his practice, which I was discovering through the back door.

Igor then introduced me to Marie Weinhart, a biochemist at Freie Universität, with whom he is collaborating to find new ways to construct artificial organs. Through discussions, I understood that a major challenge in experimental surgery worldwide is the rapid, efficient, and transfusable production of extra-cellular matrices (ECM), the tissue that holds cells in our organs, to palliate the scarcity of donated organs. These tissues must be biocompatible, and are structured in myriads of vascular micro-networks, allowing blood to exchange efficiently with the cells. One of the solutions considered is the use of biocompatible 3D printing (Elomaa et al. 2020), but the results are still too coarse and complex. Sauer and his laboratory are also using another principle, that of the ghost organ, in which they use an existing organ, empty it of its cells, 2 Extra-cellular matrix liver casting, Experimental Surgery Lab, Charité Hospital (Source: Igor Sauer, 2018)

3 First vascular structures generated by partial discharge of a PMMA block initially irradiated via a 2.5MeV electron beam (Source: Emile De Visscher, 2020)

4 Electron accelerator exposure room, where the samples are placed in front of the beam. The electron beam generator is in another room, separated by condensed concrete walls, to lower the risk of gamma ray exposure and ease the operator's work (Source: Emile De Visscher, 2020).



and re-cellularize it by injecting healthy cells into it (Everwien et al. 2020). Despite these promising avenues, the idea that it would be possible to imagine other ways of fabricating architectures for cells remained to be explored.

Biomaterials and Fluids

My quest to find out what a “design to support life” could look like led to a very concrete and specific form: that of vascular networks. Just as corals in the oceans, mycelial networks in fungi, or the dendritic shapes of a tree, the biological kingdom functions with little energy and complex structures that maximize interactions (Eder, Sharhouz, and Fratzl 2018). My own design heritage of producing the simplest forms for a defined function (as defined in the “form follows function” and “good design” principles) was challenged by a need to produce the most complex forms to eventually generate possible functions.

When it comes to producing complex forms, the current and immediate answer would be 3D printing, as seen in many design research labs around the world. Although interesting for some specific applications, its construction principle is always based on geometries by layers or points. Labor-intensive, it never uses the materials’ own activity to generate forms – geometry is brought by code and precise machinery rather than by the inner intelligence of material behaviors. My aim was to explore how to use a material phenomenon to self-generate microvascular structures rather than rebuild them from scratch. One of these phenomena that has always fascinated me is that of fulgurites, which are the result of lightning strikes on the beach or in the desert. The discharge of current is so strong that the sand melts in the form of tubes, which multiply in depth. This phenomenon is called “electrical treeing” and is well known and studied at microscales in the context of high-voltage electrical insulation, particularly in the case of underwater cables (Zheng, Chen, and Rowland 2019). The constant exposure to electrons eventually generates dendritic cracks in the cable insulation, and researchers are exploring ways to hinder these propagation mechanisms. Based on these studies, my aim became the opposite: to promote these tubular propagation mechanisms to generate microvascular networks in bio-compatible materials eventually resulting in architectures for cell growth. Electricity is comparable to a liquid. My hypothesis was that using it to carve a material will self-optimize vascular paths.

Irradiating Biocompatible Materials

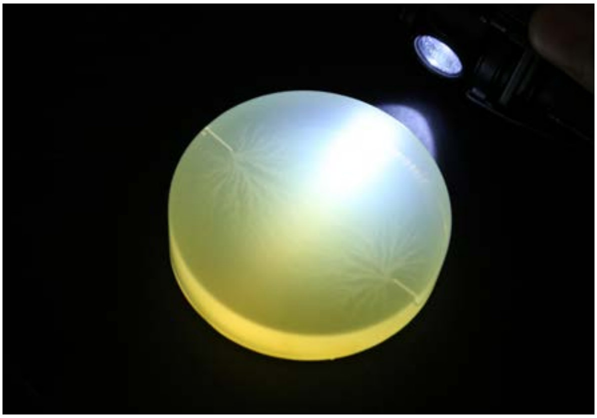
To reproduce this process in a fast and controlled way, I needed to force the electrons into the material. I therefore found in the literature (Huang et al. 2009) a protocol that allowed me to simulate the same principle, using a specific technology: particle acceleration. Indeed, to create vascular structures in a block of matter, it was necessary to force electrons to enter and remain stuck in a block of matter, and then discharge them instantly to dig channels through their escape routes. After a lot of research, negotiations and scientific evaluation, I finally gained access to an electron accelerator at the École Polytechnique, Paris, in the Laboratoire des Solides Irradiés, in 2021.

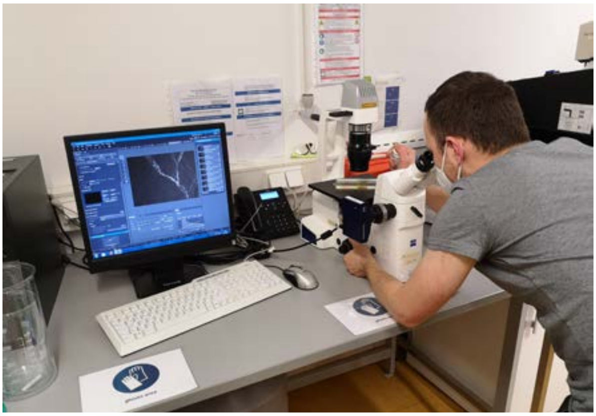
The discovery of this laboratory was, like the one for surgery, a great surprise. Despite the simplicity of its principle (producing electrons from a metal string and accelerating them thanks to electromagnets, a phenomenon present in all cathode ray televisions), an electron accelerator is a machine used in the field of nuclear research that produces strong gamma rays. The normal research conducted in this lab comprises testing reinforced concrete resistance for nuclear plants, or the behavior of metal structures when exposed to solar irradiation for space satellites. But my objective was to produce biocompatible, vascularized and transfusable samples of material in order to be able to inject a liquid potentially loaded with cells and nutrients. Initially, we tried the experiment on oil-based PMMA (poly(methyl methacrylate)) blocks to understand the protocol for generating multi-channel networks, a technique we were then able to apply to biocompatible plastic blocks, which I molded from PLA (polylactic acid; corn- or sugarcane-based plastic). Interestingly, the engineers and physicists from the lab became extremely involved in the research. Instead of experimenting on how to improve material resistance to irradiations, my proposal was to introduce irradiation as a mean to generate biological patterns and life-compatible applications. Instead of improving *stability*, we were exploring how to foster *activity*—which was quite unusual in this context.

Conclusion: Design and Monsters

This research project, although promising, is not intended to provide a solution for the manufacture of artificial organs. The results are still too experimental and premature, and the technology it requires is too complex. Its interest lies elsewhere: understanding how, within a research framework, design can decompartmentalize disciplines and technologies with different logics. Nuclear technology, the symbol of warfare, annihilation and decay (Barad 2017), is used here for

5 Detail of bioplastic (PLA) in which a tubular network has been created through electron irradiation and partial discharge (Source: Emile De Visscher, 2021)
6 Control room of the SIRIUS electron accelerator at École Polytechnique, Palaiseau (Source: Emile De Visscher, 2020)
7 Analysis of the network created, with a pumping device and a microscope. With the support of Marcus Lindner from Freie Universität, our aim was to make sure the samples were transfusable (Source: Emile De Visscher, 2021)





life-support functions. Although they may seem incompatible, new kinds of alliances were forged through a design research project, producing frictional assemblages between the nuclear and the biosphere – as in the famous case of biodiversity renewal in the midst of the irradiated Chernobyl landscapes.

What is the status of the objects developed through this research? Functional objects? Prototypes of an upcoming product? Samples of materials? None of those. They are monsters of the Anthropocene, representatives of the contemporary cyborg condition we have to adopt. They are monstrous in two ways: first because they are the result of an improbable assemblage of disparate knowledge, techniques, and materials – as all monsters are, by tradition. But they are also monstrous in the etymological sense of the term – “monstrare” in Latin – as they are meant to show, make public and provoke debate about what a “design for the trouble” (Von Busch 2022) could be. These objects could be called “techno-phanic” (Simondon 1961), or revelators of *techno-logical* problems (De Visscher 2018), because they show commensurabilities between accelerated electrons and animal cell behaviors, thus questioning the modern partition between natural and artificial realms.

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A Critical Cut Through a Designed Thing:

A Short Study on Oblique Matters of Design

Viola S. Ahrensfeld

Puig de la Bellacasa's notion of "care" is the starting point from which to explore the relationality of the design practice enacted by designed things through their mediating effects on the social. Introducing social relations and boundaries as oblique matters of design directs the attention to design's implications for the making of the social itself, which provides the very conditions within which we create, again. If one does not follow the common paradigm that design solves problems, but that it creates them by the same means within the social realm, design – and thus we, the designers – need to question its modes of production.

Keywords: Care, dis/ability, mediation, communities of practice

In the perspective proposed here, foregrounding care at the heart of critical constructivism reminds us that, in order to be livable, a critical cut into a thing, a detachment of a part of the assemblage, involves a re-attachment. This means, on the one hand, that we become able to cut in a certain way because of our own attachments, because we care for some things more than others. And it means, on the other hand, that to produce a caring account, critical cuts shouldn't merely expose or produce conflict but should also foster caring relations.
— María Puig de la Bellacasa

Detachment
As a designer, I can easily relate to the idea of cutting a thing, detaching and reattaching material, and reassembling it, for instance to design a more ergonomic, easier to handle product that creates an interaction that is more seamless or meaningful to its user. As a design researcher reflecting on the same practice, I am intrigued by the idea of making a critical cut into a thing. Not just cutting the tangible object itself to somehow increase the benefit, but cutting through the meta thing, the part of the thing that enacts the actions a user may perform through the usage of this thing, the part of the thing that co-shapes the in-between.

This side of a designed thing is not necessarily obvious from its physical appearance, but it is nesting somewhere in between its, for example, color, size, shape, and interface, and the user's understanding and interpretation of the thing itself; "[w]hen things are used, people take up relations to the world that these things, thanks to their handiness, 'co-shape'" (Verbeek 2005, 209). By the use of things, we alter our relations to the world around us, or they might get enacted within the usage in the first place by nudging or persuading us, for instance, to perform or not perform an action upon the world. Thus, in the perspective of technological mediation, as outlined here, designed things connect us to the world (as it were – this presupposes a world independent of humans, which is already there and can be connected to) by mediating our relationships to it instead of being separated entities. The relations between humans and the world emerge by encountering it through the use of things. Consequently, designers alter the relations between users and the world by the deliberate act of designing things.

Let me give you an example of such a material and technological mediation. The hearing aid is a technological device that digitally processes, filters, and/or amplifies the sound picked up by integrated microphones in real time to counteract a hearing loss to a certain degree in the best possible way. Depending on the characteristics of the hearing impairment, different types of hearing aids are employed, referred to as behind-the-ear, in-the-ear, in-the-canal, and completely in-the-canal hearing aids,[1] since hearing impairment is not a homogeneous condition but rather "a spectrum of conditions or characteristics" (Adams and Rohring 2004, 6).

1 This text is referring to hearing aid technologies that are worn rather than fully incorporated, such as cochlear implants; a comparison to auditory wearables is drawn here.

The hearing aid is thus a designed technological object that actively shapes how one perceives, or even is enabled to access, the auditory realm. By modulating the auditory perception of the user the hearing aid alters their perception of and access to the world. Thus, it co-shapes the user's construction and understanding of the world and their being in it in a fundamental way: "[w]hat humans are and what their world is receive their form by artifactual mediation. [...] Humans and the world they experience are the products of technological mediation, and not just the poles between which the mediation plays itself out" (Verbeek 2005, 130). Designed things co-shape how and what we perceive of the world and, therefore, ultimately how we experience it and act in it since we encounter the world with and through them. They mediate the in-between between an individual and the world. Hence, a critical cut into a designed thing can reveal the manifold relations between a user and the world designed things mediate based on the "practical dealings with things" (ibid., 211).

However, neither user nor designed thing are alone in the world. Nor is the user's interpretation and understanding of it a given fact. There is a social world within which the user, as well as the designed thing, are embedded. Color, size, shape, or interface of a designed thing obtain meaning, and meaning is created within the use of them. According to the theoretical framework of Symbolic Interactionism, meaning – such as self-understanding, cultural values, or symbolic meaning – is created within the social domain through processes of negotiation. Based on language and symbols, meaning emerges and is constantly recreated, reproduced, or transformed in everyday interactions through individual actions and within social contexts between physical objects, social "objects," and society (Blumer 1969).

Designed things embedded in such symbolic interactions do not only operate on a utilitarian or a semiotic level. They are not only used to enable or carry out the negotiation, nor do they only refer to or project something. However, they mediate interactions, content, and environment as such, therefore they are part of the negotiation process itself. Meaning is gained within actions and interactions with designed things. Hence, designed things do not only provide the very basic infrastructure we operate with, through, and upon in the form of physical objects that mediate relations between user and world based on one's dealing with things. They are subject to and a means of a meaning-making process in social negotiation. Consequently, designed things do not only alter the relations between user and world but also the meaning one might establish with them.

The hearing aid thus does not only mediate the in-between between individual and world – with whom, what, when, and where one might be enabled to interact (at all or differently). It may also mediate how others interact with and perceive or interpret another's actions, since we give meaning to and make meaning with things. The hearing aid thus functions as a sign that is "especially effective in drawing attention to a debasing identity discrepancy, breaking up what would otherwise be a coherent overall picture, with a consequent reduction in our valuation of the individual" (Goffman 1963, 43–44).

This is also reflected in the design of hearing aids, which is not only concerned with functional aspects: their aesthetics seem to be guided by an aspiration that goes beyond utility and product semantics – the use of skin-coloring and veiling shapes, and miniaturization to the point of almost complete incorporation. Hearing aids are being concealed because they render someone not only into a person with an apparent medical condition, but "disabled" compared with, and in the mind of, the social majority.[2] Hearing aids embody meaning and make it apparent and tangible for the social other by emphasizing a difference between what is considered as dis/abled.[3] This effect becomes even more apparent when hearing aids are compared with "hearables," which represent a relatively new form of auditory technology. Hearables can be considered not only as wireless headphones that allow interaction with smartphones (e.g., listening to music, making phone calls, or interacting with the smartphone's intelligent personal assistants). In addition to many other functions[4] that vary depending on model and manufacturer, they are equipped with the ability to suppress noise and amplify single sound events, just like hearing aids. Ambient sounds, voices, or music can be technically separated from each other and filtered, amplified, or suppressed. However,

2 For a detailed discussion of the medical ("being disabled") and social ("becoming disabled") model of disability, see Michael Schillmeier 2007.

3 The differentiation and demarcation in the social domain is thus also made visible in writing by emphasizing it with the slash. See also Schillmeier 2007, 91.

4 Hearables are often equipped with sensors that capture biometric data for medical purposes or fitness monitoring, for example. It is not uncommon for other intelligent technologies to find their way into hearables: they not only collect body data but also evaluate it and provide corresponding feedback, for example in the area of athletic performance. Other hearing aids, equipped with the right software, even function as simultaneous translators.

as the numerous other functions of hearables suggest, they are not specialized to compensate for a physical impairment such as hearing loss. The various types of hearables belong to the field of consumer electronics and are marketed in the areas of sports, work, well-being, or music entertainment. They are associated with an urban, self-confident, and modern lifestyle. Their design turns out accordingly: they sit visibly in the middle of the concha, very often bright colors or high contrast are used, as well as glossy material. Their shapes reflect the fields they are marketed in. Hearables are designed for athletes, managers, and music lovers, in contrast to hearing aids.

Hearables thus mediate very different relations not only between user and world but foremost between user and social world when compared with a hearing aid. Both a hearable and a hearing aid alter one's social relations to the communities one engages with and feels belonging to. By conveying socially constructed information about their users, through color, size, form, or interface, for instance, things perform a form of social mediation. Things mediate the in-between of the individual and their communities.

By this, the hearing aid co-shapes the basis of the social; things co-construct the individual and thus their communities, which are constitutive elements of societies. If one is identified as hearing impaired and therefore stigmatized or disadvantaged because of wearing a hearing aid – for instance, in a job interview – laws become effective. Such laws seek to create equal opportunities for marginalized communities. Hence, things co-shape the relations between communities and thus co-shape the structures of the social itself up to superstructures, such as the norms, conventions, and laws that a society agrees on. Things mediate the spaces in between of communities.

A hearing impairment only becomes visible through its compensation – the hearing aid – through the designed thing itself. In doing so, it has greatly helped shape the social by creating marginalized accounts in the form of the "(hearing) disabled," and not just recently, as the history and the design of hearing aids suggest.[5] Certainly, the hearing aid is rather an "extremely" designed thing in this sense. But because it has, from a historical perspective, co-shaped the social drastically, it serves well to illuminate the relationality of a thing and what its design entails. The hearing aid, in the same way that it helps to co-shape relations to the world, how one interprets and acts in it, also helps shape how one is interpreted by the world,

5 For some striking examples of the concealment of hearing devices in the 19th and 20th centuries, see the Deafness in Disguise Exhibition provided by the Bernard Becker Medical Library at https://beckerexhibits.wustl.edu/did/index.htm.

namely the social world, when one is wearing it. Things help to co-shape human–world relations, and, accordingly, social relations that also produce differentiation between individuals and thus boundaries in the social domain.

Such social relations and, by the same means, boundaries can be considered oblique matters in design processes. The relationality enacted by designed things is also reflected in their production, since social conceptions and practices that develop in dealing with things are eventually taken up again in design processes. By staging the negotiation within design, the methods and equipment, but, most importantly, the participants in such a designerly negotiation – who is considered to be a user and/or stakeholder and thus participates in a design process in one way or another – design processes frame who is included in the design of a hearing aid (a hearing-impaired person?) and a hearable (an athlete, a businesswoman?).[6] In this way, social conceptions are mirrored in design processes, and, therefore, ultimately in the design of things, which, again, co-shape social interaction and the resulting social structures. Consequently, relations, and by the same means, boundaries, within the social realm are matters of design, even if oblique. Design can thus be understood as an activity that does not only detach and reattach matter but, following Puig de la Bellacasa's notion of care, fosters or diminishes social relationships.

6 Thus, design processes can also be regarded as designed things. See also Binder et al. 2011.

This conclusion raises many questions about the social matters design deals with, whether it wants to or not. In what way is the design of a thing constitutive of such marginalization, given that social relations are oblique matters of design? To what extent is such a wicked relation between the dis-/ and the abled just a relational byproduct of design if it is not considered explicitly in the design process due to its obliqueness? And to what extent do we, the designers, recreate, reaffirm, and reinforce such a boundary between the dis-/ and the abled not only by the things we design and their unintended side effects but by the way we design them? How can we prevent the reproduction and reinforcement of boundaries between social communities through design practices? And what does it mean for the practice of design to deliberately co-shape meaning and, therefore, social production, or rather accidentally interfere with it when shaping matter? Moreover, who is and who should be part of the deliberate design processes that co-shape meaning and thus relations and boundaries within the social domain?

The "making of deeply unequal, insensitive, and destructive social orders seems to remain design's own 'wicked problem'" (Escobar 2017, 47). In order to be able to create more caring relationships, one needs to understand and question existing ones and their modes of production. Thus, a critical cut through designed things is proposed here to lay bare the relationality they enact and, therefore, their social structuring power as the partial outcome of a deliberate act of designing. A critical cut, then, allows us – the designers – to explicitly consider relations and boundaries between social actors as matters of design itself, and thus enables us to care for them in the first place.[7]

Critically cutting through designed things means shifting from critiquing the production of knowledge about and through things to the production of things themselves, the detachment and re-attachment of not only matter but human world relations, and thus relations and boundaries within the social that become installed by the practice and the mechanisms of design.

Re-attachment

As a designer, I detach and reattach matter and, therefore, indirectly social relations and boundaries since they are oblique matters of design. I co-shape the social itself, which provides the very conditions within which I create. "Design designs," as Tony Fry (2005, 24) puts it. Consequently, design does not only solve problems; it may implicitly create them by the same means.

Without forgetting that a critical cut also involves a re-attachment, however, this endeavor is not intended to reveal only the problems generated by design. I would like to offer at least the outline of a framework grounded in pragmatist social theory that allows us to consider the implicit problem-making inherent to the practice of design. This "requires a more rigorous process of problem-definition" (Willis 2006, 84). Hence, I want to suggest such wicked social boundaries as matters of design in order to help consider the social in-betweens in design processes explicitly, or the other way around, "the agency of the designed object" (Willis 2006, 86) within the social domain.

As stated, some relations designed things co-shape get debunked as mere boundaries when critically cutting through them. Boundaries, understood as a structuring force not only between humans and the world but also between individuals and communities, can become insurmountable – they then

7 Understanding design as an ontological and epistemological act unfolds the doing of things in the in-between, between user and world, between user and social world, in between social worlds. It considers that designed things not only provide the very basic infrastructure we operate with, through, and upon, but that this thingy matter enacts structuring effects on the social operating in between; it creates relations and thus affiliations, and by this, distinctions and boundaries in between social worlds. This emphasizes the inherent ethico-political dimension of things, as hopefully becomes evident in this short piece even without touching on Barad's Agential Realism. In this sense, the critical cut, as proposed here, would be to retrace Barad's "agential cut" to determine what (problematic) boundaries were thereby (unintentionally) generated in the social realm by the explicit design logics that come into play in the shaping of matter. However, if one follows Puig de la Bellacasa's idea of "cutting" in the context of care, it is a more affective mode of encouraging intervention into what might be, and, therefore, lends itself to critical questioning of design as a practice as well as an approach to practice design.

turn into wicked problems (Rittel and Webber 1973) if not approached (designed?) carefully. But considering design as a social structuring practice through designed things that enact such boundaries, as done here, allows us to consider wicked problems not only as relational byproducts of design but as “wicked boundaries” within the social realm.

The idea of wicked boundaries is installed here since wicked problems are often intangible, abstract, and unsolvable issues. Due to complex interdependencies, they refuse to be located or traced, and thus for their nature to be understood sufficiently. Whereas a boundary needs to run somewhere; it demarcates A from B; it has residents that can indicate if and where a (designed) boundary runs, and what it is made of; it can be located and traced; it can be looked at; its social and material constitution can be examined and described. Thus, it can be worked on, it can be relocated, it can be crossed, and therefore it can become an explicit object of design.

Approaching wicked boundaries through design and as matters of design allows us to account for the doing of things in the social realm explicitly, by considering the communities they help to co-shape, rather than thinking of them only as users who are also social actors. This enables me, as a designer, to consider diverse communities and their conflicting needs, the resulting practices, and the related value systems that create boundaries in the social domain as such and manifest in things. This attempt, therefore, holds ready relational frictions not just based on common needs that affect many users but foremost on divergent “communities of practice” (Lave and Wenger 1991; Wenger 1998).

Practice, as understood here and characterized by Wenger, evolves through mutual engagement in a joint enterprise that creates a shared repertoire – including designed things – and is thus the source of the coherence within a community (Wenger 1998, 72 ff.). A design process that builds on practice would not be initiated based on utility and needs within one community of practice, pertinent users that are, but is grounded in shared or similar artifact use and thus similar practices performed in diverse communities of practice, despite their varying needs. Thus, classifying stakeholders within design processes according to aspects of shared practices in diverse communities of practice could ultimately lead to designed things that are not characterized by the distinction between technology design for “disabled” people as assistive devices, and technologies for “non-disabled” people as consumer products, as in the example given here. Such an approach to design processes would incorporate their shared use of artifacts, as well as the differing ideational social conceptions, in this case the wicked boundary between the dis/abled, which result from the artifact use. In such social design negotiations based on shared practice rather than exemplary users, things can take on a different meaning, and new meaning might be gained with them; designed things could emerge that mediate relationships between communities of practice rather than reinforce their boundaries.

Considering shared practices in between differing communities of practice from a designerly perspective could help to bridge the boundary between them through designing not exclusively for the prevailing needs and problems within one community, and by doing so indirectly co-shaping its boundary with other communities of practice. By considering shared practices – such as the technological modulation of auditory perception shared by both hearing aid and hearable users – between communities that appear to have nothing in common, between "adjacent communities," new mediations based on mutual practices can take place.

This theoretical conceptualization of design from a pragmatistic perspective can also help to explicate the mediating effects of design on social structures – the boundaries that demarcate them from each other – and therefore deliberately acknowledge the act of co-shaping social structures by design in general. Ultimately, neither meaning nor human–world relations are pre-existing, nor are they simply made up (Wenger 1998, 54) – they are mediated and negotiated within design processes.

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Sympoietic Futurities

ESSAY

Sympoietic Design as an Ethical Project

Susanne Witzgall

Drawing on neo-materialist approaches and ecological thinking, this essay elaborates on the idea that an ethical design practice has to be characterized as a complex twofold endeavor. It demands not only an intimate correspondence with and attunement to the essential properties, dynamics, and transformational qualities of materials, but also the special participation of the designer in local assemblages and global nexuses, bringing a maximum of potential and connection to a situation. In both cases the design process can be considered a “making-with,” “a worlding-with, in company” (Haraway 2016, 58) and therefore as sympoietic design.

Keywords: Distributed agency, ecological thinking, making-with, (collective) potential, response-ability, “good” design

New materialism and the corresponding ecological or relational thinking – which became increasingly prevalent in humanistic and social-scientific discourses at the beginning of the 21st century – challenge conventional assumptions about the process of making. In doing so, not only are conventional dualisms of form and matter, mind and body, nature and culture eroded, and the human fantasy of exclusive agency and control deconstructed: neo-materialistic or relational approaches also promote a fundamentally different understanding of what could be termed "good" design practice given our manifold environmental problems – whereby the term "good" is quite naturally stripped of its modernistic aesthetic-formal connotations and ethically recharged. Drawing on – meanwhile familiar – basic neo-materialist and relational-ecological assumptions and referring to an indigenous design practice and a related artistic project by the Forager Collective and Cooking Sections, this essay carves out several central landmarks that may provide rough orientation for a design practice considered to be "good" in the sense of "ethical." It focuses on relational processes taking place in two distinct spatial and temporal dimensions that are deeply interconnected but must nevertheless be differentiated: one, the immediate and intimate intra-action between maker and material, and the other the specific participation of the designer in local ecological networks and planetary nexuses. Both relational processes make their own rational and affective demands on an ethical design praxis and are subject to local and distributed situatedness; however, they also follow basic criteria beyond cultural volatility, as I intend to demonstrate.

Responding to the Potential of Materials ("Form Follows Material")

Neo-materialist approaches have fostered an understanding of the process of making that differs significantly from the conventional view known in philosophy as *hylomorphism*. The latter is usually shaped by the idealistic idea that in the making of artifacts, practitioners impose a form (*morphe*) internal to the mind on inert matter (*hyle*) or homogeneous raw material distinct from the realm of imagination and meaning. In *A Thousand Plateaus*, however, Deleuze and Guattari, who provide essential foundations for numerous new materialist strands, highlighted that Gilbert Simondon already "exposed the technological insufficiency of the matter-form model," demonstrating that the hylomorphic model leaves many important things by the wayside (Deleuze and Guattari 1987, 408).

One of them would be that the matter, which should be formed, is an “energetic materiality in movement” that already carries “implicit forms that are topological, rather than geometrical” or invariant essential properties intra-acting in the processes of shaping. In the case of splitting wood, this means, for example, that the “variable undulations and torsions of the fibers [are] guiding the operations” – in other words, the axe will follow the grain. Moreover, the wood is shaped by *variable intensive affects*, rendering it “more or less porous, more or less elastic, and resistant,” which might depend on whether the wood is dry or wet, how long it was stored, etc., and which also plays an essential role in the process of making. Instead of imposing a form upon the wood, it is more equivalent to “surrendering to the wood,” to “following where it leads by connecting operations to a materiality” (ibid.).

The anthropologist Timothy Ingold provides another enlightening example for the neo-materialist, non-hylomorphic understanding of making originating from a “field project” he conducted with his students. Near Aberdeen Beach in north-east Scotland, his students gathered on a windy day in February to make baskets out of willow. They first had to stick an odd number of thin willow branches vertically into the ground to form a rough circle, tied at the top. In a second step, “[h]orizontal pieces were […] woven alternately in and out of the vertical frame so as gradually to build up a surface in the form of an inverted cone” (Ingold 2013, 22). However, the students quickly realized that this was not always an easy undertaking. Many were “surprised by the recalcitrant nature of the material,” Ingold reported. Sometimes the willow even sprang back and struck the weaver in the face. But once the students managed to carefully put the willow branches in place and finish the basket, “the willow seem[ed] to sit so naturally there, as if it had always been meant to fall into that shape and was merely fulfilling the role for which it was predestined” (ibid.). Indeed, all of them comprehended in a very corporeal way that besides its pliability, it was also the resistant quality of the material, the friction of the willow, that allowed it to be woven and which held the basket together. “The form,” Ingold explains, “was not imposed on the material from without, but was rather generated in this force field, comprised by the relations between the weaver and the willow” (ibid., 22–23).

In particular, the second example demonstrates that material not only participates in the process of making and determines it to a certain extent; it furthermore supports – or even enables – a very specific design process due to its invariant essential properties and *variable intensive affects*. In the case of traditional basketry, the craft technique is often attuned so perfectly to the existing features of the material that it comes together with them in a smooth way, and the skillful and sensitive intra-action between maker and material gives rise to what is at least temporarily a sturdy shape that seems to have fallen automatically into place, as it were.

This way of designing, in which the maker remains in mutual correspondence with the material and derives a benefit from its potentialities in the form-taking activity, stands in harsh contrast to key strategies of industrialized mass production. The latter, as Manuel DeLanda highlights in reference to contemporary industrial metals, engenders an entirely different procedure, squeezing materials forcefully into an arbitrary form, initially stripping them of all their complexity and heterogeneity and subjecting them to processes of uniformity and homogenization, which cancel out the differences among their components (DeLanda 2004, 19–20). One rationale behind this process, DeLanda points out, is that "both human workers and the materials they used needed to be disciplined and their behavior made predictable" (ibid., 20). This development was accompanied by serious side effects. One of them was the conviction that a single universal material could be used for multiple kinds of structures and tasks, whereas the numerous roles of structures and the complex requirements of different tasks would require the appropriate material in each case – a material, I would argue, that contributes to a specific role and task with its own singularities and affects, frictions, and tendencies. In this line of argument, engaging with the appropriate material in a specific form-building process would mean being aware of its potential and letting it unfold itself *instead* of reducing it with a lot of energy use to make the material take on a particular shape. Yet the taming of materials through homogenization not only includes the danger that the structure or the task does not fit the appropriate material and that its potential is downgraded and wasted. It also means that the potential for something unexpected happening is diminished – the potential for a new solution, a new structure engendered by the encounter and correspondence between the material and the maker.

DeLanda's elaborated critique of the predominant handling of materials in industrial mass production (which, by the way, must not be interpreted as a critique of industrial mass production in general) allows – and this is a very crucial step – the development of the non-hylomorphic neo-materialist understanding of making into an affirmative project, propagating a fundamentally different way of engaging with materials as a “good” practice of designing – a sensible, skillful, and respectful mutual correspondence with materials that allows them “to have their say in the structures we create” (ibid., 21). Instead of taming the materials, investing a lot of power and energy to force them into a desired precast form, a neo-materialist model of making or designing as an affirmative project advocates respecting the essential properties of a material, and treating it as an actor and co-creator in the design process that offers forms, colors, structures, and solutions itself. This new model of designing may be fostered by, among other things, new digital processes of simulation and manufacturing developed to take better advantage of the properties, dynamics, and transformational qualities of materials.[1] However, it should also be kept in mind when it comes to craft practices, especially when confronted with a change in material.

1 An early example of this would be the *Responsive Surface Structure* project from 2007 by Achim Menges and Steffen Reichert. Based on their research into the hygroscopic characteristics of wood, with the help of digital simulation and manufacturing techniques the architect and the computational designer developed a spatial structure using “wood’s inherent moisture-absorbing properties and the differential surface expansion associated with them“ (Stattmann, Schröpfer, and Fogelberg 2014, 93).

This occurred, for example, in the course of the project *The Forest Does Not Employ Me Any More* by the Forager Collective, a former Bangalore-based group of writers and artists, and the British duo Cooking Sections (Daniel Fernández Pascual and Alon Schwabe), who are known for their research-based practice exploring the overlapping boundaries between visual arts, architecture, ecology, and geopolitics. In collaboration with the Soligas, a tribal Indian community, the collective and the duo developed a new manufacturing technique and a new prototype for hand-crafted furniture using lantana branches that comply with the material’s specific characteristics. *Lantana camara* is an invasive plant that was brought to the Indian subcontinent by the East India Company, an important agent in the British colonization of India, in the early 19th century and evolved into a serious threat to wildlife and farming. Since it could not simply be eradicated, the evolutionary biologist R. Uma Shaanker and his colleague Ramesh Kannan supported the Soligas in their use of lantana for the production of furniture in order to control its spread. The Soligas in turn welcomed it as a zero-investment resource, since their communities have been expelled from the forest by more recent policies and thus no longer have unhindered access to bamboo, their former standard furniture material. Although the Soligas exchanged the material, they did not change the traditional shapes of the furniture and more or less used the same production techniques. “But in contrast to the sturdiness of bamboo,” Cooking Sections and Forager Collective explain, “lantana is much more pliable, and allows for more flexible use. Once lantana’s bark has been removed, the wood bends easily, but putting the branches in hot water, the Soligas craftsmen can

1, 2 Cooking Sections and Forager Collective, *The Forest Does Not Employ Me Any More,* detail, 2016, branches of *Lantana camara* (photos by Tim Bowditch, courtesy the artists).

strip the bark more quickly than cutting it off with a knife" (Cooking Sections and Forager Collective 2018, 33). In other words, the new prototypes developed by the artists in a dialogue with the Soligas took advantage of the invariant essential properties, the pliability and flexibility of the material, and the *variable intensive affects*, rendering the bark more easily removable after the hot-water bath – in other words, they realized the material's potential. Or, to put it differently, the encounter and correspondence between the material (*Lantana camara*) and the maker (Soligas/Cooking Sections and Forager Collective) actualized the material's potential for a new solution, a new structure.

Scaling Up Collective Potentials and Connections ("Design Follows Ecology")

The Forest Does Not Employ Me Any More is part of Cooking Sections' larger project and program *The Empire Remains Shop*, which explores the colonial remains of the (British) Empire and the implications of selling them today. According to Cooking Sections, this is "a method to understand the space in which power structures operate and to explore how to use that knowledge to challenge them," or, as they write further, "in order to imagine political counter-structures that promote greater equality in a hyper-globalized world" (Cooking Sections 2018, 26–27). The discursive part of *The Forest Does Not Employ Me Any More* introduces *Lantana camara* as a tenacious remnant of the colonizers' violent shaping of the Indian continent and disentangles the enmeshment of current indigenous design practices with *Lantana camara* in complex historical and (socio-)ecological relations. From this analytic endeavor, we can derive the insight – and this is what makes this project so valuable for the subject of this essay – that designing with *Lantana camara* is a problematic heritage of colonialism caused by the destruction of the Indian landscape through the exploitation of its resources and the introduction of the invasive plant, and at the same time a decolonizing counter-practice that yields beneficial effects through its partaking in Indian naturecultures.[2] In working on the relations between humans and non-humans, this design practice helps to fight against *Lantana camara* and hold further destruction of local ecosystems at bay, ameliorating the living conditions for at least some indigenous people for whom the plant constitutes "the only raw material they could legally and economically access" (ibid., 33).

2 The participation of Cooking Sections, who live and work in Great Britain, in this counter-practice can in this connection be interpreted as allyship.

The specific design approach with *Lantana camara* rests on and is cognizant of the vibrating interdependencies between diverse human and non-human actors, their cohabitation, their mutual becoming, and their constitutive entanglements in biological-artificial and material-semiotic assemblages. It can therefore be designated as relational, as a design practice saturated by relational or ecological thinking. This should not lead to the wrong assumption, however, that every design practice inspired by ecological or relational thinking can automatically be labeled as "decolonial" or "good." "The ecology that – literally and metaphorically – generates its core," Lorraine Code writes, "is no innocent place from which to derive pure, benign 'alternatives' to the epistemologies of mastery" (Code 2006, 6). According to Code, ecological thinking importantly needs deliberative decisions and practices as well as the vigilant observation of the dynamics of their enactment in order not to fall prey to old patterns or new forms of oppression.

But how can we know, then, what a "good" decision and "good" practice is? What does it mean to design in a relational way that is inspired by ecological thinking and could be considered ethical? In *Parables for the Virtual* the Canadian philosopher Brian Massumi invokes an idea of ethics as a political knowledge-practice "that takes an inclusive, nonjudgemental approach to tending belonging-together in an intense, affectively engaged way [...] – as opposed to a morality." "Ethic," Massumi adds, "is a tending of coming-together, a *caring for* belonging as such" (Massumi 2002, 255). Even if this statement does not yet provide a satisfying answer to our question, it addresses two aspects that are highly relevant for our topic: on the one hand, it designates ethics as inseparable from an intense experience of "coming-together or belonging-together of processually unique and divergent forms of life" (ibid.) and from an active and affective participation in the heterogeneous ecological meshworks of the world aimed at a symbiotic becoming-with. And on the other hand, it strictly discerns ethics and morality pursuant to Deleuze's interpretation of Spinozian philosophy, which relates ethics to a knowledge-practice, whereas morality or moral law "has no other effect, no other finality than obedience" and "makes nothing known" (Deleuze 1988, 24). Thus, Massumi's concept of the ethical has ontological as well as epistemological and affective implications. It is bound to a relational ontology in which relations, connections, and interdependencies are inherent to being and the conditions of a dynamic becoming. And it is also an epistemological as well as affective practice, with insight into our complex embeddedness in the world's heterogeneous networks, fostering our intense participation in these assemblages and caring for our belonging to them.

Donna Haraway, who links ethical practice to the ability to respond (with *response-ability*), also sees ethics as grounded in a relational ontology, an ontology of becoming-with. Haraway's response-ability towards and with our fellow beings can be understood as a reconceptualized and relational version of responsibility that is in turn "a relationship," as she explains in *When Species Meet*, "crafted in intra-action through which entities, subjects, and objects come into being" (Haraway 2008, 71). The physicist and feminist theorist Karen Barad further sharpens such ideas in their theory of Agential Realism and describes responsibility as something that the individual cannot evade but an ethical obligation anchored in the relational entanglements of being. "Responsibility is not an obligation that the subject chooses," they explain, "but rather an incarnate relation that precedes the intentionality of consciousness" (Barad 2014, 162).[3]

3 Karen Barad is here referring to their text "Quantum Entanglements and Hauntological Relations of Inheritance: Dis/continuities, Space-Time Enfoldings, and Justice-to-Come," in *Derrida Today,* page 265, from 2010.

Since we are bodies of belonging that only came into being due to immanent relations and co-constitute the becoming of the other in an ongoing process of affecting and being affected, we are indebted to, we are responsible for, the other. In turn, response-ability, this special variant of responsibility, acknowledges the difference of the other, attunes itself to the other, and can lead to practicing kinds of response that "alter common becoming for the better or make it possible in the first place" (Hoppe 2019, 25) and answer not only *to* but *with* the world. In *Staying with the Trouble,* Haraway links such kinds of response to the word *sympoiesis*, which is to say "making-with" and that she describes as a "word for worlding-with, in company" (Haraway 2016, 58). Heather Swanson, Anna Tsing, Nils Bubandt, and Elaine Gan speak of sympoiesis as "symbiotic makings" and emphasize, in reference to Haraway, that "[s]ymbiotic relations must be constantly renewed and negotiated within life's entanglements" (Swanson et al. 2017, M5). As a prerequisite for an appropriate response-ability, enabling multispecies flourishing, Haraway defines a "non-mimetic caring" and "a robust nonanthropomorphic sensibility that is accountable to irreducible differences" in *When Species Meet* (Haraway 2008, 90). Her nonanthropocentric feminist ethics, however, provide no specific guidelines. They must be understood as political and situated ethics that demand constant renegotiation of what it means to respond in a "good" way (see also Hoppe 2019, 263). Allowing a better common becoming, a "living and dying well in multispecies symbiosis, sympoiesis, and symanimagenesis" (Haraway 2016, 98), seems to be its only binding benchmark.

At this juncture, I would like to add that cultivating certain kinds of response in favor of a common becoming also means dismissing other possible ways to answer and inevitably excluding alternative forms of making or worlding-with. That is to say, the process of responding also implies boundary-making and acts of exclusion, for which it is likewise necessary to assume liability (see also Barad 2007, 158). Thus, the nagging question remains of how we can pin down "good" ways to respond if they necessarily involve not only decisions *for* but also *against* someone or something. Or, to put it differently, what kinds of response are worth fighting for politically, or better, what kind of responses are politically beneficial? Are we capable of defining basic criteria, providing at least an approximate idea of what a "good" or ethical practice might be? Criteria that make no pretense of generalizing but neither become a puppet of contingent cultural values and sociopolitical negotiations? Criteria that demand no blind obedience but to which we can relate both affectively and rationally? To approach this difficult question, it seems worth referring back to Massumi, this time to his supplementing explanations on ethics in *Politics of Affect*. Here Massumi emphasizes the situational and pragmatic character of the ethical and adds: "The ethical value of an action is what it brings out in the situation, for its transformation, how it breaks sociality open. [...] Basically the 'good' is affectively defined as what brings maximum potential and connection to the situation. It is defined in terms of becoming" (Massumi 2015, 11). A few paragraphs further down he elaborates:

> In a way I think it becomes an ethics of caring, caring for belonging, which has to be a nonviolent ethics that involves thinking of your local actions as modulating a global state. [...] So it takes a great deal of attention and care and abductive effort of understanding about how things are interrelating and how perturbation, a little shove or a tweak, might change that. (ibid., 43–44)

Massumi once again draws on Spinoza and his notion of "good" as something that enhanced the efficacy or potential – the *potentia agendi* – of affected bodies, with the fundamental difference, however, that he reinterprets this notion in a radical, nonanthropocentric way. Whereas the 17th century Dutch philosopher is especially concerned with the enhancement of the human body's capacitation – the capacitation of one's own body – and hence primarily with human self-preservation and development, which are ethically charged, Massumi is first and foremost interested in bringing a collective potential, a collective capacitation, to the situation, or, as one could also say, to an assemblage or ecological meshwork. It is all about increasing this potential through caring for relations or belonging, for which “you have to abdicate your own self-interest up to a point” and “you have to place yourself not in a position but in the middle” (ibid., 43). Moreover, Massumi stresses the importance of caring attention and epistemic effort to discern and conceive the interrelation between things, the dynamic intra-action between different agents of an ecological meshwork, to render ethical decisions possible, enhancing its potential and connections. In summary, Massumi advocates for a “caring for the relating of things as such – a politics of belonging instead of a politics of identity” (ibid., 18), in order to bring the most connection and collective potential to a situation. In my opinion, this goes beyond Haraway’s idea of sympoietic becoming since the aim is to maximize capacity and ability in terms of becoming in a given situation.

Thinking about Haraway’s, Barad’s, and Massumi’s different but highly resonating approaches together and through one another therefore seems quite promising for the purpose of outlining relational or sympoietic designing as an ethical project.

A telling and multilayered example of such an ethical project is the indigenous design practice mentioned earlier that uses *Lantana camara,* as well as the project *The Forest Does Not Employ Me Any More* by Forager Collective and Cooking Sections. The latter supported the indigenous practice by modifying the manufacturing process and distributing the new prototype through *The Empire Remains Shop* (of course without a sales fee or a commission), with the objective to ”un-work” or “unshop” the Empire (Povinelli 2018, 11), ridding it of its toxic colonial remains.

This design practice emerged out of a caring participation in an ecological system in crisis whose biodiversity and thus collective potential – its potential in terms of becoming – is continuously threatened by an extremely dominant invasive species that invokes, on a metaphorical level, the persistent vitality of colonialist power. The extensive proliferation of *Lantana camara* eliminates indigenous plants and leads to a depletion of wildlife. It reduces the many-sided web of relations and impedes the mutualism of other species – among them the intra-action between the Soligas and their forests, since the plant has become almost like a thick wall that “even elephants cannot penetrate” (Forager Collective/Cooking Sections 2018, 32) and has made many parts of it inaccessible. The response cultivated by the Soligas and later by the Forager Collective and Cooking Sections also comprises acts of exclusion and boundary-making in an attempt to contain *Lantana camara*’s devastating impact on ecosystems. Thus, the designing it implies can be considered a making-with, which works in the field of belonging and fosters a maximum of ecological relations. It facilitates the re-establishment of diversity and symbiotic connections in the Indian ecosystems affected and thus their potential to flourish. Not least of all, it enhances the economic and social potentials of the Soligas as well, enriching their existential conditions and opening up new possible relations to their environment (since, for example, they may gain renewed access to their forests).

In a neo-materialist manner, the collective potential of a situation highlighted by Massumi can be understood as distributed agency. It might be referred to as agentic capacity disseminated throughout a multitude of non-human and human agents in assemblages or ecological meshworks. This agentic capacity is always relational, since it is invariably bound to other forces in a field, "in relation to which alone it takes effect" (Saar 2019, 143), as we have already learned from Spinoza. Bodies – human and non-human – only unfold their agency in relation to others, to other elements of a network, through mutually affecting and being affected, which augment or diminish, foster, or impede the body's "power of activity" or *potentia agendi* (Spinoza 2018, 105). To bring a maximum of collective potential to a situation therefore means to enhance the distributed agency of a network via caring for and enhancing the relations of its heterogeneous agents in such a way that they can flourish in mutual affecting correspondence, and that the *potential agendi* of the whole network even goes beyond the sum of its parts.[4] This may involve not least the effort to ward off the constantly lurking danger that one of them – human or non-human – suddenly lays claim to dominant superiority.

The Solegas' design practice with *Lantana camara* channels the capacity of this agent to act and works on relations and interdependencies, restoring the capacitation of other humans and non-humans and thus enhancing the distributed agency of the ecological meshwork. However, as many affect theorists explain with reference to Spinoza, it is not clear what a body is capable of doing.[5] Affection fosters or impedes the body's "power of activity" in an unforeseeable way; consequently, the complex relational dynamics of ecological networks are also, to a certain extent, unpredictable. Therefore, neither a relational nor a sympoietic design practice can fall prey to wrong fantasies of control, which would mean returning to old colonial patterns. Humans are not masters or protectors but active participants in the world's assemblages (see also Puig

4 Practices that enhance the distributed agency of a network also include, for example, ustainable farming practices. In stark contrast to the conventional management of fields, the latter tend to result in more abundant and complex fungal communities, which are crucial for ecosystems since webs of mycorrhizal networks and non-mycorrhizal fungal mycelia "stitch organisms into relation," as Merlin Sheldrake explains. Those fungal meshworks feed and sustain plants, consume their rotten parts, hold soil together, help the soil to absorb more water, reduce "the quantity of nutrients leached out of the soil by rainfall," and more (Sheldrake 2020, 161, 178). They weave a multitude of living and nonliving entities into their webs, often enhancing not only the potentia agendi of individual plants or microorganisms but also that of the whole ecosystem.

5 Or, as Gilles Deleuze cites Spinoza: "We do not know what the body can do […]" (Deleuze 1988, 17). Spinoza himself formulates it as follows: "For no one has yet determined what actions the body can do, i.e., experience has not yet taught anyone what actions the body can and cannot do without being determined by the mind simply on the basis of the laws of nature […]" (Spinoza 2018, 97).

de la Bellacasa 2017, 129). A design practice requires permanent attunement to the situation and an ongoing adjustment to structures of power, patterns of affection, and flows of materials. The challenge is to keep one eye on the local situation and at the same time the other eye on those global nexuses that are affected by the pragmatic decisions made in the specific situation. One can speak of a *distributed situatedness* here, an additional situatedness in global contexts and dynamics beyond concrete locality.

Conclusion

The preliminary claim of this essay is that designing as an ethical project, within the context of "capitalist ruins" (Tsing 2015) and a "damaged planet" (Haraway 2016, 67), must take into account both factors: the intermediate intra-action between maker and material, and the specific participation of the designer in local ecological networks and global entanglements.

On the one hand, it is vital to engage in conversation with the particularities and *variable intensive affects* of the materials involved in order to avoid downgrading or squandering their potentials. On the other hand, the design practice has to bring a maximum of relations and collective potential into a situation. This means that it has to take care of the relations between the heterogeneous actors in a meshwork in such a way that its distributed agency is enhanced – which also includes carefully weighed and responsible practices of boundary-making. In both cases, one can speak of a "making-with," or a "worlding-with, in company," and therefore of a sympoietic design practice – a sympoietic practice that appreciates and attunes itself to the rich potentials of the living and the non-living, of single materials and entire material-semiotic ecologies, and fosters them in mutual correspondence. It is a design practice that acknowledges the relational entanglements of being as relations of obligation and participates in their shaping in a responsible way. And it is not at least a researching design practice that investigates its intra-actions with materials and human and non-human actors in a well-informed but open experiment, as the design practice with *Lantana camara* demonstrates – which, not by chance, evolved in a common explorative endeavor incorporating different forms of knowledge and experience: indigenous, scientific, and artistic. The particular beauty of designing with *Lantana camara*, by the way, consists of the fact that it is not only driven by the goal to create abundance for humans and non-humans alike but also that it cannot be threatened by the possible scarcity of its material. Instead, running out of raw material and exhausting all 13 million hectares of *Lantana camara* across India is the ultimate aim of this design practice, and the lantana business, which also makes it a practice, as Cooking Sections and Forager Collective themselves emphasized, is going “against the conventional logic of market growth” (Forager Collective and Cooking Sections 2016).

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ESSAY

When Mirrors Metabolize:

Towards a Metabolic Perspective in Art and Design

Roman Kirschner

This contribution outlines a metabolic perspective in art and design as a tool to integrate the thinking of exchanges of matter and energy deeply into the process of creation. It introduces and looks into three recent examples from the field of experimental art and design, each featuring its own specific way of dealing with ongoing transformations of matter and energy within a chosen ecological and metabolic system. Like mirrors in a system without a view from outside, the three examples serve as objects of reflection for estimating a current position within and in relation to the omnipresent meshworks of metabolism. Through these mirrors, issues clustered around three topics are identified: (1) reduction, passivation, and control; (2) reappreciation of physical space and its offerings; and (3) authorship and collective methods. The topical clusters shall facilitate and encourage further investigation in art and design research and ultimately lead to intelligibly linking wider audiences to the life-supporting dynamics of our planet.

Keywords: Metabolic perspective, arts and design research and methods, collective metabolization, metabolic connectedness, functionalization in the arts.

Initially starting from an inquiry into performative surfaces as active entities, this contribution presumes that surfaces, if they are not only conceived as abstract constructs, depend on a hinterland, i.e., their body and an environment. This necessary spatial dimension and its implicit exchanges and transformations of matter and energy can drive versatile activities. Taking these exchanges and transformations into account is the core of a metabolic perspective that is not only imperative for the emergence of activity, but also concerns other important aspects. These aspects include, but are not limited to, the conversion from output to new input and from waste to nutrition, the connection of collective and distributed processes of different species and their environment, and the understanding of the traveling of substances between different systems. The metabolic perspective is also key in creating situations that make people not only understand but physically experience and feel their personal involvement in the immediate as well as the wider ecological environment. If these situations are appropriately developed, they can transmit the sense of immersion and risk that comes with humankind's dependency on our planet and the care that this overall situation requires. Thus, beyond providing prospects for improving the experiential involvement of audiences, the experience of metabolic connectedness has the potential to change individual behavior as well as public policy decision-making in the face of environmental challenges. Finally, the metabolic perspective shows the potential of having a transformative impact on the field of art and design research. Its quality of linking processes, energies and materials together in its particular ways brings up the question of whether a practice that is informed by the metabolic perspective can foster novel collective approaches and thus new productive relationships for "digesting," repurposing, building on and drawing energy from each other's work.

The Metabolic Perspective

Metabolism is generally defined as "the chemical processes that occur within a living thing in order to maintain life" (OED 2001) and is central to the definition of life.[1] Philosopher Hannah Landecker provided plausible arguments for why metabolism has not been dealt with more prominently over the past decades and why it has not received the societal attention that it deserves (Landecker 2013). One substantial reason has to do with the complexity of metabolism, which goes beyond the transformation processes of organisms.

Metabolism connects an organism and its environment. Rather than being one process or entity, metabolism is a "cumulus of

1 "The condition that distinguishes animals, plants, and other organisms from inorganic or inanimate matter, characterised by continuous metabolic activity and the capacity for functions such as growth, development, reproduction, adaptation to the environment, and response to stimulation" (OED 2023).

interlocking cycles" that happens inside and between cells, organs, individual organisms and groups in the "space of conversion of one to another, of matter to energy, of substrate to waste, of synthesis and break down" (Landecker 2013, 193). The interlocking force of metabolism crosses the boundaries of organisms and environments and undermines them, in the sense that the efforts of biology to introduce boundaries are subverted as the environment turns into an organism and, vice versa, the organism becomes the environment (Hird 2012, 232).

Metabolism on a Planetary Scale

On a larger scale, one cannot simply speak of metabolism in reference to organisms but must also consider ecosystems or the planet as a whole. For Yadvinder Malhi, professor of Ecosystem Science, metabolism is the flow of complex energy through biological systems (Malhi 2014). On this planetary scale there are regulatory principles in place that are being described in Earth system science (e.g., Jacobson et al. 2000; Kump et al. 2014; Schlesinger and Bernhardt 2013). In the 1970s, before the advent of Earth system science, the Gaia hypothesis (Lovelock and Margulis 1972) suggested that our planet could even be considered an organism, but this theory met serious criticism (e.g., Schneider et al. 2004). However, biogeochemical cycles are central for understanding Earth's metabolism as a nearly closed complex system, in which matter and energy are constantly flowing between the biosphere, the atmosphere, the geosphere and the hydrosphere, and are crucial for sustaining life.[2] Life, the sum of all organisms, is deeply embedded in these cycles and involves processing energy to build complexity (Mahli 2021). As scholars such as Vernadsky, Lovelock and Margulis pointed out, life played a decisive role in creating and maintaining its own living conditions (Vernadsky 2007; Lovelock and Margulis 1972). Within life's shared environment without boundaries, nothing gets lost.[3]

2 It should be noted that it is not pure energy (e.g., solar energy) that is cycling but chemical elements that travel through environments and organisms, most of all carbon, nitrogen, phosphorus, calcium, sodium, sulfur, hydrogen, oxygen, and smaller amounts of other chemical elements (Jacobson et al. 2000, 48).

3 Only hydrogen and helium manage to leave the Earth's atmosphere in small quantities due to thermal and non-thermal escape processes.

Social Metabolism

Taking the impact of humans as part of the biosphere into account, scholars have developed several metabolic approaches over the past decades (e.g., Baccini and Brunner 2012; González De Molina and Toledo 2014). Their historical reference point lies in Marx's late-19th-century analysis, according to which mankind has entered into a problematic metabolic relationship with the Earth, mostly due to capitalism being a merely profit-oriented mode of production indifferent to sustainability. It remains to be seen how attempts to shift to less exploitative economic paradigms or a convincing circular economy can manage to sustainably integrate human economic activity into our planetary system.

Related Concepts and Oppositions

The concept of metabolism as outlined above is concerned with participation in shared spaces and access to resources. It is closely related to the concepts of symbiosis (Frank 1877; de Bary 1878; Margulis 1998), endosymbiosis (Mereschkowski 1905; Sagan 1967; Margulis 1998),[4] holobiosis/holobiont (Meyer-Abich 1943; Margulis 1990; Haraway 2016; Baedke, Fábregas-Tejeda, and Nieves Delgado 2020),[5] and ecology as a whole (Brown, Kodric-Brown, and Sibly 2012). Therefore, metabolism can potentially provide the means to avoid the reductionist approach that has been pushed to the limits in the natural sciences[6] and was thereafter mirrored in the arts. A far-reaching critique of reductionist regimes can be found in Oron Catts' and Ionat Zurr's neolifism, where they diagnose an increasing fragmentation and abstraction of bodies and lives (Catts and Zurr 2016). According to them, neolifism, as for example found in synthetic biology, turns life into a resource for human manipulation and control while ignoring life's context as a requirement for its own existence.

On the opposite side of the spectrum from the described reductionist functionalization to respectful participation and care, indigenous knowledge, as for example described by scholar Shawn Wilson, propagates the relationality of life as a whole and each individual's – including researchers – accountability to this very relationality (Wilson 2008). Furthermore, responsible land relations are expressed through positive methods such as *Honorable Harvest* by Robin Wall Kimmerer (2015) or negative counter examples as in Max Liboiron's politically explicit claim of *Pollution is Colonialism* (Liboiron 2021).

Metabolism in Arts and Design

The metabolic perspective focuses our attention on the life–milieu hybrid and its implications and connections that are essential for sustainable being and becoming on our planet. Consequently, it follows biologist Carl Woese's call to "put the organism back into its environment" and to "feel that complex flow that is organism, evolution, and environment united" (Woese 2004). The metabolic perspective is slowly gaining ground in arts and design. Through numerous initiatives such as the Critical Zones exhibition at ZKM in 2020,[7] which was accompanied by Bruno Latour's theoretical calls for a long-postponed landing on planet Earth (e.g., Latour 2018), or the claims of New Materialism (e.g., DeLanda, 1992; Dolphijn and

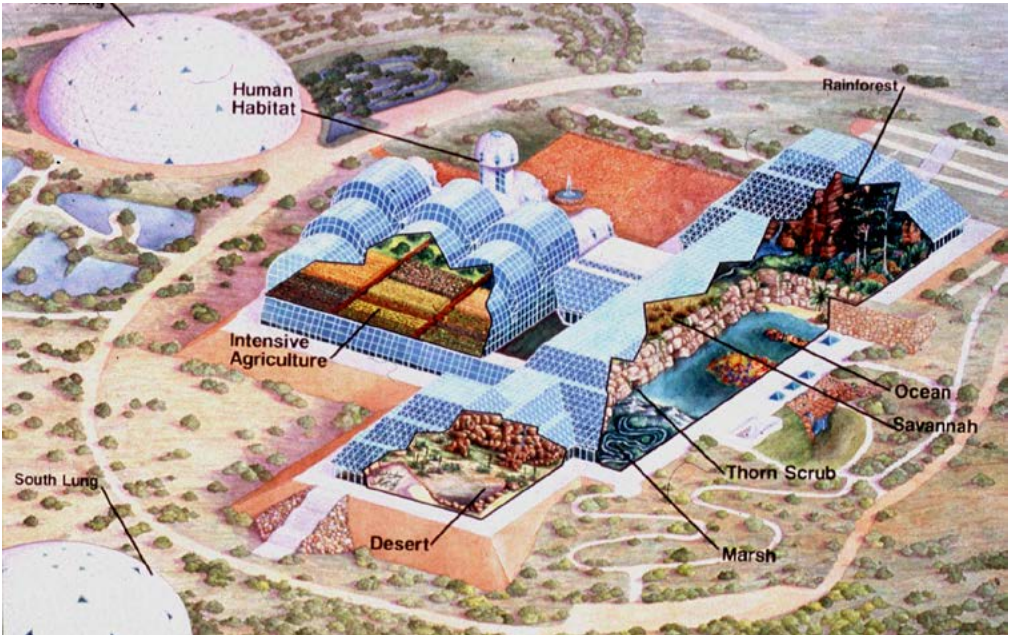
4 "A form of symbiosis in which one organism lives inside another" (OED 2018).

5 While symbiosis is a well-known term and is used in everyday language, holobiosis has not found its way into most dictionaries yet. Holobiosis describes a close association between different individuals, usually host–microbiota symbioses, that together form anatomical, physiological, immunological or evolutionary units (Baedke, Fábregas-Tejeda, and Nieves Delgado 2020).

6 For example, in molecular biology, the identification of species by culturing, microscopy or, lately, by metagenomic sequencing, does not reveal the true nature of microbial ecosystems. Instead, looking at the metabolism of the system can explain additional aspects, such as the activity or productivity of the ecosystem, and foster a better understanding of what is actually happening in such invisible worlds.

7 Curated by Bruno Latour, Peter Weibel, Martin Guinard, and Bettina Korintenberg.

1 Schematic layout of Biosphere 2 (Source: CDO Venture LLP/University of Arizona Biosphere 2)



van der Tuin 2012), the art and theory world is in full swing to tackle challenges such as resource depletion, environmental degradation and global climate change, to name just a few. Recent attempts to emphasize metabolic aspects in these fields have been undertaken by theorists and practitioners such as philosopher Monika Bakke (2017), curator and writer Jens Hauser with artist Thomas Feuerstein (Feuerstein and Hauser 2020),[8] and media studies scholar Desiree Förster (2021).

8 Feuerstein and Hauser were supported by a group of scholars led by Adam Bencard, who are working on developing the outlines of Metabolic Humanities at the Center for Basic Metabolic Research in Copenhagen.

Metabolic Connectedness

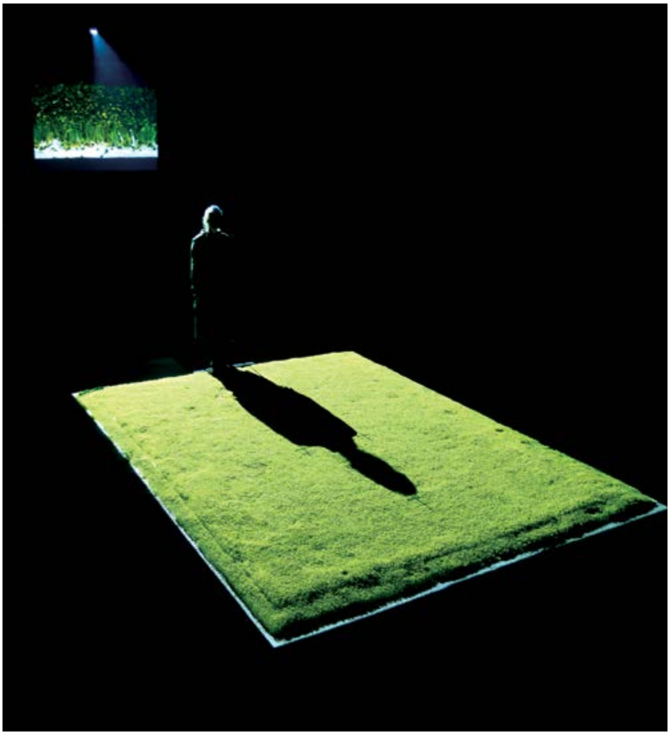
Following the question of how humans can relate to metabolic processes through embodied experience, together with Karmen Franinović I developed the idea of metabolic connectedness (Franinović and Kirschner 2020). Metabolic connectedness, as mentioned above, is the immediate feeling of being an integral part of our planet's metabolic system or of a smaller metabolic patch. This concept is the result of our research into the impact of soil microbes on humans and the environment in a closed ecosystem, namely Biosphere 2. In the first experimental phase of this large artificial glasshouse ecosystem built in the desert of Arizona, the survival of eight humans was meant to be assured for two years (1991–93) without any external material inputs. Based on historical investigation of primary and secondary sources as well as interviews with biospherian Mark Nelson, metabolic connectedness emerged as an enhanced sense of the connectedness of human vital processes, breath and food intake with the metabolisms of plants, animals, and other living beings. For the following three cases, metabolic connectedness can serve as a tool for evaluation and as a horizon for further development.

Three Cases and Their Challenges

Metabolic connectedness is not easily achieved in art and design works but it provides prospects for improving the experiential involvement of audiences. Common sense and previous practical experiences with metabolic processes suggest that metabolic systems or patches can't be invented from scratch. Only careful ecological shifts can be considered. Designers and artists have yet to find functioning ecological segments or recombinations that can endure a staging that usually involves a transposition into a different environment for public viewing and experience. But how can one build on and extend already existing attempts to work with this metabolic perspective in art and design research and practice? Which methods of knowledge transfer and material or processual continuation and difference adequately correspond with the core principles of metabolism? Does working with metabolism and its connective and integrative force require and drive new ways of collaborating in art and design? Can we establish methods we can call collective metabolizations in which practitioners don't shy away from re-using and re-purposing other artists' work, but proudly build on each other's achievements? And finally, how deep did the knowledge about metabolic interdependencies seep into the European art and design scene? How aware and appreciative are art and design practitioners of each individual's necessary embeddedness in the complex and omnipresent networks of metabolism?

In the following, I will introduce three pioneering works in which a series of non-human actors are responsible for essential metabolic activities, and formulate questions concerning crucial challenges of each in relation to metabolic aspects. These three examples serve as mirrors in a metabolic system in which we are all always embedded and that we cannot impartially observe from the outside. They act as objects of reflection in an attempt to identify a current position from where the metabolic perspective can be developed further. The raised questions will not be ultimately answered but rather delineate paths for further digestion and development. The three works – *Confronting Vegetal Otherness: Skotopoiesis* by Špela Petrič, *Prometheus*

2 ***Confronting Vegetal Otherness: Skotopoiesis*, Špela Petrič, performance view at Click Festival 2017 (Source: Špela Petrič, Micha Turšič)**
3 ***Confronting Vegetal Otherness: Skotopoiesis*, Špela Petrič, view of the cress after the performance 2017 (Source: Špela Petrič, Micha Turšič)**



Delivered by Thomas Feuerstein, and *Earthlink* by Saša Spačal – are all characterized by operating with metabolic processes and their translations between our directly perceptible life world and smaller scales that are mostly only accessible through technical mediation. The projects differ in the involvement of performer, artist or audience in the works' metabolic pathways.

Confronting Vegetal Otherness

Confronting Vegetal Otherness: Skotopoiesis (Petrič 2015) is a performance that was produced to question inter-species cognition between plants and humans. Petrič was the main human performer, standing still for more than 12 hours to cast a shadow onto a field of watercress. The germinating cress grew pale and elongated to escape her shadow and grow towards the light. In the meantime, Petrič claimed to have slightly shrunk due to the loss of fluid from her intervertebral disks (Petrič 2016). In the cress the process of whitening, etiolation, was initiated by the plants' photoreceptors, their phytochromes, which communicated the reduced light situation. As a reaction, the production of the hormone auxin was started in order to solidify the cell walls for better growth in height while leaf growth was reduced. The plant processes aimed at escaping the performer's shadow to reach the light.

The performance took place in a gallery space using only artificial light. This indoor location reduced environmental influences on the experimental situation to a minimum. Following the historic claims of Land Art to work directly in the landscape, the question arises how the relationship between the plants and the human would change if the performance took place outdoors. What would the performer need to do to produce the same shadow while the sun travels across the sky? How would rain or the shadows of clouds influence the whole situation? Is such kind of reduction and passivation in a gallery space just another repetition of humankind's difficult relationship with its larger environment or does the performance's symbolic act help reveal additional layers? Does it highlight or distort the metabolic situation? Did the effort of standing still overshadow the possible feeling of metabolic connectedness in the performer? Can the audience comprehend the experience of the performer beyond the hardship of standing still? What could be done to get the audience closer to the qualities of the metabolic processes experienced by plant and performer? These questions mostly point toward the overall setting of the performance and its structure. They show that neither the work with ongoing metabolic processes nor the involvement of audiences in them is easily achieved or frequently attempted.[9]

9 It must be noted that Petrič's core interest lies in the exchange of physico-chemical signals rather than rendering metabolic processes perceptible.

Prometheus Delivered

Thomas Feuerstein has explicitly dealt with ongoing metabolic processes and the narrative dimensions of the topic. In his work *Prometheus Delivered* (Feuerstein 2017) chemolithoautotrophic bacteria decompose pyrite in a bioreactor. Pyrite is an iron sulfide and its decomposition results in sulfuric acid. Some

4 ***Prometheus Delivered*, Thomas Feuerstein, marble replica of Prométhée enchaîné (Source: Thomas Feuerstein)**

acidic water from the bioreactor is subsequently dripping over a marble sculpture, a replica of *Prométhée enchaîné* by French neoclassical sculptor Nicolas Sébastien Adam from 1762. The sulfuric acid dissolves the marble – also called calcite – resulting in calcium sulfate, or gypsum, which in turn serves as food for human liver cells. The piece is playing with the classical topic of human technological achievement and the

5 *Prometheus Delivered*, Thomas Feuerstein, chemolithoautotrophic bacteria decomposing pyrite in bioreactor (Source: Thomas Feuerstein)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burden that it brings, while the used bioreactors made of glass allude to classical laboratory aesthetics.

The work poses many questions regarding the accessibility of metabolic processes in general and the role of humans and the audience in the sculpture's digestion, transformation, and autotrophic growth processes. Industrial-sized equipment has a strong impact on the aesthetic program. But does the use of laboratory equipment express the artist's underlying propensity to functionalize microorganisms as they are put into a highly controlled environment for a specific purpose? What does functionalization in the arts mean – and what in design? How far should functionalization go in symbolic culminations that mirror tendencies in society? Do we also have to reconceptualize the idea of productivity of metabolic processes in this context? Are there non-functional and yet productive ways of working with metabolic processes in art and design and how far can or should the use of isolationist equipment be avoided? Besides the power to provoke such questions, what sets Feuerstein's work apart is the way he achieves his specific conceptual and metabolic coherence of chains of transformation processes.

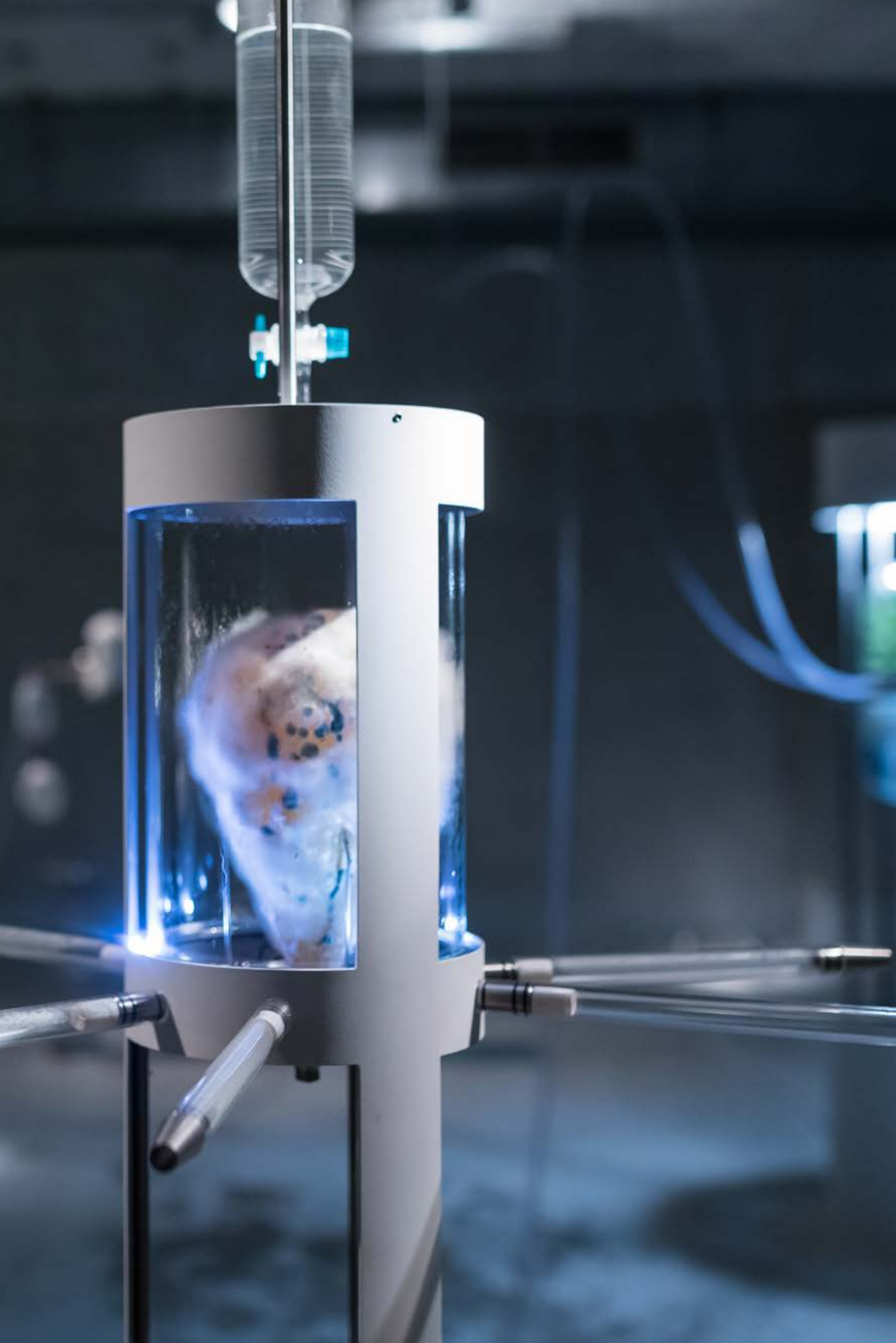
Earthlink

While several aspects of Feuerstein's work also resonate in Saša Spačal's projects, she has made the additional effort to create physical access points to ongoing metabolic processes for the audience. In her work *Earthlink* (Spačal 2018), she aims at reproducing planetary biogeochemical feedback loops that are catalyzed by microbial metabolisms. The installation consists of several glass containers connected by tubes for airflow. It has three main modules: Inspiration, Expiration, and Symbiome. In the modules, a specific kind of technology-driven metabolism is in operation, representing and mimicking the planetary processes found in the lithosphere, biosphere, atmosphere, and hydrosphere. In Inspiration, visitors can inhale a bacterial aerosol exuded by the soil at the bottom of the module. In Expiration, they can exhale into a breath collector. A central agar nutrient is thus seeded with the audience's bacteria, which then become part of the installation. In Symbiome, a red clover plant is growing, profiting from the shared atmosphere of all the processes present in the installation's tubing system.

The modules are presented behind glass. Human interaction with the biomes is focused on specific inhaling and exhaling. *Earthlink* uses the results of reductionist analysis, the production of a single compound by a single bacterial

6 ***Earthlink*****, Saša Spačal, exhibition view at Ars Electronica (Source: Saša Spačal, Miha Godec)**
7 ***Earthlink*****, Saša Spačal, close-up of Expiration (Source: Saša Spačal, Miha Godec)**

8 *Earthlink*, Saša Spačal, close-up of Symbiome (Source: Saša Spačal, Miha Godec)



species, to enable interactions with visitors under controlled circumstances. The glass containers make the problematic separation of humans from “nature” visible. But how could the presentation behind glass be rethought, and what would that do to the interfaces? Could or should the interfaces themselves be metabolizing entities and even help to update the classical human-computer interaction terminology (i.e., interface, interaction, etc.) from a biological perspective? If *Earthlink* were shown without the focusing glass shell, would it quickly dissipate into the environment? Could the chain of metabolic processes be kept intact? What would the attention shift to? In any case, the benefits of isolating and reducing metabolic patches come with a price. At worst, it could go as far as hijacking or deflecting the audience’s attention. However, taking into account the possible presence of pathogens in the substances and microorganisms used in *Earthlink*, Spačal introduced a functional balance between ensuring a safe environment for the microorganisms and the audience and her choice for providing input and output channels for participants to engage with the metabolic pathways of the installation. Due to this balance, and despite all obstacles, *Earthlink* induced a sense of metabolic connectedness within the constraints of a gallery space.

Conclusion

The metabolic perspective stands out due to a particular connective and integrative force. It does not only reveal new paths for the conception of, and thinking with, metabolic processes in art and design projects. It is also a deeply anti-isolationist paradigm that puts an emphasis on relationality and energetic/material embeddedness. This embeddedness in a system of interdependencies assigns humankind a less dominant role in ecosystems and fundamentally questions the widespread functionalization of non-human entities. It is the basis for respectful participation and care as well as the omnipresent and thus almost imperceptible backdrop against which individual accountabilities need to be evaluated.

From the metabolic perspective, three pioneering projects were examined and questioned. They served as system intrinsic mirrors to estimate art and design’s – as well as my own – current position inside the complex networks of metabolic interdependencies. From this position, I identified issues clustered around three topics. First, reduction, passivation, and control; second, reappreciation of physical space and its offerings; and third, authorship and collective methods.

The first cluster is initially about isolating and reducing metabolic processes in order to understand and use them properly. This requires a controlled spatial environment that places an emphasis on certain processes while it passivates or eliminates others. The challenge lies in keeping enough chains of metabolic processes intact while also providing a safe environment for both microorganisms and the human audience. A delicate balance with the feeling of personal concern or even risk needs to be negotiated in relation to metabolic processes and the variety of engagement with metabolic pathways that can be offered to participants. From the angle of form-giving, there is a need to balance artistic intention with modes of control over the flow of matter and energy.

The second topic builds on the first one in the sense that while the above balances are sought, the overall spatial settings and their provision of flows of matter and energy shift into focus. Structures and infrastructures are being rethought, processes and performances scrutinized and optimized. Along the way, requirements and constraints of specific ecologically condensed environments are under evaluation, and possible scales of these systems are checked for parameters such as matter/energy provision, types of immersion, metabolic productivity for appropriate feedback, and so on. Assessing and developing these design options as well as models and terminologies for framing metabolic processes may bring audiences closer to experiencing the qualities of these metabolic processes and furthermore to the sensation of metabolic connectedness.

The third cluster is grouped around the fact that metabolic processes are complex, distributed, entangle multiple participants, and can't be invented from scratch. The art and design practices dealing with metabolisms thus force us to rethink the notion of authorship. Answers to questions like "who is creating?", "where exactly?" and "when?" need to reflect the interrelated environment in which metabolic processes take place. Nevertheless, the field of art and design can certainly profit from diminishing the limiting concept of artists as geniuses. And in the spirit of collective metabolizations it should encourage a more generous exchange of experiences, procedural knowledge, and methods in working with metabolic systems.

Finally, I want to point out that using different art and design examples will lead to a different fixed position from where, in consequence, different issues can appear. I encourage any further examination of this line of investigation. The above topics are only stepping stones on the way to intelligibly linking wider audiences to the life-supporting dynamics of our planet through immersion in metabolic patches.

My deepest gratitude for making this contribution possible goes to (in alphabetical order): Julian Chollet, Thomas Feuerstein, Karmen Franinović, Jens Hauser, Claudia Mareis, Anthea Oestreicher, Špela Petrič, Léa Perraudin, Saša Spačal, Lucie Strecker, Rasa Weber, and Clemens Winkler.

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ESSAY

Design for Future Coexistences

Fara Peluso

The design for future coexistences shows how my practice, placed at the intersection of art, design and biology, establishes a new hybrid methodology in which speculative design implements caring and resilience from nature. The biological interactions of symbioses and coexistences are taken as models and translated into new closer experiences with the public, employed in our daily spaces through their embodiment into new artifacts. These speculative artifacts act as references for alternative social constructions, proposing a democratic and empathic way of embracing coexistence. In this article I elaborate a complex methodology that promotes the adoption of processes between design, art, science and poetry, reflecting the interweaving system we are living in today. Through this practice of making and prototyping, delving into micro- and macro-scales and perceptions, new models are generated that challenge how humans consider the environment. I will discuss the development of a new type of object, embodying living organisms into machines. These objects alter and enrich individual considerations of the world rather than perpetuate the idea of changing it proactively.

Keywords: Symbioses, coexistence, living organisms, care, speculative design, DIY biology, post-Anthropocene collective memory, living machines

We relate, know, think, world, and tell stories through and with other stories, worlds, knowledges, thinkings, yearnings.
— Donna J. Haraway

I present a design "with nature"[1] as a practice of "making with" instead of "making for" as a sympoietic[2] method, queering the nature of artworks and artifacts that are conceived for a world where nothing makes itself, where nothing is really autopoietic or self-organized. A practice that is part of a world of worlding-with and in company (Haraway 2016). Design with nature for me means design with caring and resilience as a speculative methodology combined with nature's biological interactions. It's when art and design employ symbioses and coexistences from nature, translating them into a project that can provide a remarkable lesson about the role of human beings in the whole ecological system, leading to a subversion of hierarchies and of the idea that humans are superior.

Stemming from these motivations the project *Viva* (2017) was developed studying the symbionts[3] *Elysia chlorotica* (green sea slug) and *Ambystoma maculatum* (spotted salamander), two fascinating examples of how symbioses happen between different species. Observing how both of the species are tied to algae (photosynthesizing microorganisms) for a primary nutritional purpose, it became central to remark how these relationships have a long-lasting outcome, acquiring the plastids from the ingested algae and allowing the chloroplasts to continue to photosynthesize (Pelletreau et al. 2014, 2; Kerney et al. 2011, 1). *Viva* questions how human beings are also connected to the photosynthesis process, and how they are not that different from the above-mentioned symbionts – proposing a speculative accessory that allows an intimate exchange of elements, carbon dioxide and oxygen, between human breathing and algal respiration. How can a future generation of artifacts and manufacturing techniques embed the photosynthesis process into their processes, supporting the improvement of all life quality, both from a human and a non-human perspective?

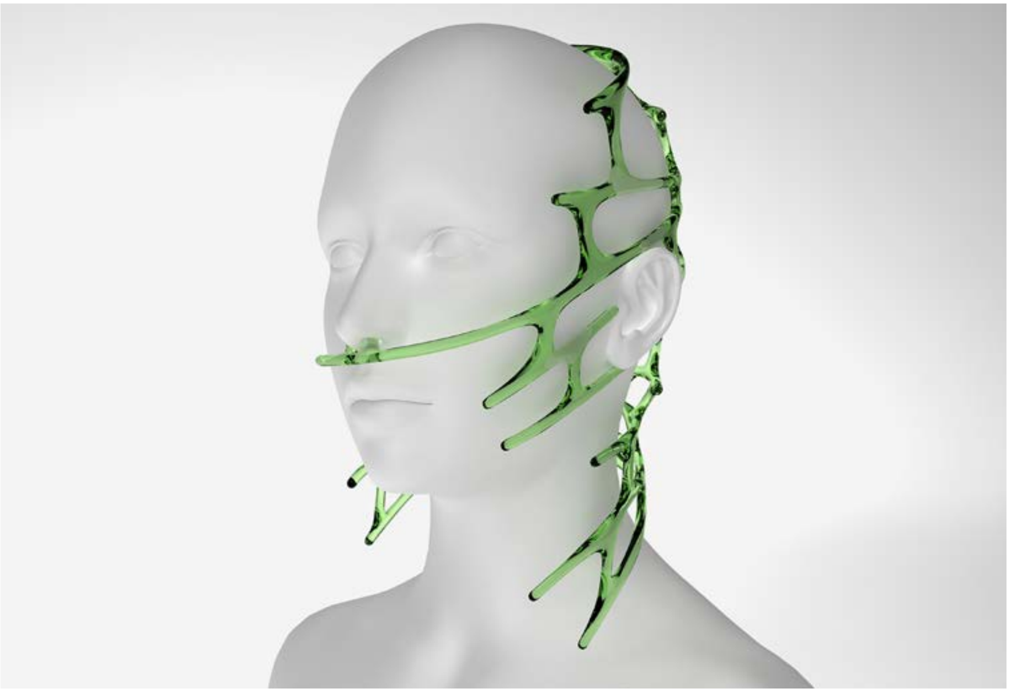
Viva shows how art and design practices adopt speculative methods to inquire into living organisms' agency and poetry, observing and employing them as reference models to become a learning tool with a premonitory attitude towards the future we can live in

1 By "design with nature," Ian L. McHarg argued for a regenerative design and planning practice with careful regard to both the ecology as well as the forces and flows of the landscape, which would lead to a stronger sense of place and identity in communities (McHarg 1969).

2 With the term sympoiesis, Donna J. Haraway replaces the term autopoiesis from Maturana and Varela, objecting that no "thing" makes itself: "'Sympoiesis' is a simple word; it means 'making-with.' Nothing makes itself; nothing is really autopoietic or self-organizing. In the words of the Inupiat computer 'world game,' earthlings are never alone. That is the radical implication of sympoiesis. Sympoiesis is a word proper to complex, dynamic, responsive, situated, historical systems. It is a word for worlding-with, in company. Sympoiesis enfolds autopoiesis and generatively unfurls and extends it" (Haraway 2016, 58).

3 Lynn Margulis explains symbiosis as a "system in which members of different species live in physical contact, explaining how animal symbionts are omnipresent." She affirms that "we are symbionts on a symbiotic planet, and if we care to, we can find symbiosis everywhere" (Margulis 1998, 5).

1 Fara Peluso, *Viva,* October 2017. The project *Viva* was developed as a final thesis work for the "Industrial Design" course at the Architecture University Roma "La Sapienza." Rapporteur: Prof. Carlo Martino, co-rapporteur: Prof. Valter Luca de Bartolomeis



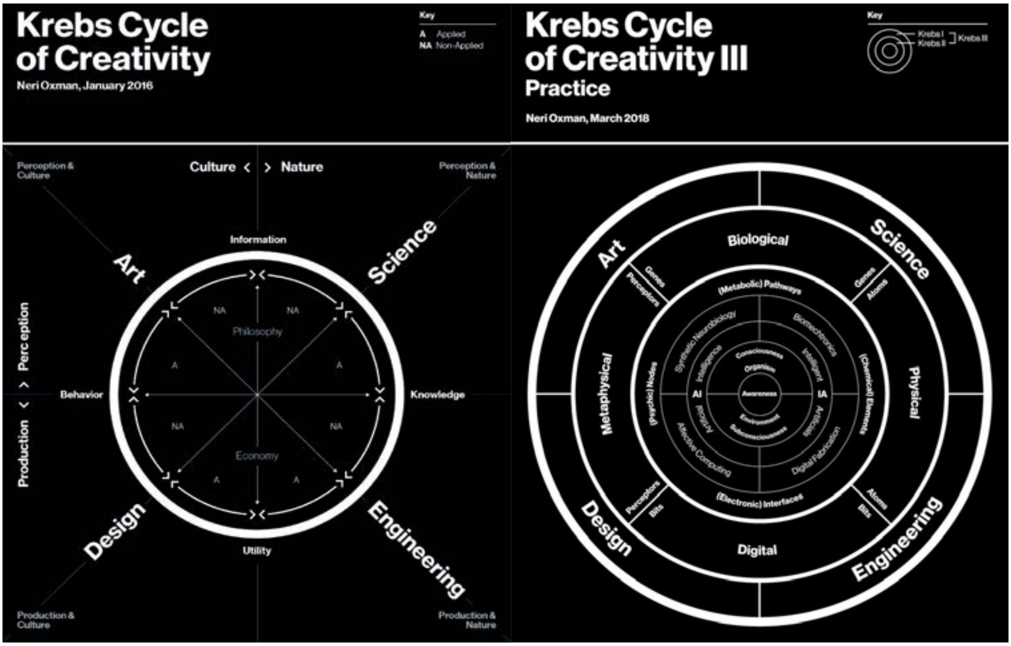
We learn that we are all part of the same interconnected system and that symbiotic events are also part of our evolution. Lynn Margulis influenced the ideas on symbiosis, making us consider how unaware of other forms of life we are in our thinking and how our social constructions are far from reality (Margulis 1999).

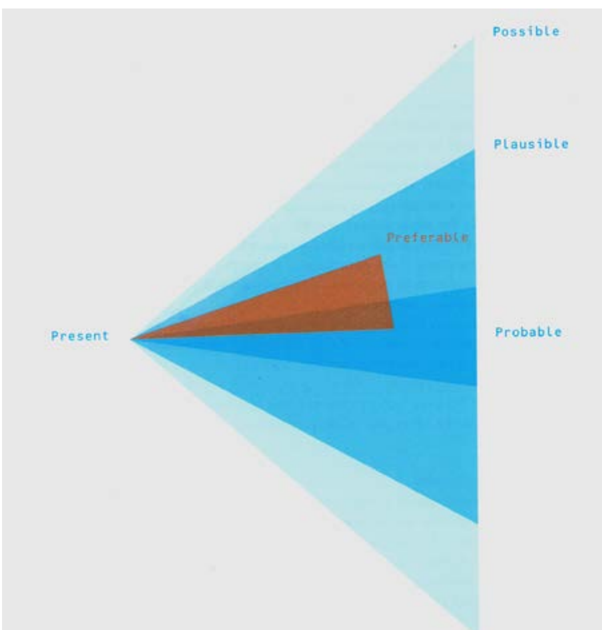
> Any idea we conceive as fact or truth is integrated into an entire style of thought, of which we are usually unaware. Call the cultural constraints "trained incapacities," "thought collectives," "social constructions of reality." Call the dominating inhibitions that determine our point of view whatever you wish. They affect all of us, including scientists. All are saddled with heavy linguistic, national, regional, and generational impediments to perception. (Margulis 1998, 3)

This methodology has the purpose of shaping a new awareness about human beings' effects on Earth, about their anthropocentric ideas, which influenced many domains — religious, economic, scientific — and of understanding how to set some factors, acts, thoughts, and methodologies aimed at defining a possible post-Anthropocene scenario of coexistence between humans and nature.

2 **Neri Oxman “Krebs Cycle of Creativity,” January 2016. The diagram represents a framework that considers the domains of art, science, engineering, and design as synergetic forms of thinking and making in which the input from one becomes the output of another. “The Neri Oxman Material Ecology Catalogue” by Paola Antonelli with Anna Burckhardt. The Museum of Modern Art, New York. 2020**

3 **Stuart Candy redraw illustrates different kinds of potential futures. Every cones, from the present opening towards the future, represents different levels of likelihood. “*Speculative Everything: Design, Fiction, and Social Dreaming”* by Anthony Dunne and Fiona Raby, MIT Press 2013**





Art, design, science, and new technologies combined can be the way to reshape a future with more awareness and action through a collective mindset. The theorist and architect Richard Buckminster Fuller stated that "to make a man a success on Earth we must design our way to positive effectiveness,"[4] complaining about the massive diversification and specialization between applied fields happening in the 1960s, and claiming that a new methodology coming from a new education of the young generations would help to redesign a way of being on Earth. Through his "theory of comprehensive man," Fuller affirmed that it was possible to be a synthesis of an artist, inventor, mechanic, and economist, but also a person who knew about biology and new discoveries and was able to work with them (Fuller 2009). Today we are living in a period of crisis in our society but, like in every crisis moment in history, we are also experiencing great changes. Thereby new methodologies are proposed, proving for example what Neri Oxman suggests through her "Krebs Cycle of Creativity," a diagram of exchange between art, design, engineering and science that is going beyond exploring new organizational scenarios.

4 In the last chapter of *Ideas and Integrities,* R. Buckminster Fuller discusses the relationship between designers and politicians, claiming that "[t]here is a new dedication on the part of the young in this world. This young world is about to take over, to help us design ourselves to make a man a success on Earth. If this is successfully done, the Malthusian and Darwinian frustrations will be completely irrelevant. There will be enough to go around, and the politicians will have no mandate to build weapons. To get rid of weapons we must design our way to positive effectiveness, and not just be negative about politicians and what they are doing" (Fuller 2009, 308).

It shows that the transit between fields generating forms of intellectual energy – where science produces knowledge, engineering produces utility, designers produce changes, and art produces a new perception of the world – is inspiring new scientific query, leading the human species to criticize and question its predominant role (Oxman 2016).

Therefore, designers can acquire knowledge and build a practice coming from a classical industrial design education intended also to pursue deep research aimed at becoming an important aspect of the working methodology. In this way they can watch nature not just with fascination but question how to adopt its elements as a strategy for their design process (Pearce 1978).

Consequently, together with artists, designers question how much their work is still driven by a human-centered perspective still focused on satisfying the needs coming from the human sphere. Together they can merge the critical aspect of art with the practical character of design by developing experiences for a whole system. where not only humans are present but a multitude of living organisms on Earth as well.

Ideas of Possible Futures

Among things that art and design have in common is their critical role in questioning society, such as the effects of the

4 ***WeaReactor* by Fara Peluso, DDW '17 Eindhoven. The project was developed in collaboration with BioArt Laboratories in Eindhoven and exhibited at the Dutch Design Week 2017**
5 ***Memory Matter* by Fara Peluso, 2019. The work was developed during the Residency Program "Imagining Ecological Futures," 2019, supported by The Goethe-Institut Brussels in collaboration with KIKK Festival, its Creative Hub and Fab Lab TRAKK and the cultural center Les Abattoirs de Bomel**

Anthropocene and how humans have influenced and driven the world to drastic changes. Their speculative and critical practice looking at the contemporary human condition aims to imagine possible futures and to define scenarios in which problems can be challenged through a fictional methodology.

They propose new possible future relationships between technology, nature and human beings, developing ideas of possible future coexistences, demonstrating how they can be a tool to better understand the present.

Ideas take the form of scenarios, starting from the open question "What if...?", and are aimed to be provocative and fictional, drawing inspiration from other fields such as literature, music, cinema, and science. One of the outcomes of their practice focuses on the relationships humans can build with other organisms, and how we can be part of a circular and human-decentralized system.

Through the question what-if, the fictional scenarios open debates and provocative discussion (Dunne and Raby 2013)

A diagram by the futurologist Stuart Candy illustrates different kinds of potential futures consisting of a number of cones fanning out from the present into the future, where each cone represents a different level of change. Probable, plausible, possible, and preferable futures help to explore alternative scenarios where the "reality can become more malleable and, although the future cannot be predicted, today we can set factors that will increase the probability of more desirable futures happening. And, equally, factors that may lead to undesirable futures can be spotted early on and addressed or at least limited" (Dunne and Raby 2013, 6).

The wearable speculative accessory *WeaReactor* suggests how to create a symbiotic relationship between human beings and living organisms becoming part of their biological process: a wearable tool intended to be an experiential object instead of just a fashion accessory. The accessory is an imaginary artifact that aims to draw attention to atmosphere quality, criticizes our attitudes, and questions our choices on how we want to deal with it.

Inspired by scientific research developed by the Institute of Food Technology and Bioprocess Engineering and the Center for Translation Bone, Joint and Soft Tissue Research of the Technische Universität (TU) in Dresden in 2015 (Lode et al. 2015, 75), it aims to depart from the aesthetic codes celebrated until now, seeking to build new awareness about living organisms by experiencing and wearing them differently and not as an accessory.

The work *Memory Matter* from 2020 shows how art and design can be mediators to build a collective memory aimed at educating thinkers for a post-Anthropocene world. Discussing the the climate change phenomenon of algal bloom and its connection with human beings' activities, it reclaims the urgency to question the reasons for this event and how it is devastating water ecosystems (Cavicchioli et al. 2019). The process of changing and the urgency to build a memory are conceptualized by employing the scientific technique of chromatography to build minimalistic patterns of algae pigments. The installation recreates a drastic scenario of algae eutrophication[5] and an experience that reconnects water bodies with humans, promoting a public discussion about how we are all connected.

5 Eutrophication refers to the increased input of minerals and nutrients into an aquatic system, typically nitrogen and phosphorus input from fertilizers, sewage, and detergents (Cavicchioli et al. 2019).

These works result from scientific research, some in collaboration with scientists and curators, as well as with universities, demonstrating how concepts and processes from the natural world can be adopted by a design intended for an entire system inhabited not only by human beings but also by other living organisms.

Why Working Together with Living Organisms?

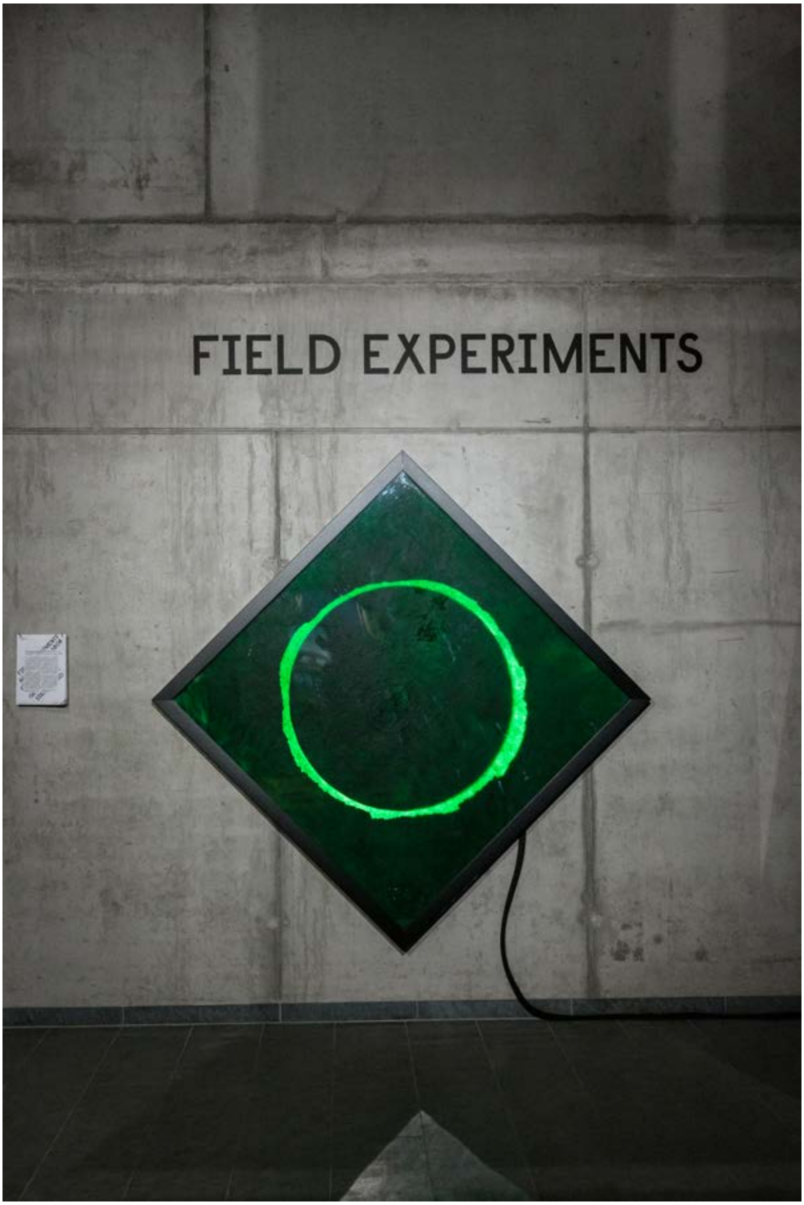
Working with living organisms requires a close collaboration with scientists and biotechnologists, adopting a speculative approach, and collaborating through the sharing of knowledges and spaces. The growth of knowledges and the rise of new techniques are, of course, positive aspects of this hybrid methodology, but something entirely new happens when artists and designers decide to work with living matter. They obey what their growing conditions demand, and this affects the timeline of a design process as it requires strong reconsideration.

This helps to define and to consider what a living organism truly needs, implementing its requests in an artwork or artifact with the aim of avoiding a hierarchical relationship.

6 **“Mind the Fungi” exhibition at Futurium Museum, Berlin. *Niche* and *Zweisamkeit,* ©Fara Peluso, 2020. A fungi and algae co-cultivation installation and a sculpture made of an algae- and fungi-based bioplastic. The projects were developed in collaboration with two departments of TU Berlin’s Institute of Biotechnology – Prof. Dr. Vera Meyer’s Department of Applied Molecular Microbiology and Prof. Dr. Peter Neubauer’s Department of Bioprocess Engineering – and with Art Laboratory Berlin for the collaborative project “Mind the Fungi.” Photos ©Tim Deussen**

7 **“Mind the Fungi” exhibition, *Niche*. An example of coexistence, ©Fara Peluso, 2020. Installation and living sculpture hosting a fungi and algae co-cultivation developed in collaboration with Prof. Peter Neubauer and Dr. Stefan Junne from TU Berlin’s Institute of Biotechnology and Art Laboratory Berlin for the collaborative project “Mind the Fungi.” Photos ©Tim Deussen**

8 *Living Canvas* by Fara Peluso, Field Experiments exhibition at STATE Studio Berlin, 2019. A speculative design project exploring the role of algae biofilm technology for future sustainable development. The project was developed in collaboration with Solaga and was supported by the Innogy Foundation for Energy and Society



Indeed, it is no coincidence that we are living in a time when an almost invisible entity like a virus is asking to coexist with us, to change our habits and social interactions

Artists and designers experience a partial loss of control over their previous practices, noticing how this will be strongly remarked on their new framework. When one decides to work with living organisms, a productive communication begins between the maker and the organic matter involved, going so far as to drive the aesthetic codes and the design timeline.

Between 2018 and 2020 I was part of the collaborative project "Mind the Fungi"[6] between Art Laboratory Berlin[7] and the Institute of Biotechnology TU Berlin, which I present here as an influential experience of mutual exchange between curators, scientists, artist, engineers, designers, and the public. It was a two-year citizen science cooperation, Art and Design Residency program and scientific research, dedicated to local mushroom research and current fungal biotechnology through the STEM to STEAM (Science, Technology, Engineering, Art, Mathematics) program aimed at expanding scientific research with artistic and design methodology.

While Theresa Schubert studied the effects of sound on fungal growth developing the interactive video installation *Sound for Fungi: Homage to Indeterminacy,*[8] I based my research on new biomaterials inspired by the symbiotic relationship that algae and fungi have in lichens, therefore combining nature, biotechnology, and art. I developed a new bioplastic material named *mydia* with which I designed the sculpture *Zweisamkeit*, assembling two topographies made of oak wood and bioplastic.

> I think the tree is an element of regeneration which in itself is a concept of time. The oak is especially so because it is a slowly growing tree with a kind of really solid heartwood. It has always been a form of sculpture, a symbol for this planet ever since the Druids, who are called after the oak. Druid means oak. They used their oak to define their holy places. I can see such a use for the future [...] The tree planting enterprise provides a very simple but radical possibility for this when we start with the seven thousand oaks. (Beuys and Demarco 1982, 46)

My research was based on studying the concept of coexistence inspired by the lichen organism to develop the hybrid installation and living sculpture *Niche*.

6 The Art + Science Research Project "Mind the Fungi" is a cooperation between Art Laboratory Berlin and the Institute of Biotechnology TU Berlin. Team: Prof. Vera Meyer, Bertram Schmidt, Carsten Pohl (Dept. Applied and Molecular Microbiology), Prof. Peter Neubauer, Stefan Junne, Zakieh Zakeri, Martin Drostert (Dept. Bioprocess Engineering), Regine Rapp and Christian de Lutz (ALB), Theresa Schubert (artist, Berlin), Fara Peluso (artist and designer, Berlin), Alessandro Volpato, Flavia Barragan, and Tuçe Erel (TOP Lab, Berlin).

7 Together with the expertise of applied and molecular microbiology in the field of fungal biotechnology (Prof. Dr. Meyer), bioprocess development (Prof. Dr. Neubauer), the artist Theresa Schubert, Fara Peluso and citizens from Berlin, Art Laboratory Berlin developed new ideas and technologies for fungal- and lichen-based materials of the future.

8 Theresa Schubert's *Sound for Fungi: Homage to Indeterminacy* (2020) "is a generative video that simulate hyphae's growth and via hand tracking sensor allows people to interact with these. Thus, a visitor can take on the role of a sound frequency modulating the hyphae growth in real time and move through the network" (Schubert 2020).

The sculpture, designed in close collaboration with the bioprocess engineers at the TU Berlin Institute of Biotechnology, is the result of a study about the coexistence in co-culture of algae and fungi and how an ecological niche can maintain diversity between two organisms under a specific environmental condition. The installation has been conceived following the co-cultivation protocol developed by the department, in collaboration with Prof. Peter Neubauer and Stefan Junne, with the aim to bring together design, art, science and technological knowledge to show how the algal and fungal organisms work together and raise questions about how we can be positively influenced by integrating them into our daily existence (Rapp and de Lutz 2020, 80–88). The *Niche* sculpture also questions how new objects and landscapes can coexist through the embodiment of living organisms as “currency” for the establishment of a new way of living together (Rapp and de Lutz, 2018–2020).

The development of this new practice, which introduces materials and knowledge from science, can be the way to create new understanding and awareness by changing the opinions people have about microorganisms, which are often considered annoying and meaningless. The project *Living Canvas* (2019) is an example of how it could be possible to reinvent a photo-bioreactor, a device normally used in science and industry as a system for growing microorganisms, transferring it to an artistic and public context to provoke thought and discussion.

Living Canvas suggests a solution for how to find a balance between human beings’ needs and the desire to consume, considering the problem of our planet’s limited resources, and developing the idea that our machines should start to come to life and help change our view of the future. In the end, it will be possible to integrate them into our daily spaces and routines as “supporting life devices.”

The use of living machines will contribute to changing our cities and landscapes not only in terms of architecture, but also questioning what relationships our cities will have with the environment.

> ***There’s hope that our cities will become more like entities, nuclei totally connected to the whole system (Brain City Berlin, 2019)***

Before engaging in the design process, it is important to first question which relationships we want to build in relation to

9 *Le Chateau de Pyrenees*, by Rene Magritte, 1959 Belgium. This artwork was chosen by Italo Calvino and his publisher for the first edition of Invisible Cities novel in 1972. Oil on canvas, The Israel Museum, Jerusalem

10 *Algature* workshop by Fara Peluso at STATE Studio, 2019 Berlin. *Algature* is a participatory workshop where participants learn how to grow algae and rethink everyday routines through the knowledge and practice of speculative design and DIY biology (courtesy of the artist, ©Anne Freitag)

desired futures. A future where cities can become more promoters of connections between people, their ideas, and the environment rather than supporting isolation and exclusion. Today the problems are potentially solvable in our attitudes and choices as human beings, as the ones directly responsible for our social conditions, climate changes, and the exploitation of natural resources. Therefore, the speculative approach is a method that prompts a lesson and explores the present – it helps us to understand the reality, to become critical thinkers, and to be open to new solutions. Furthermore, it also creates space for thinking poetically, inspired by different media, for example from the realm of literary fiction.

Invisible Cities by Italo Calvino (1972) represents an important metaphor and lesson for my practice. Experiencing it as a holistic lecture, it reflects how human beings should behave towards the natural environment, questioning what it means today to build and to experience our cities. A collection of pieces that don't fit conventional architectural writing, it goes beyond the consideration of cities as containers with their own boundaries and functions[9] – it's an intricate experience where ideas of time, identity and language are fluid and interconnected with each other. The novel gives nature a central role in the relationship between cities and their inhabitants, showing how natural elements are the driving forces that shape architectural typology as well as the relationship between the cities and people. One example is *Isaura*, the city of many wells built over a deep lake, where inhabitants dig long vertical holes in the ground and draw up the water, as far as the city extends.

> The city's gods, according to some people, live in the depth, in the black lake that feeds the underground streams. According to others, the gods live in the buckets that rise, suspended from a cable, as they appear over the edge of the wells. (Calvino 1972, 20)

I consider "The city's gods" a call to destroy the walls we've built between ourselves and nature by going deeper and understanding how to become all complicit, human and nonhuman, by dictating a new coexistence. Considering this, I believe that the cities of the future can be shaped in the interest of biology not only by architects but also by scientists, designers, artists, and engineers, all working together with a common goal of renewing the way we see the world rather than changing it. Including other forms of life in a context other than scientific laboratories and integrating new devices to keep them alive will contribute to creating a new awareness about other living organisms, understanding that we are part

9 Italo Calvino's *Invisible Cities* is a novel and a collection of 50 fictional cities, written in 1972 and published in Italy by Giulio Einaudi Edition. Every city has the name of a woman described by the Venetian traveler Marco Polo to the emperor Kublai Khan through a magical language. Calvino declares that all cities stem from one foretype, and Marco Polo through his descriptions proclames that city is his native Venice, but the whole idea is that all variants are the result of many layers of a single city always in construction and metamorphosis.

of the biodiversity that surrounds us, and opening ourselves towards more sustainable living. Our cities can be designed to house living machines, an action to merge and connect different ecosystems by reducing the distance between the human and non-human spheres. Bioreactors, incubators, hydroponic cultivation systems, greenhouses and green facades can be introduced into our daily spaces, helping to break down boundaries between inside and outside, between design and science, between humans and nature.

In support of this the project *Algature* (2017) started with the aim of connecting my artistic design research with a DIY biology practice, a "do-it-yourself" biology that explores possible interactions between different fields. DIY biology is a new and growing biotech-social movement where individuals, small organizations, artists, designers, and biologists are studying and working with life science outside the classic consolidated environments, sharing methods and exploring new ones. Thanks to this, the *Algature* workshop encourages collaborations in which the public is also involved and can learn about science, discovering how powerful the combination of different approaches can be. Through a participatory format, the audience of different backgrounds, from the curious to professionals, are involved in an immersive experience with algae's ecology and a DIY photo-bioreactor design prototyping. Important is the discussion on speculative practice to raise a new awareness of daily habits considering a new way of approaching living organisms.

The workshop raises questions such as how can closeness to living organisms give us economic, political, and artistic contributions? The introduction to the speculative design combined with the DIY methodology can be an occasion to study some objects, and by stimulating critical questions it will help to define a new possible generation of tools.

Supporting ecosystems, for example novel algae aquacultures, it will contribute to sustainable production rather than reinforce human practices based on resource extraction and exploitation of the natural landscape. *Algature* proves how the sharing of different knowledges, and the discovering of unknown organisms, is a central aspect—combined with a thinking by doing, it contributes to shaping critical minds. In this way the public, actively understanding about design, art, biology, and DIY, can intervene in aspects of fundamental importance linked with our contemporary and future existence. They understand why it is meaningful today to be an active part of a system by

11 ***Theca: The Function of the Invisible*** **by Fara Peluso 2022. The installation was developed in collaboration with Cultivamos Cultura and Dr. Giulia Ghedini from the Gulbenkian Science Institute Oeiras, Lisbon**

manipulating the factors that have affected and shaped our habits, our society, and our choices.

Democratic Artifacts

Education in critical thinking is an important antidote to the conformism that is increasingly predominant – it is an important ingredient for accepting diversity, other points of view, and for becoming democratic and empathetic. Bruno Latour's article "Which politics for which artifacts" provides an interesting example of how artifacts and politics can be linked. He talks about the story of a bridge built in New York in the 1960s by urban planner Robert Moses when he wanted to redesign the city's parkways to reach his beloved Long Island beaches (Latour 2004).

Speculative practice and its artifacts have great social, relational and political value because they can be a powerful tool of influence

At that time Moses wanted to make sure that the bridges that gave access to these areas and the recreational parks were low, so that buses could not get there, only private cars. However, there were people who lived in discrimination and poverty, they didn't have enough money to own private cars, and many of them were also Black. As Moses worked without any apartheid law, without even an appearance of impropriety, he helped to create a racist operation through the design of a bridge. This is an example of how designers can sometimes use deviations through material objects to impose types of behavior. This doesn't mean that only oppression and discrimination are expressed through certain objects, but that they also "allow" us to do things.

We do things we would not have done otherwise every time we enter into contact with an artifact [...] Thus to say that our ordinary course of action is intermingled with artifacts does not mean that they have politics – at least not yet. (Latour 1972, 50–51)

Speculative practice and its artifacts have great social, relational and political value because they can be a powerful tool of influence for individuals but also for "powerful politicians" whose role is to somehow decide the fate of our planet and society. Speculative artifacts have a democratic and emphatic value because they can set and help to understand what directions and solutions post-Anthropocene[10] life should take.

10 I consider the post-Anthropocene as the claim to envision the era after the Anthropocene where a non-hierarchical system among all species is present, the human activities are no more predominant and not exploitative of the natural landscape but rather in support and maintenance of biodiversity and ecosystems.

The project *Theca: The Function of the Invisible* is a result of a complex methodology that embodies the intertwined systems in which we live. It borrows the concept of coexistence from the scientific research of Dr. Giulia Ghedini, leader of the Functional Ecology Group at the Gulbenkian Science Institute Oeiras in Lisbon. It exists through the coexistence of separate micro-algae and their maintenance through the interaction and the exchange of information between analogue and digital, organic and inorganic matter, and living and non-living entities. It's another example of how the creation and the prototype, rummaging through micro- and macro-scales and their traditional perceptions, can contribute to reconsidering our environment through the development of new types of objects and living machines.

Theca, with its "cyborg"[11] identity, asks: What is behind the design of an artifact? Is there only an aesthetic and functional intention or are there also ideological and social aspects that help to define and complete it in relation to its use? Can an object influence our existence to such an extent that we make certain decisions rather than others, thus helping to define our consciousness?

11 Through the philosophical work of Donna J. Haraway on human–machine and human–animal relations I share the idea that a "cyborg is a cybernetic organism, a hybrid of machine and organisms, a creature of social reality as well as a creature of fiction" (Haraway 1985).

As a speculative designer and bio-artist I believe that I'm a creator of questions before I create objects, and that the tools I create must be able to make a critical contribution and help to reconsider human habits and consciousness (Mitrović et al. 2021).

I adopt practices of caring and resilience from nature as ecofeminist actions aimed at repairing the ecological disasters of the culture of capitalism by contributing to building new models, and supporting "the human species to escape from death, maintaining biodiversity and continuing to have a future."[12] The design for future coexistence is my hybrid practice, which stems from these philosophical investigations to develop a transdisciplinary methodology where speculative design implements caring and resilience from nature.

12 Ecofeminism was coined by French feminist Françoise d'Eaubonne in 1972. She launched it as a new action by publishing her book *Le Féminisme ou la Mort* in 1974. The book was translated into English as *Feminism or Death* (d'Eaubonne 2022).

Therefore, through this practice I am affirming that the object is not the solution, but rather represents and indicates it, as an instrument of contemplation or even as a "thinking" object. In conclusion, I question: What can the relationship between said object and its environment be today? How can an object today contribute to envisioning a possible post-Anthropocene scenario of coexistence between human and more-than-human?

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Careful Practices

ESSAY

Stop Mixing Materials:

Mono-Material and Variety

Lea Schmidt

The ever-increasing material complexity in our artifacts is a crucial obstacle in pursuing material circularity. If artifacts consist of one single material, they can be more or less directly put back into a material cycle. Therefore, reducing material complexity in our artifacts – in the best case, the reduction to a mono-material approach – is economically and ecologically attractive. From a designer's point of view, a reduction to a single material in artifacts might be, at first sight, unattractive, as designers use different materials to achieve aesthetic or functional contrast in artifacts. In a restriction to a single material, however, a closer look reveals an exciting field for design. A wide range of aesthetic and functional variety can be achieved with a single material using specific design strategies. In developing these appropriate design strategies, looking at nature's mechanisms for achieving variety and circularity is insightful.

Keywords: Mono-material, material complexity, material circularity, design

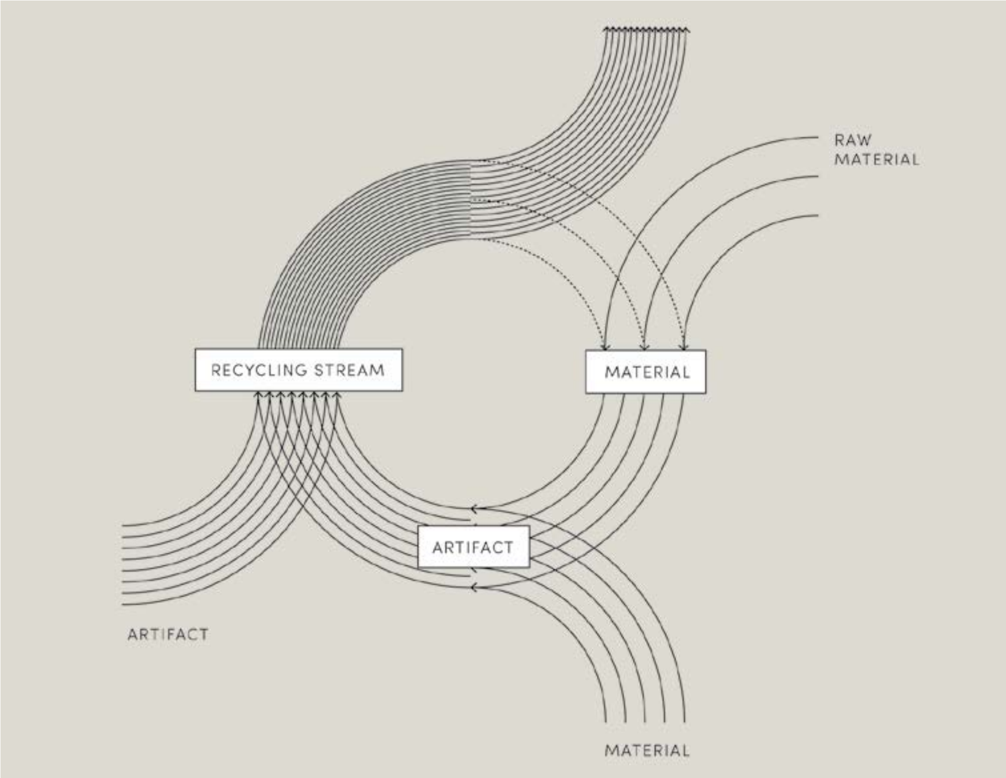
Gatherings of materials in movement are what we call things.—Tim Ingold

Material Complexity as a Constraint in a Circular Economy
Whether it is a smartphone or an outdoor jacket, or even simpler artifacts like a toothbrush or take-away packaging, the majority of our artifacts are complex conglomerates composed of a wide variety of materials. Very seldom do they consist of a single material. M. F. Ashby, a materials scientist, estimated in 2004 that designers have a choice from between 40,000 and 80,000 materials (Ashby et al. 2004). Most of these 40,000–80,000 materials are already composites, made up of various raw materials. This wide variety of materials used in our artifacts is primarily a development of the last few decades (Greenfield and Graedel 2013; Stahel 2019). Smartphones exemplify this development of increasing material complexity in two ways: firstly, more and more different chemical elements are being used. The first commercial mobile phone of its kind, Motorola's DynaTAC 8000X, launched in 1983, consisted of 35 chemical elements. In 2018, 35 years later, our mobile phones consist of between 65 and 70 elements out of the 118 elements in the periodic table (King 2019). Secondly, the proportion of individual materials is becoming smaller and smaller: according to Brian Merchant, an iPhone 6 with a total weight of 129 grams contains, for example, 0.01 grams of arsenic, 0.014 grams of gold, and 0.02 grams of bismuth (Merchant 2017).

Utilizing an increasing number of different elements and increasingly small-scale use leads to an ascending material complexity of our artifacts. In a linear "take-make-waste" system, material complexity is secondary—at the end of their life cycle, the artifacts are typically landfilled or incinerated. Deconstruction of these material conglomerates is not foreseen. In linear systems, artifacts are designed as if the lifetimes of material and artifact were equal.

Contrary to linear systems, material complexity is a significant constraint in a circular economy model. In a circular system, the lifespan of materials is intended to be longer than the lifespan of the artifacts. As the last step in a circular economy, materials should be recycled after all preceding value-retention options are exceeded. Recycling requires a dissection of the different types of materials combined in an artifact to extend the life of the materials beyond the artifact. A dissection

1 **Ever-increasing material complexity from raw materials to recycling streams. Source: adapted from "Kreislauf der Werkstoffe" (Hornbogen, Eggeler, and Werner 2019) and "Technical Circle" (Braungart and McDonough 2002)**



of materials is only possible, however, if one knows which materials these artifacts consist of and if a process exists for dissection into their different materials.

Typically, at the end of the life cycle, all these multi-material artifacts are collected in recycling streams – for example, all textiles or all electronic artifacts. In these recycling streams, the material complexity multiplies again. The ever-increasing material complexity along every step from raw material to recycling streams results in a disproportionately high dissection effort. These numerous micro-material flows must be brought together along with complex logistics. Furthermore, a high level of material complexity at the end of the life of artifacts has an economic aspect: "[…] new material combinations push waste management costs ever higher" (Stahel 2019).

Mono-Material as a Design Strategy

The design strategy of using one single material can reduce these challenges of material complexity and further support maintaining material purity at a desirable level, as material purity is linked to quality in secondary raw materials. A mono-material design approach is therefore apparent. The term mono-material is well known in design and has been increasingly mentioned in sustainability discourse in recent years (Carlsson 2017; Ellen MacArthur Foundation 2017; Vezzoli 2018). However, the term mono-material is not unambiguous in materials science – because materials used in the design field are not pure elements but primarily compounds. Nevertheless, the abandonment of increasingly complex composite materials and artifacts is discussed in materials science due to the challenges of fractional processes (Hornbogen, Eggeler, and Werner 2019; Welsch, Schwab, and Liebmann 2013; King 2019).

The Ellen MacArthur Foundation puts it very clearly: sorting in recycling is very complex (Ellen MacArthur Foundation 2017). If we only have one material, sorting is much more manageable; in best cases, a product can be brought quite directly back into the material flow. An infinite cycle cannot be guaranteed though, because even materials continuously fed into a homogeneous material cycle usually lose quality. While these quality losses can hardly be avoided by design, designers can influence the quality loss caused by material complexity.

Designers use different materials to achieve a specific functionality or a particular aesthetic in artifacts. Laetitia Forst describes the reasons for mixing different materials in textile design as follows:

> Across history and different sectors of the industry, blends can occur for a variety of reasons. These are often connected to the performance of the materials, either to increase or balance the characteristics of the different components or with a consideration for cost and production optimization. [...] Beyond considerations for the technical properties of a material or textile, blends also may occur from a desire to achieve aesthetic effects or motifs by contrasting textures or colours as part of the same fabric. (Forst 2019)

This description can be transferred to other design fields by example. Consequently, the principle of mono-materiality is unattractive from a designers' perspective as it initially seems to result in a limitation in the sense of Forst.

However, in this limitation, designers' competencies of differentiating and defining contrasts that bring aesthetic or functional benefits to artifacts are needed, but from a new perspective: How can a wide variety of contrasts be achieved in one single material? How can functional requirements still be met?

Living Organisms as a Model for a Mono-Material Approach in Design

With a mono-material design approach in mind, the question arises of how living organisms, such as plants and animals, can achieve such abundant variety with simultaneous circularity. Given the complexity and diversity of living organisms, one might assume that they consist of diverse, highly complex multi-material mixtures that use the entire periodic table. However, living organisms use far fewer elements than many human-made artifacts while achieving endless variety. Material scientist Alexander H. King investigated how nature utilizes materials in living organisms. He assumes that almost all life forms on Earth are based on only 29 periodic table elements – from the simplest to the most complex (King 2019).

While the material complexity of human-made artifacts increased alongside technological development, evolution in living organisms did not require any additional elements for its further development:

> Evolution seems to add functional complexity without adding significant elemental complexity. Using only a few building blocks, the biosphere is a triumph of diversity and complexity far beyond anything created by any human engineer. (King 2019)

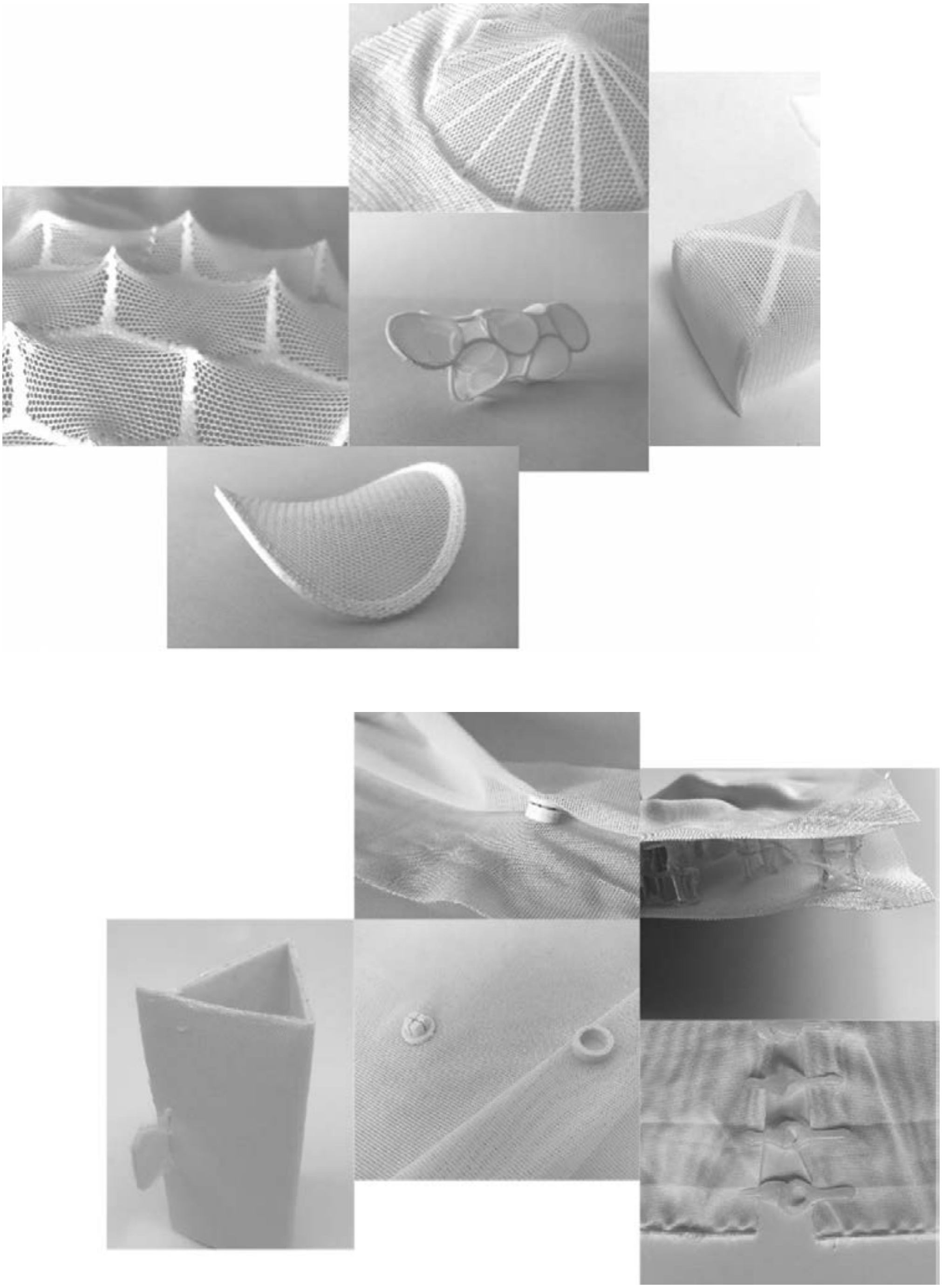
As Michaela Eder and her colleagues describe, living organisms cannot use a free choice of materials to design a system; they generate it from the available supply of basic materials. For a constantly renewable system, it is essential that organisms draw on the same building blocks. The diversity of properties and functions of organisms is due less to a diversity of compositions of many materials than to a diversity of structures (Eder, Amini, and Fratzl 2018).

Mono-Material Design Approach in Practice

How can the goal of mono-materiality and, at the same time, a wide functional and aesthetic variety be realized in concrete terms in design? The mono-material design approach has been developed in an interdisciplinary feasibility study launched in 2020 by the research group Product and Textiles at Lucerne University of Applied Sciences and Arts, in collaboration with

2 A series of experiments focusing on the achievement of variety within a mono-material design approach (Photo: Research Group Product and Textiles, "3D-Printing Textile Waste", 2022)

3 A series of experiments focusing on the achievement of variety within a mono-material design approach (Photo: Research Group Product and Textiles, “3D-Printing Textile Waste”, 2022)



Eastern Switzerland University of Applied Sciences and Bern University of Applied Sciences and Arts. Using polyester as an example, the study shows how diversity can be achieved in a single material.

In a first step, polyester textile waste was collected. One part of the collected waste polyester was processed using additive manufacturing technology, leading to a material with solid characteristics. The other part of the waste is used as a textile substrate; in that form, polyester has a flexible characteristic. These two characteristics are combined in one artifact—fabric and additively manufactured applications bond without adhesives by melting together during the additive manufacturing process. As a result, mono-material artifacts are generated. Due to a mono-material design approach, material recovery in later recycling operations is supported, as no additional material has been added. The contrast between the solid application and flexible substrate is the underlying design principle. Combining flexible fabrics with different solid application structures opens up a wide range of potential mono-material applications in, for example, fashion, consumer products, sportswear, or protection wear. Besides aesthetically motivated finishes in textiles, solid applications can replace functional parts in apparel, such as fasteners or protective parts often made of different materials. Further, small applications of solid material on the fabric can define pleats or gatherings or control the artifact's flexibility and movement to achieve aesthetic or functional effects.

The feasibility study illustrates two aspects. Firstly, as a precondition for the intended material circularity, the study demonstrates the technical feasibility of a basic material circularity while converting polyester textile waste into a filament for additive manufacturing processes. Secondly, it shows how we can gain variety in one single material—in this case, the contrast of solid application and flexible substrates was chosen to achieve a wide design variety.

Handling Materials with Care

Resources are finite—we have to handle materials with care. As a last option after the previous value-preserving or avoidance principles, through recycling materials should outlive the artifacts they were part of. The goal of recycling is a preservation of resources so that they stay close to their original state (Reike, Vermeulen, and Witjes 2018). According to the Circularity Gap Report 2023, the global economy is now only 7.2% circular (Circle Economy 2023). Therefore, much material is burnt and irretrievably lost. In 2018, Ellen MacArthur was quoted in the *Financial Times* as saying: “We have not been successful at recycling. After 40 years of trying, we have not been able to make it work" (Hook and Reed 2018). While humans seem very good at designing new materials and combining them into high-functioning artifacts, dissection of these artifacts and handling the resulting complex waste streams seems to be mainly unsolved. The mono-material concept is quite simple: what is not combined does not need to be dissected.

When it comes to a mono-material approach in product design, there is a strong association with monoculture. By examining the aspects of material complexity and diversity/variety, comparing the use of mono-material in product design to monoculture in cropping systems can offer valuable insights. However, it should be noted that this comparison is not exhaustive or definitive. Why is the mono-material design approach promising for achieving better material circularity, while the negative effects of monocultures in agriculture are becoming more apparent?

Especially in sustainability discourse, monoculture cropping systems[1] have recently come under criticism. According to McLennon et al., they play a crucial role in, for example, land degradation.[2] In contrast to monoculture, regenerative agriculture is characterized by crop rotation and high biodiversity in and above the soil. The overarching goal of regenerative agriculture is to maintain and support the natural biogeochemical cycle (McLennon et al. 2021). The biogeochemical cycle copes with diverse crops and organisms; the high biodiversity is even described as an advantage. The presence of a wide range of organisms is considered crucial for maintaining the stability of the biogeochemical cycle.

Unlike biodiverse crops, monoculture involves planting only one species. The uniform rows of monoculture plantations represent the opposite of diversity, and disrupt the stability of the biogeochemical cycle (Liu, Kuchma, and Krutovsky 2018). Diversity is necessary for the proper functioning of the biogeochemical cycle.

In recycling, we are far from an integrated, well-balanced system comparable to the biogeochemical cycle in a regenerative agriculture system. We are trying to build *isolated* recycling cycles for *isolated* materials. Reducing material complexity may support these isolated recycling cycles and therefore support highly needed material circularity on a technical level. Starting from these isolated material cycles, we can build a wide variety—taking inspiration from the fact that

1 Monoculture cropping systems are characterized by the cultivation of a single plant species over several years on the same soil.

2 "Monoculture plays a key role in land degradation (Pacheco et al. 2018) which over time develops into a myriad of other environmental (e.g., reduction in land productivity, soil erosion, water quality deterioration, loss of biodiversity, and dysfunctionality of ecosystem etc.) problems" (McLennon et al. 2021).

living organisms display considerable diversity despite being composed of only a few elements, as previously shown.

Within a design approach that is limited in material complexity or even focuses on a single material, a shift occurs. As a result, functionality or aesthetics are not integrated into artifacts through a complex mixture of materials any more. Instead, functionality or aesthetics can be integrated through a clever and complex application of structures and forms and/or a combination of different technologies. This means using the scope of action from the design perspective within a given material cycle. From the design perspective, achieving functionality and aesthetics with limited materials is an exciting task. Digital manufacturing technologies continue to evolve, and functional structures in nature continue to be explored. In this sense, new technologies and expanded knowledge can support us in achieving high functionality and aesthetics in artifacts using fewer materials in the future.

A mono-material design approach does not apply to every artifact. Nevertheless, material complexity can be reduced to some extent for many. Furthermore, confronting material complexity in our artifacts can lead designers to a new way of thinking in terms of “handling materials with care.” A mindset that is in some respects more modest: the benefit of four different materials in a toothbrush – with a lifespan of three months – is in no proportion to losing all four materials forever because it is almost impossible to separate them.

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ESSAY

Designing Performative Surfaces:

A Textile Approach to Active Architectural Facades

Maxie Schneider and Ebba Fransén Waldhör

The research project Adaptex investigates the potential of using the shape-changing material shape memory alloy (SMA) in an adaptive sun-shading textile for architecture. By incorporating SMA as an actuator into a textile membrane, the permeability of a surface can adapt in response to temperature changes in the immediate environment. The aim is to create a responsive textile system that prevents the interior of a building from overheating, without the need of electricity or external controlling mechanisms. In an interdisciplinary and material-driven design process, the project explores how the structure of textiles – the interweaving of filaments – can be utilized for the integration of active materials such as SMA, in order to create a material system where the actuator, the textile, and the environment work together to form a resilient, cyclic movement. This paper describes the process of developing the prototypes. To a large extent, the active materials guided the experiments and developments, meaning that the behaviour of the material became a driving force in the design process. This focus on the processual, adaptive and active qualities of material structures opens up the creation of new forms of design and can contribute towards a more integrative, resource- and climate-conscious building culture.

Keywords: Textile facades, active materials, shape memory alloy

A Textile Approach to Active Architectural Facades

Global warming requires a paradigm shift in architecture: both in architectural construction and in the energy management of buildings. As the climate gets hotter, the need for thermal protection of occupants and infrastructures from heat stress is becoming increasingly urgent and the use of cooling technologies is expected to rise. However, conventional cooling systems require large amounts of energy, and currently account for nearly 20% of the total electricity used in buildings around the world today (The International Energy Agency 2018). Shading strategies that deflect sunlight before it enters a space are considered the most efficient method to prevent overheating. Throughout history, textiles have been used for this purpose, and there is a wide range of textiles and textile systems for shading. As exterior architectural façades, textiles offer several advantages as they are lightweight and allow for a large degree of flexibility in application.

By adding further adaptability to textile façade systems, their permeability to solar energy can be changed in response to different thermal requirements. In the last two decades, developments in this area have shifted from mechanical control mechanisms to digitized approaches. In parallel, a new understanding has emerged through the synthesis of materials engineering and design, where the facade becomes adaptive through active materials that respond autonomously to environmental conditions (Kretzler and Hovestadt 2014). The use of SMA as an actuator for kinetic sun shading has been increasingly investigated, especially in attempts to replace motorized control systems of shading devices.[1] In addition to these approaches, which often use rigid panels, soft mechanisms of foils or textiles have also been discussed. However, most of these projects have remained in the conceptual and experimental stages. In the area of architectural textiles, the use of SMA is still relatively unexplored, but a number of experimental approaches have shown promising potential.[2]

The objective of Adaptex is to develop a performative textile that can make autonomous structural adjustments within a textile surface, with the help of integrated SMA. SMAs are engineered metals that can change into a previously defined shape when a certain temperature is reached, due to a phase change in the molecular lattice structure of the alloy (martensite and austenite). In the form of flexible wires, they can be incorporated as linear actuators into textile structures. The idea of Adaptex is to use their thermomechanical properties to close a textile surface when the solar radiation and ambient temperature is high to provide shade, and to open it

1 The project Harvest Shade Screens, for example, uses an SMA wire to control multiple louvers (Grinham, Blabolil, and Haak 2014). Decker and Yeadon (2014) similarly employ SMA to control a vertically moving screen system. The project Air-flow(er) uses two sets of counteracting SMAs to individually control multiple rigid panels (Payne and Johnson 2013). In the Chameleon membrane, a perforated multilayered design, SMA springs shift single layers individually (Deniz 2014).

2 The project Blind anchored SMA springs within an elastic membrane with eye-like openings (Khoo, Salim, and Burry 2011). Finnsdóttir and Sauer (2014) developed a full-scale mock-up with SMA-controlled umbrella-shaped textile elements.

up when solar radiation and ambient temperature is low—to allow for natural light, ventilation, and view (Schneider et al. 2021). Due to their inherent sensing capabilities and small size, SMAs can supersede complex motors, driving mechanisms, and control systems. Thermally activated by solar energy, they eliminate the need for energy consumption in operation.

Rather than substituting mechanical or motorized components of existing sun shading systems with SMA, the aim in Adaptex was to directly integrate SMA wires into a textile surface structure. Due to the one-way shape-memory effect of the SMA, the wire needs to be mechanically returned to its original shape before it can be activated again. Instead of separating the functional elements into actuator (SMA) and passive body (textile), the textile is given actuating agency to elongate the SMA once the temperature cools down. This textile integration enables an intrinsic and cyclic movement sequence of opening and closing, whilst at the same time reducing components and overall complexity.

Furthermore, textile technology allows for an exceptionally high degree of configurability; depending on the textile structure, completely different mechanical properties can be achieved with the same fiber material. This variable adjustability of performance characteristics makes textiles especially suitable for the integration of active materials. Textile technology also enables the transfer of the small-scale SMA wire to the architectural scale, as textiles can be produced to cover large areas and spaces.

Textile, here, is not a firmly defined material, but rather describes an open system and strategy for joining linear elements that connects different materials through various construction techniques (weaving, knitting, crocheting, knotting, felting, bonding). The defining feature is that the filament-shaped elements are interlocked in various ways, creating bonds that are more or less secured. This structural openness allows experimentation with a wide range of possible surface properties. Understanding textile as a material strategy allows the transfer of active materials such as SMA into new scales and contexts (Sauer 2019).

An Interdisciplinary Process

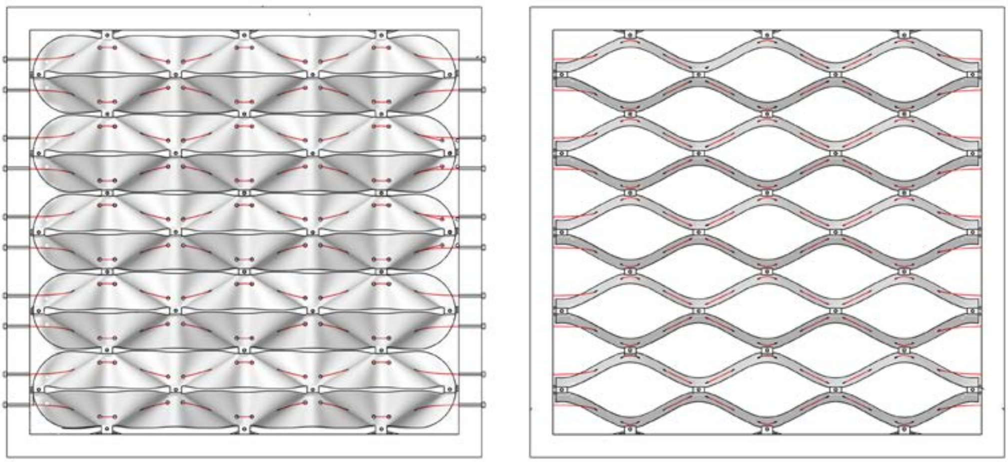
The research was conducted as a collaboration by an interdisciplinary team from the fields of architecture, textile design, facade engineering, textile fabrication, and smart textile engineering. The close cooperation from these different contexts ensured the alignment of all relevant parameters, which were compiled in a visual matrix. The matrix categorized the most important properties and requirements from SMA technology, textile design, building envelope construction, and architectural application. The matrix was used to conceptualize possible use scenarios and to evaluate and compare them with each other (Denz et al. 2021) using criteria defined by the different disciplines (such as industry standard requirements). Further criteria were defined specifically for the project — for example, to use the SMA in moderation (with regards to the negative environmental impacts of metal mining), not to train the wire into a form by exposing it to high temperatures (as this requires an additional expenditure of energy), and utilizing the SMA in a longitudinal direction (as this enables a higher force as well as higher amount of cycles, compared with SMA that is deformed geometrically, such as springs).

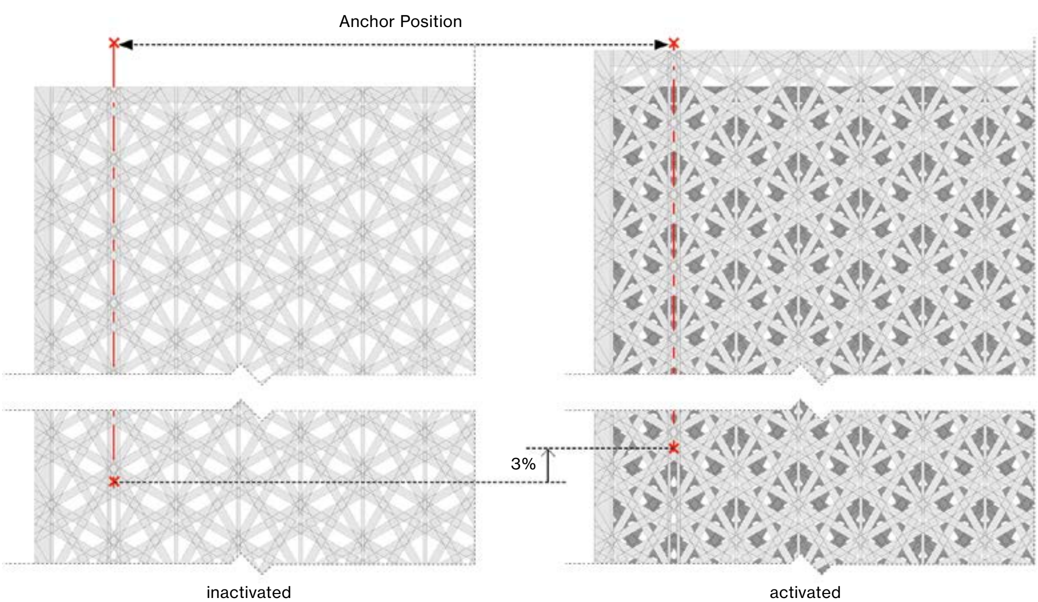
At the intersection of this collaborative process was the design discipline, weaving together knowledge and requirements from the other disciplines into a material prototype. In an iterative process between designing, modeling, and testing of smaller-scale demonstrators, the combination of functionality with aesthetic values was emphasized. Instead of working on a design prototype as a means of validating an already formed hypothesis, the research evolved through variations of different solutions where form and meaning were continually re-adjusted and informed each other.

Physical Prototyping

In this material-driven approach the design process was guided largely by the possibilities and constraints of the materials. By observing and experimenting with various SMA wires in combination with textile fiber structures, the material interactions became the focus of the design process. In the initial prototyping stage, the geometrical transformation of the shading textile was explored by designing various opening and closing mechanisms. With SMA contracting in a range of only 3–5% when activated, the challenge was to design a system in which the actuator makes the shading area expand and collapse by a significant percentage. In a series of fabric models, potential movement sequences were tested for their shading efficiency and aesthetic appearance. This was done with low-fidelity prototypes: by sewing, gluing, and taping different fabrics with varying degrees of elasticity, weight, and softness. This creative investigation did not follow a strict protocol but was rather an open-ended process that allowed elements such as curiosity, chance, and intuition to be integrated into the design process.

1 Technical drawing of Adaptex Wave in its closed and opened state, showing the placement of the SMA in red. (weißensee school of art and design berlin)
2 Technical drawing of Adaptex Mesh in its opened and closed state, showing the placement of the SMA in red (weißensee school of art and design berlin)





The prototypes were then evaluated by the team according to the defined target criteria (technical suitability, aesthetics, functionality, and feasibility). Two motion principles were chosen for further development: the elastic bending of a textile band and the vertical, planar sliding of a screen.

In the first concept, "Adaptex Wave," textile bands are interwoven over their entire length with SMA wires. The initially flat bands curve along a cable net as they are attached at alternating points. When sunlight increases the ambient temperature, the integrated SMA wires heat up and contract by a few percentage points. The contraction of the activated wires creates a force that gradually causes the textile band to buckle into a closed position. As soon as the temperature drops again, the elastic band returns to its original state and the system opens. The result is a surface that changes gradually and reversibly.

In "Adaptex Mesh," two membranes with identical perforations are aligned in front of each other to provide maximum permeability. As one of the membranes slides vertically with the help of integrated SMA, the overall permeability of the total surface decreases. As the temperature drops and the SMA cools down, the weight of the membrane itself moves it back to its original position.

Designing Material Properties
Once these concepts had been selected, the task was to implement them in a concrete textile construction. In terms of materials, the constraints of the industry standards (requirements on durability, ultraviolet stability, fire retardancy) narrowed the possible options. In both concepts, the required material properties to reach an equilibrium of forces between textile and SMA are largely achieved through form and textile construction.

In "Adaptex Wave" the degree of softness/rigidity of the textile can be adjusted to the SMA by adding or decreasing layers of lamination to the textile and the required strain of the band can be fine-tuned through its geometry. The flat textile is cut using waterjet technology, into a pattern that when assembled, takes on a bent and strained form. Starting from simple, paper-based geometric prototypes, the system layout was digitally modeled to obtain the optimal geometry in terms of shading angle and openness factor. The elasticity and bending behavior of different textiles, in relation to the positioning of the SMA, were explored physically and fed back into a digital 3D model, revealing relevant correlations between material properties and geometry.

In "Adaptex Mesh" the textile receives its ability to sustain the force of the SMA through the alignment of the filaments and the mass of the textile. The initial prototypes were made with woven, orthogonally structured fabrics. This proved to be challenging as the dimensional stability of woven open-mesh fabrics is low, meaning that the production of two identical textiles, especially on large industrial looms, is unfeasible. If the two membranes have slight differences, the shading efficiency is diminished and unwanted moiré patterns appear. Furthermore, the undulating filaments in a weave (the warp and weft going over and under each other) creates points of friction between the perfectly straight SMA (in its activated state) and the other textile fibers. These reasons prompted a rethinking of the manufacturing process towards a multi-axial, non-crimped fabric. In this textile technology, uni-directional filaments are layered and positioned in different orientations to achieve structural stability while maintaining the best strength-to-weight ratio. This way, the interplay between textile and the integrated SMA can be calibrated through filament orientation and thickness, so as to prevent deformation of the fabric and ensure it has the sufficient weight to go back to its original position. The final pattern is a combination of optimized structure and appearance; however, other patterns are possible.

Conclusion

Through the interdisciplinary textile approach and focus on the processual qualities of material structures, Adaptex emerges as two distinct material strategies that can be implemented in a variety of different contexts. The material assemblies themselves are adaptable, as the textile construction allows for a variety of configurations. Both systems can function as an energy-saving refurbishment of already existing buildings.

The two concepts follow different strategies regarding the type of kinetic motion, textile construction technique, and degree of permeability of the surface, but they both illustrate a material system in which the interplay between the SMA, the textile and the environment enables a resilient cyclic actuation. The focus on a system where the active material is embedded in the textile to create a cyclic movement creates a robust system that, despite being high-tech, is low in complexity and maintenance. This integrative, textile approach to architectural sun shading – relying on a textile operation logic with

3a, b **Photo of the fullscale demonstrator setup at the German University of Technology in Oman (left) and close-up of the finished Adaptex Wave prototype (right) (Photo by: Janis Rozkalns)**

4a, b **Photo from installing of fullscale demonstrator setup at the German University of Technology in Oman (left) and close-up of the finished Adaptex Mesh prototype (right). (Photo by: Ebba Fransén Waldhör and Janis Rozkalns)**

few components – can help reduce the number of deployed materials and minimize the energy and material consumption required for its fabrication and operation.

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ESSAY

Leather as a Carrier of Meaning

Jessica Bulling

In addition to its functional properties, leather has been a popular material in various cultures for centuries due to its meaningful power. Despite its popularity, there is an increasing demand for leather substitutes. To be able to design adequate leather substitutes, the question arises as to what role semantics plays in the substitution of leather with regard to acceptance.

Keywords: Leather, leather substitutes, material semantics, material design, material research, vegan materials.

Introduction

In addition to its functional properties, leather has a great symbolic and meaningful power in many cultures. Depending on the area of use, context and design, it has developed into a representative of power, status, luxury, tradition, naturalness, or even audacity and rebellion. Due to the procedures of tanning with chrome and dyeing with colors containing heavy metals in countries with low health and environmental standards, leather has lost much of its original naturalness and is no longer obtained, processed, or reused in a sustainable way (Dispan and Mendler 2021, 93–103). Changing lifestyles, the establishment of veganism and vegetarianism in Germany and across Europe (Heinrich Böll Foundation, German Federation for the Environment and Nature Conservation, and Le Monde Diplomatique 2021; Bessant 2019), and the accompanying demand for ethically and ecologically better products are increasingly challenging the use of the material. This change also poses a new challenge to design: the need to design adequate leather substitutes. This paper is intended to contribute to a better understanding of the aspects that are crucial for the acceptance of leather substitutes and thus contribute to successful material development.

The changing lifestyles initiated the development of ecological leather substitutes. Leather substitutes that are already available on the market, such as artificial leather, Desserto® made of cactus fibers or Piñatex® made of pineapple fibers, are attempts to replace leather and its properties. From an ecological point of view, however, the above-mentioned substitutes do not yet represent an adequate substitute for leather: artificial leather consists of fossil raw materials, mostly polyester coated with polyurethane. Furthermore, artificial leather contains substances that are harmful to health and the environment, such as tin, chromium, and nickel (Jossé 2016, 52–57). Although some of the existing leather substitutes, such as Piñatex®, are based on renewable raw materials, the study by the FILK Freiberg Institute gGmbH "Comparison of the Technical Performance of Leather, Artificial Leather, and Trendy Alternatives" shows that most of the leather alternatives offered on the market contain fossil raw materials such as polyurethane (PUR), polyvinyl chloride (PVC) or other plastics in addition to plant-based raw materials (Meyer et al. 2021), and must therefore be evaluated critically from an ecological point of view. Regarding future developments in leather substitutes, it can be assumed that these will be ecologically better evaluated: leather substitutes made from 100% renewable raw materials, such as cellulose or microorganisms, are currently under development (MakeGrowLab 2022; Polybion™ Spain 2022).

The evaluation and design of sustainable leather substitutes is not the subject of investigation in this paper and therefore will not be further addressed. Instead, the focus is examining the role of semantics in leather substitution in respect to acceptance. Preliminary research revealed that leather, in addition to its functional properties, is also accepted due to its sensory perception and meanings (Bulling 2017).

Related Work

In addition to the presentation of leather as a carrier of meaning, two design-scientific theories on the significance of the sign-like character of products are highlighted below to explain the concept of product semantics. At this point, it should be noted that in this paper, according to Markus Holzbach and Nico Reinhardt, materials are understood as designed products and carriers of meaning with practical and sensual functions (Holzbach 2015, 26; Reinhardt 2018, 7ff, 62).

Leather as a Carrier of Symbols

In his book The Black Leather Jacket, Mick Farren describes the qualities of black leather as a blank, reflective surface with a tendency to accentuate the natural forms of the body. Furthermore, Farren describes the tactile appeal of leather as the strangest of all aspects. He goes on to describe leather as a natural, second skin that can be shed at will (Farren 1986, 109). With the skin, touch and feel can be experienced. The sense of touch is the first sense to be formed in humans. Oliver König says that it remains the most important sensory organ (König 1997, 440). According to Gabriele Mentges, the use of leather intensifies the feeling of the second skin. In some cases, leather can even replace human skin and act as a substitute for human touch: Valerie Steele examined the various symbolic connotations of fabrics and found that leather and fur, for example, can substitute for soft female skin (Boesch 1983). Mentges says that apparently, the need for a certain materiality is increasing in modernity; it serves the need for a contact that wants to express itself haptically and tactilely (Mentges 2000, 46). In addition to its soft feminine symbolism, leather is used as a sign of power and strength. The modern interpretation of an iron knight's armor is the leather jacket, which is intended to give its wearer hardness and strength. The question of whether the transfer of power and strength stems from the mystique and reputation of the leather jacket or from the imaginary slaying and display of the animal from whose skin the jacket is obtained remains


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unanswered so far. Extravagance is given using reptile leather, for example in watch straps or bags, marking the status of a person. In contrast, leather can also be used as a symbol to express conformity – like black smooth leather, used for formal business shoes.

Design Science Theories on the Semantics of Products
In the 1970s and 1980s the examination of products as signs in the context of design science started (Bürdek 2010, 28). Discussions shifted away from function to meaning, in the form of symbolic and semantic aspects of products (Bürdek 2010, 28; Mareis 2016, 102).

Despite criticism from design science, two models of product meaning have become internationally established (Bürdek 2015, 147): the theory of product language developed at the Hochschule für Gestaltung (HfG) Offenbach and the product semantics of Klaus Krippendorff and Reinhart Butter, two former scholars of the HfG Ulm.

The core statement of both models is that they describe products, in addition to being carriers of function, as carriers of meaning, playing an important role in the social fabric of societies (Bürdek 2010, 28). Furthermore, both models advocate the approach that designers are responsible for the meaning of a product and its communication or experience (Gros 2021, 51; Krippendorff 2012, 270, 283). Nevertheless, the two approaches differ in fundamental ways: product language assumes that products function as signs and that designers convey meanings to users via the product – provided designers know the context and the experiences of users (Bürdek 2015, 180). Product semantics, according to Krippendorff, highlight the importance of interaction between product and user, and stresses that the process of meaning-making in the use of the product depends as much on the product as on the user and the context (Krippendorff 1984, 14).

The objective of this paper is to determine the relationship between semantics and acceptability in leather substitution. Claus Dethloff defines the concept of acceptance as the "[…] positive acceptance or adoption of an idea, a fact or a product, in the sense of active willingness and not only in the sense of reactive acquiescence" (Dethloff 2004, 18). The goal of this work is thus not the generation of meaning through the use of or interaction with the material, as required by Krippendorff's product semantics. The focus is rather on the acceptability of the material prior to its acquisition or use. Since the theory of product language essentially summarizes the semantic product effect, this paper uses this model.

The theory of product language divides sign/semantic functions into sign and symbol functions. Sign functions (pragmatics) convey information between object and person and refer to the practical functions of a product. Accordingly, they are responsible for the interpretation and handling of a product and mark the "area of design that allows the least individual interpretations and personal statements" (Bürdek 2015, 164).

Symbol functions, on the other hand, are more complex and subjective. Philosopher Susanne K. Langer wrote in 1984 that when we talk about things, we possess conceptions of them, but not the things themselves, and the conceptions, not the things, are what symbols directly mean (Langer 1984, 69). Symbols arise through convention and are defined as signs because they stand for something imperceptible. Symbols represent ideas that are associated with products (Bürdek 2015, 149; Fischer and Mikosch 2021, 140). Their interpretation of meaning is therefore mostly associative and depends on the context, or sociocultural background of the individual, such as experience, intuition, values, and cultural norms (Bürdek 2015, 149). Symbolism is not to be confused with the individual impact and meaning of a product. If a watch seems cheap to the observer, the neighbors' new furnishings stuffy, or a car ostentatious, it describes the assessment of product symbolism (Steffen 2000, 82).

Main Body

The Material Effect

As already explained, leather acts as a carrier of meaning and triggers emotions and ideas in the observer through a sensory experience. For the definition of the material effect, the description of the product effect according to Zeh is used (Zeh 2017): In this work, material effect is understood as the sensual perception of materials and the ideas and emotions triggered by it.

Leather and Its Sensual Perception

Leather and leather products differ from other materials due to their individual characteristics, which are sensually perceived by users; for example, the typical smell or look of leather. Scientific studies on the sensory perception of leather could not be found in the preliminary research. In the following a systematic characterization of leather and its sensory perception will be made: depending on the type and processing it can be visually described as smooth, rough, matte, shiny, artificial, natural, light, or highly textured. Depending on the context, leather can appear sporty, classic, traditional, or rebellious. Its sweet and heavy odor (of dyeing and tanning agents) is usually appreciated. The distinctive scent is even used to describe the fragrance of a perfume or the taste of a whiskey (e.g., Bischofberger and Bischofberger 2022; Meinduft Beauty UG 2022). Haptically, leather is sensed as a warm and soft material. Leather usually feels soft and adapts to body shape and temperature. The acoustic perception of leather depends on the strength of the material: the stronger and firmer the leather, the more it creaks and squeaks, just like a riding saddle or a heavy leather jacket.

The Classification of Substitutes into Imitations and Originals
Leather substitutes are distinguished in this work between imitations and originals. Preliminary research shows that neither type of substitute is yet an adequate replacement for leather in the sense of a generally accepted alternative material (Bulling 2017). The reasons for the lack of acceptance and the difference between imitations and originals are summarized in the following.

- Imitations

In this paper, imitations are defined as leather substitutes that visually simulate leather. Examples are artificial leather, Desserto® based on cactus, or Appleskin®, a material made from apple pomace. According to the study “Haptic and tactile – visual perception and perceived value of vehicle interiors,” imitations are perceived by the observer as inferior and inauthentic (Richter 2008, 290) and therefore will not be considered further in the remainder of this study.

- Originals

Originals are understood as optically independent materials that do not imitate the material to be substituted in its appearance. Previous work shows that materials, in this case leather substitutes, must be optically independent, genuine, and novel in order to be accepted by the user (Brochmann 1956, 128; Richter 2008, 290). While existing leather substitutes such as Piñatex® or MuSkin™ are visually distinct, qualitative interviews show that they are not an adequate substitute for companies and consumers, as they are inferior to leather in sensory perception, image, and quality appeal. They are merely positioned as a niche product for the vegan and vegetarian lifestyle (Bulling 2017).

First Part of the Investigation
In the first step of the study, semantic requirements beyond functional aspects for adequate leather substitution were defined through qualitative interviews and literature research. The requirements relate to the values and aesthetic demands of consumers regarding leather alternatives.

- Values

More and more people demand animal-free products and want leather substitutes that are harmless to health and ecologically and ethically acceptable (Bulling 2017, 222). In addition to the mentioned value concepts, it is defined for this work that the production of leather substitutes must not be in competition with the cultivation of food.

- Aesthetic requirements

Qualitatively conducted interviews show that visual factors play a significant role for consumers when choosing products and materials (Bulling 2017, 208): when buying shoes, for example, the decision is based less on the function than on the look. Furthermore, as already described, the haptic-optical independence of the material plays an essential role in acceptance.

- Material Development: Leather Substitute “Plant Skin”

Based on the described semantic requirements, a new concept for substituting leather based on fruit peels was developed by “research through design.” The so-called plant skin is an analogy to animal skin: instead of tanning animal skin to produce leather, hides/skins of plants are processed to a new material. Due to the function of the skin as a protective cover, a semantic transfer takes place. Unlike Piñatex® or Snap Pap®, which are based on a mixture of fibers, the plant skins are processed as a whole and thus complement the leather substitute selection that will be explored later. As with aniline and semi-aniline leathers, the preservation or processing of whole fruit skins produces an authentic material in which the individual, natural surface structure is retained. The choice of plant skins falls on waste from food production. For example, melon and pineapple and inedible apple peels are used.

On a sensual level, analogies of plant skins to leather can be recognized. These are described below: olfactorily, unlike leather, the substitute does not have the typical leather smell, caused by tanning and dyeing agents, but authentically like the plant raw material: for example, the processed orange skin smells like orange; the material made from pineapple peel reminds you of straw or grass. The acoustic perception of the

2a, b Plant skin: leather substitutes made of Galia melon (left) and pineapple (right) (Bulling 2017)

plant skins depends on the way they are processed: the more rigid and solid the material, the more matte and rapid it sounds when gliding over the surface. With their visually and haptically perceptible smooth and finely grained surface, orange and melon peels can replace smooth leather. The “hairy” skin of a kiwi is reminiscent of suede leather and the characteristic surface structure of pineapple skin can be compared to reptile leather.

In summary, plant skins represent a possibility for substituting leather. The variety of available plants with different surface structures allows an independent sensual perception of the leather substitute and prevents its being perceived as an imitation. First encounters between consumers and leather substitutes made from plant skins in the preliminary investigation of this work have confirmed that the substitute concept is not perceived as imitation leather. The material is perceived as an independent material, yet a similarity to leather is noted due to the visual and haptic experience. Differences in leather types and qualities, as well as conclusions from leather, linked to the animal species that delivered it are usually only apparent to experts and therefore are not essential for a material to be perceived as leather-like. While the symbolic and well-known perception of the “second skin” is maintained, the material differs enough from leather to not be mistaken for leather from animals.

Outlook

Main Investigation: The Role of Semantics in Leather Substitution

The outstanding empirical study aims to clarify the role of semantics in leather substitution and to determine the relationship between semantics and acceptance.

The study is conducted using a standardized online survey and is divided into two sub-investigations, which are conducted independently and compared with each other. The aim of the first sub-investigation is to describe the semantics of leather and leather substitutes. The second part of the study aims to describe the semantics of leather in the product context using four different types of shoe as examples. The results are then tested against the following hypotheses:

1. *The product context changes the effect of a material*
2. *If the semantics of leather and its substitute match, the substitute will be accepted*

Accordingly, it is assumed that the effect of a material changes with the use of the material in the product. As an example, it is conceivable that suede leather appears to the observer as less robust and less waterproof. If suede leather is used on a hiking boot it can be assumed that anyone looking at it would expect the suede leather to be water-repellent and robust. The second hypothesis can be illustrated by the example of leather trousers: if the leather substitute material has the same semantic properties (e.g., traditional, rough, brown) as leather, it will be accepted by the user.

The study is conducted using the Likert scale. It is a method that measures personal attitude by means of a questionnaire. Using the factors/items being assessed and a multilevel response scale, the degree of agreement or disagreement of the respondent is recorded (Brosius, Haas, and Koschel 2009, 62).

The items for the questionnaire are selected in several steps. With the help of expert panels as well as a self-conducted description round, items are collected that describe the effect of the presented material samples with adjectives such as high-quality, artificial, or eye-catching. Three of the panels take place online meeting, while one expert panel and the self-questioning occur in a physical, face-to-face meeting. The objects of evaluation are 12x12 cm material blanks selected for the study, whose effect is described visually in the online format and haptically and visually in the physical assessment stage. Five different types of leather and six different types of leather substitute are selected for the study. Only originals are considered, in the sense of visually independent materials that do not imitate leather and are already available on the market. The choice of materials is based partly on materials from the study “Comparison of the Technical Performance of Leather, Artificial Leather, and Trendy Alternatives” by FILK Freiberg Institute GmbH (Meyer et al. 2021). These include Muskin™, Teak Leaf®, Piñatex®, and Snap Pap®. In addition, a leather alternative made of cork is examined, as, according to one of the most important German fashion magazines, cork is one of “the most beautiful” leather substitutes (Moller 2021). Complementary to this, the leather substitutes from plant shells created in the preliminary work will be investigated.

Conclusion

Leather is valued not only for its technical-functional properties, but also for its function as a carrier of meaning. Materials give the product its physicality and ensure that the

3 Expert panel: collection of items (Source: Bulling, 2022)

product can be perceived sensually. Materials therefore play an essential role in the design and optimization of products.

The present work should provide information about the perception and effect of materials using the example of leather substitutes, assisting in the development of new materials and the optimization of existing materials. Transferred to further work, which meanings other materials have could be investigated, and whether the semantics of existing materials can be transferred regarding substitution. In addition, the investigation can be used to describe and better understand existing materials in terms of their semantic effect. Furthermore, it must be clarified to what extend the semantics can be integrated into existing acceptance models, since the meaning of a product/material is currently not covered in acceptance research. In view of changing lifestyles, it is imperative for future research to investigate the specific meanings that leather alternatives must communicate in order to gain user acceptance.

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ESSAY

On Materiability

Manuel Kretzer

This essay expands upon the vision behind Materiability as a shared and intrinsically motivated belief in matter as an all-encompassing entity and its potential for the development of lasting and ecologically viable design applications. It elaborates upon core concepts, how they evolved, and how they are communicated through research and education. The article concludes with the presentation of several research and student projects that exemplify the diverse range of related topics, ranging from 3D-printed biomaterials and compostable textiles to adaptive sound installations.

Keywords: Materiability, smart materials, biomaterials, digital fabrication, 3D-printing, sustainability, speculative design

What I hear I forget. What I see I remember.
What I do I understand.—Confucius

On Materiability

Materiability is many different things, but most of all it represents an idea. An idea that focuses on a concept of design through making, an understanding of actively shaping and learning from and about the world by physically engaging with it. The immediate connection between matter and human senses, such as touch, smell, hearing or sight, forms the basis for bodily engagements, material investigations, and sensual experiences. Making in this context encourages a hands-on approach to design, where the creation and study of physical artefacts and materials forms the very core of innovative development. Through the externalization of abstract lines of thought into manual actions, creative processes are instigated of which the results are not predetermined but rather evolve throughout the course of playful and unbiased exploration.

Materiability is also a call to take action, to cease accepting the status quo as a given but instead speculate about possible alternatives. Rather than solely trying to amend or modify existing solutions the focus is on wondering how things can be done differently and on speculating about what effects such approaches may have. Acknowledging change as an opportunity and aiming towards a desirable future the core motivation is to envision new possibilities that encourage holistic betterment instead of proclaiming short-sighted restrictions. Challenges are thus understood as valuable moments in time and space that allow for the rethinking of established paradigms and their potential transformation into sources of imagination and novelty.

Materiability understands itself as a playground for probing tomorrow based on the conviction that only together, across gender, ethnicity, age, culture, beliefs, and – most of all – disciplines, we can achieve what we have to (Kretzer 2022). Thus, for many of the later described projects a look beyond their own domain and experience proves to be one of the most essential ingredients. Thinking outside one's box, engaging in conceptual exchange and practical collaboration across various related fields, and the immanent search for alternative ways of design, collective living and related materiality form the underlying drivers of hope, sharing, and mutual caring.

The core idea behind Materiability originates between 2010 and 2012, during research at the Chair for Computer-Aided Architectural Design at ETH Zurich into the abundant possibilities emerging from the digitally controllable production of new, active materials, their potential for the creation of adaptive surfaces, spaces and objects, and the immanent necessity for architects and designers to understand, use and qualify their potential (Kretzer 2017). Almost a decade later, in 2019, the Materiability Research Group, with associated labs and infrastructure, is formed at the Department of Design, Anhalt University – right next to the Bauhaus Foundation and its historical buildings in Dessau, Germany. In addition to continuing the research into smart materials and systems, and the study of material fabrication in unison with digital design and production processes, a new track is opened with a specific focus on sustainable alternatives to synthetic, petroleum-based resources. Such bio-based materials are made from biological raw sources and thus completely biodegradable, which renders them largely carbon neutral. Regarding the current state of planet Earth in respect to ecological destruction, climate change, global warming and many other human-induced environmental challenges, such materials – together with a rethinking of consumerism and material life cycles – have become a topic of increased importance in not only scientific but also societal, political and cultural debates, stressing their pivotal importance for lasting design interventions.

The long-term goal of the Materiability Research Group is to emphasize and focus on the intersection of these complementing areas: 1. smart materials; 2. digital design and fabrication; and 3. bio-based materials. It is working towards the development of sustainable and ecologically viable adaptive solutions that behave and are perceived almost like living organisms, forming a nexus and mediator between human, nature, and technology.

Current Research Topics and Student Projects

Bio Formwork: Production of Thermoplastic Starch Pellets and Their Robotic Deposition for Biodegradable Non-standard Formworks

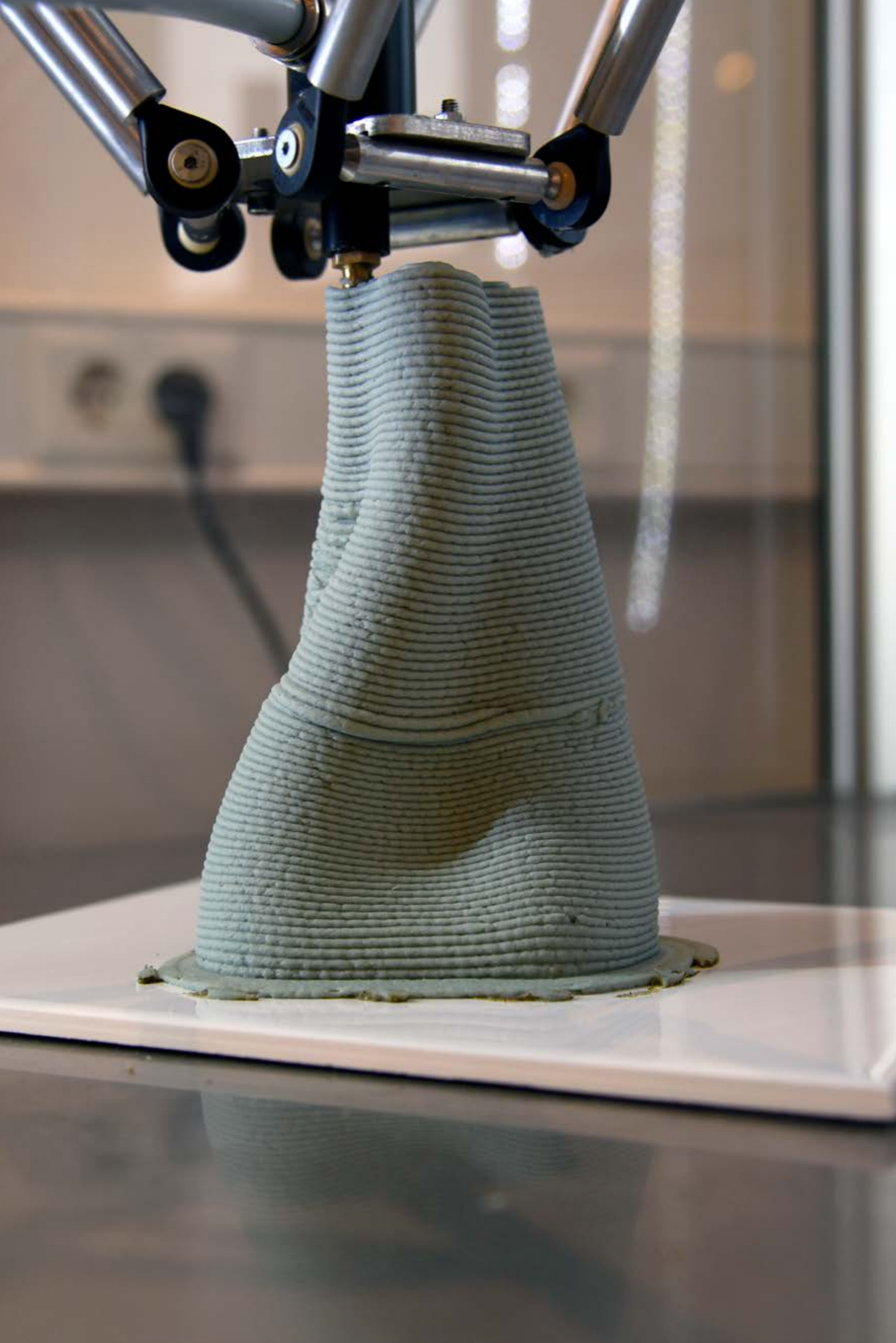
The climate crisis challenges architects and designers to explore alternative opportunities for sustainable fabrication processes. Biopolymers have emerged as a potential material to replace petroleum-based plastics used in building and construction processes. Simultaneously, existing research outlines how formworks can be 3D printed with plastics to reduce the amount of required material for formwork assembly. Printed formworks allow for individualized concrete elements that create material-optimized structures. Additionally, printed formworks help to minimize the use of non-renewable resources while decreasing the amount of on- and off-site labor during the construction process (Materiability Research Group 2023a).

The doctoral research of Benjamin Kemper suggests that examining formwork material made from biopolymers can bridge the gap between the current approach for producing sustainable concrete elements while using petroleum-based plastics for single-use formworks. The work investigates the potential of thermoplastic starch and examines the prospects and limitations of starch-based materials. Kemper compares the various effects of bio-additives, such as hemp products (hemp fibers, hemp shives), wood powders, and bio-waste (coffee grounds) and the impact of different mixing ratios on the behavior and properties of the material. Thermoplastic starch pellets with varying properties are produced and processed into sustainable formworks using a large-scale robotic 3D printing setup.

Lignin: Biobased and Biodegradable Composite Materials Produced by Means of Thermoplastic Process Technology
The PhD research of Danny Ott is motivated by a similar sense of ecological responsibility for finding and developing sustainable material solutions as economical alternatives for single-use plastics, yet with a specific focus on the biopolymer lignin, which is a by-product of the pulp industry with a worldwide annual production of about 50 million tons. Initial experiments have shown that the combination of biopolymers, natural fibers and plasticizers leads to a biodegradable composite material, which can be thermally processed and deformed. Building upon these enhanced material properties different types of fibers are evaluated to increase the material's tensile strength and deformability. Industrial fabrication processes such as injection- or compression-molding are researched and evaluated during short- and long-term studies. After refining the material's performance in respect of specific (design) applications, Ott aims to improve its biodegradability through researching the impact of different microbes. Fusing the domains of biochemistry and product design through cross-disciplinary exchange and a holistic model of thinking paves the way for novel material development, with the hope of eventually creating a material that can be processed using established technologies for the large-scale creation of consumer products or packaging.

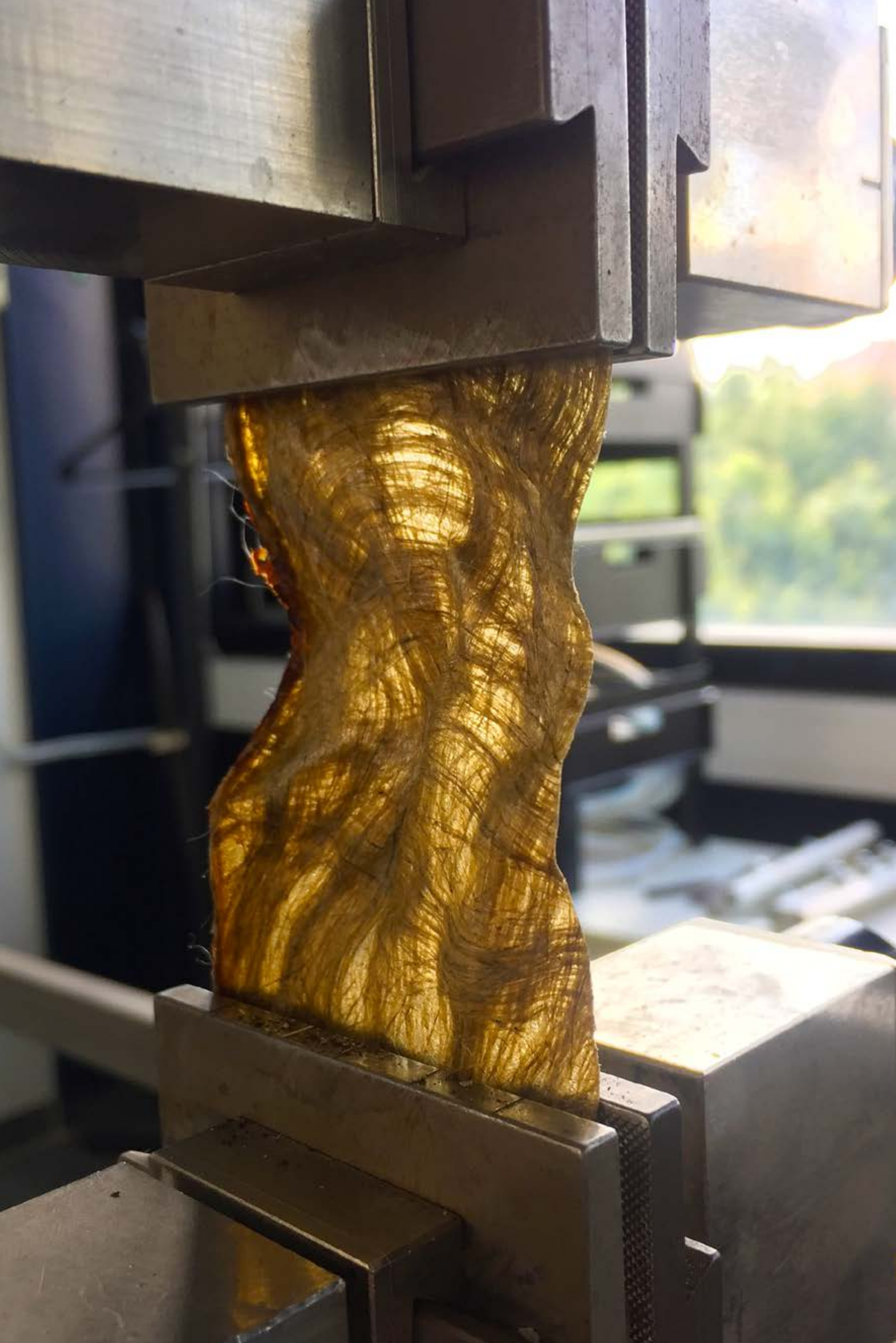
Microbial Leather: The Feasibility of Bacterial Cellulose Composites as Alternative Bio-Textiles
The textile and leather industries are ever growing and well known for their negative environmental impact. The Master's thesis of Nadia Elkady approaches this issue by investigating the use of bacterial cellulose as an alternative material source. The symbiotic community of bacteria and yeast (SCOBY) of the Kombucha beverage produces a sheet material composed of bacterial cellulose, which when dried exhibits properties akin to animal leather. Elkady's research focuses on improving the material's homogeneity in color, thickness, and aesthetic and haptic diversity, as well as appeal, thus refining the overall workability of the material. This is done through a wide array of experimental processes such as composite growing, blending, and coating. A specific focus is on coloring the material using various natural dyes and adding other biological ingredients to enhance its textile properties. All experiments are subject to extensive tensile strength tests. From these experiments, a number of composite materials were developed and applied in the context of fashion in order to prove the feasibility of bacterial cellulose food waste composites as alternative bio-textiles (Materiability Research Group 2023c).

Printing with Biofoams: Transient Futures Exploration
The biomaterial research project of Claudia Palcova explores the potential implementation of additive manufacturing in the production of temporary biofoam structures with varying zonal properties. Understanding the urgency of the current ecological crisis, this research looks for material and construction alternatives that reduce humanity's impact on the planet while encouraging new concepts of dynamic and flexible living. Biopolymers are the main subject due to their low energy and resource consumption, infinite recyclability, and full compostability. While there has been a noticeable increase in biomaterial implementations in everyday products, the materials' susceptibility to distortion and degradation caused by changing environmental conditions leads to infrequent large-scale and long-term applications. Interested in material behaviors and adaptations, the research is framed as a collaboration between the human, the material, and the technology. Learning from natural systems, materials science and digital fabrication technologies, the intention is to develop a range of printable biopolymers utilizing an adaptable manufacturing system. The goal is a non-invasive, non-toxic system that responds to the unique physical and psychological requirements of individual projects, replacing standardized material production and applications in the context of temporary buildings. Findings from the material research



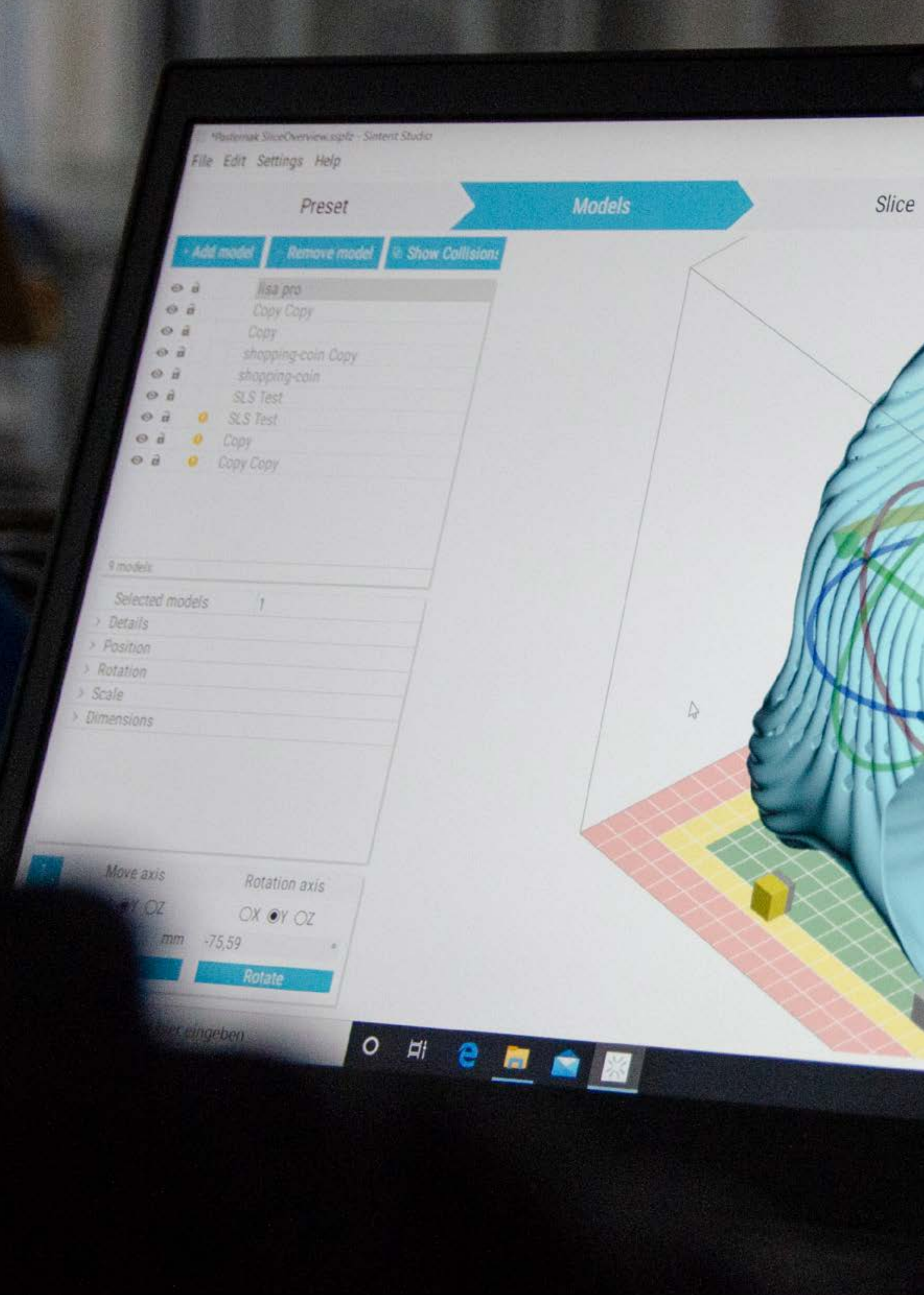
1a Exploring formal limitations and material adhesion of starch-based biopolymers (Photo: Benjamin Kemper, 2020–2022)
1b Varying thermoplastic starch pellets for fused deposition modeling (FDM) printing (Photo: Benjamin Kemper, 2020–2022)

2a Bio-composite made from combining rabbit-skin-glue, sisal, granite, and lignin (Photo: Danny Ott, 2020)
2b Form-molded prototype of biopolymer material (Photo: Danny Ott, 2020)
2c Controlled stress test of prototype material to evaluate its tensile strength and durability (Photo: Danny Ott, 2020)

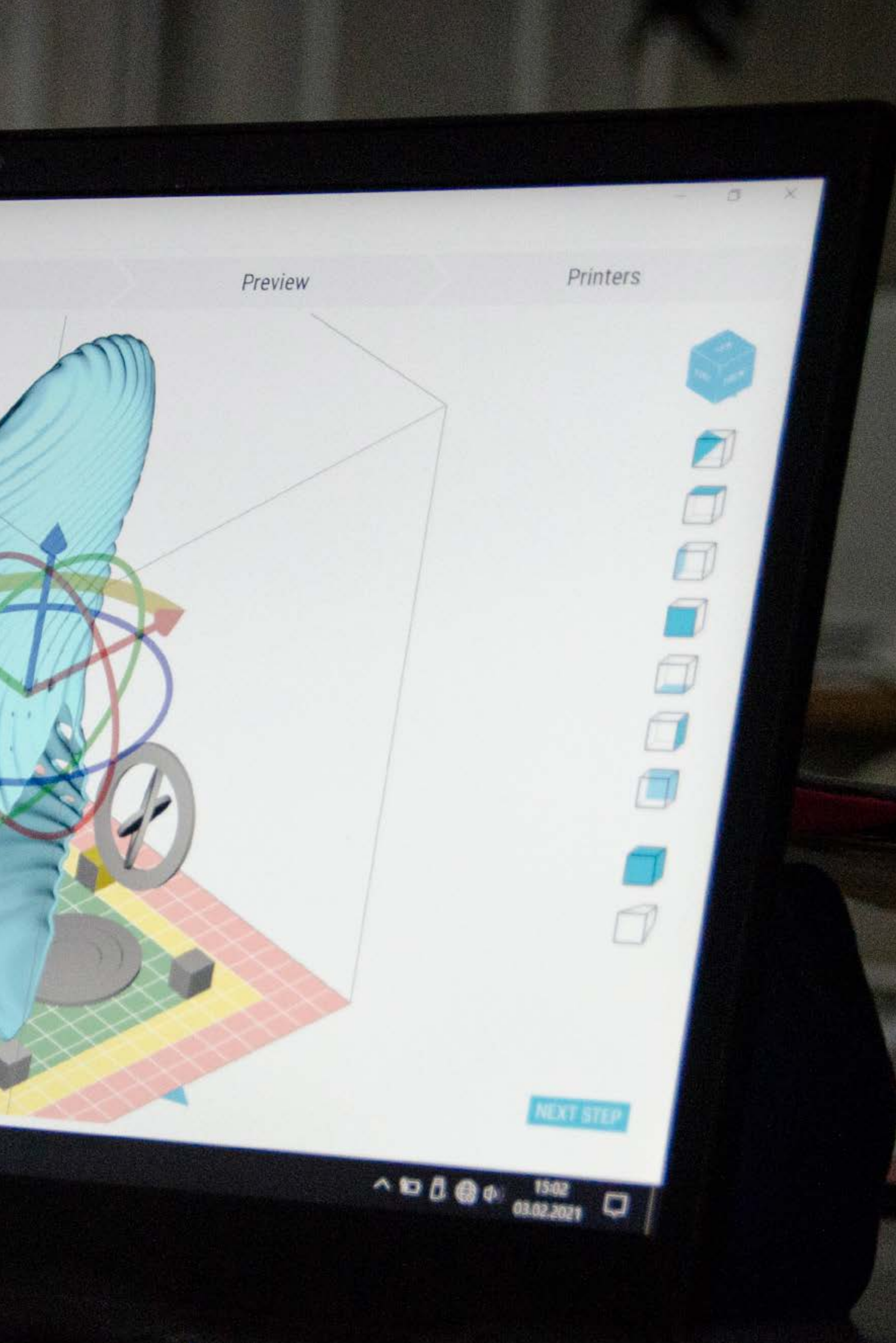


3a **Face mask (Photo: Luisa Eva Maria Oppelt, model: Nadia Elkady, 2020)**
3b **Samples of various kombucha leather materials in different colors and textures (Photo: Luisa Eva Maria Oppelt, model: Nadia Elkady, 2020)**
3c **Prototype of a biodegradable skirt made from bacterial cellulose composites (Photo: Luisa Eva Maria Oppelt, model: Nadia Elkady, 2020)**

4a 3D printing of biofoam material using a Wasp Delta printer (Photo: Claudia Palcova 2022)
4b, c Testing the material's elasticity and feel. Prototype of 3D-printed biofoams with varying densities (Photo: Paulina Schröder, 2022)



5a Shoe design process using parametric computer-aided design (CAD) software (Photo: Toni Pasternak, 2021)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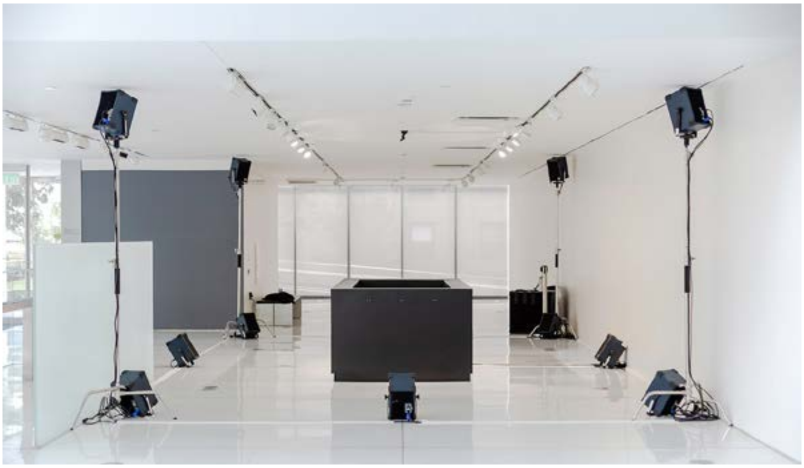
5b 3D-printed sneaker photographed from all sides (Photo: Toni Pasternak, 2021)
5c Testing of the final prototype (Photo: Toni Pasternak, 2021)

6a Examination of sound-induced ripple creation based on audience movement (Photo: Jimmy Day, 2021)
6b Overview of technical setup of superpose installation (Photo: Karsten Schuhl, 2021)
6c The Phantom Ballet, striations in vacuum plasma (Photo: Verena Bachl, 2017)



contribute to further explorations of speculative scenarios for recyclable, reusable and compostable materials in future dwelling spaces. Supporting concepts of temporary interventions in permanent environments, the material applications aim to reduce the impact of the construction sector on the environment while simultaneously increasing the accessibility and affordability of individually tailored private spaces in urban environments (Materiability Research Group 2023b).

Aragon: Metamorphosis of the Sneaker
Shoes have accompanied humanity for thousands of years, as early cave drawings depicting people wearing grass, leaves or animal skins on their feet have proven. However, the sneaker has hardly evolved since its invention more than 100 years ago. The Masters thesis project of Toni Pasternak simplifies the complex shoe production process – which sometimes involves hundreds of steps and dozens of individual parts – through the means of 3D printing. Derived from aragonite, the mineral of fossil ammonites, the shoe itself resembles the fossilized creatures due to its wave-like structure. Employing digital design strategies Pasternak developed a mono-material sneaker, which can be manufactured in one piece via FDM or selective laser sintering (SLS) printing. Due to the differentiated surface structure and the chosen material, thermoplastic polyurethane (TPU), the shoe adapts to the natural movement of the foot and provides a high degree of flexibility. Using 3D printing for manufacture allows cost-effective, location-independent and largely waste-free production (Materiability Research Group 2023d).

Sonic Envelopes: Sound-Adaptive Smart Material Systems for the Improvement of Indoor and Outdoor Acoustic Experiences
The PhD research of Karsten Schuhl aims to investigate and expand the potential of digitally controlled fabrication technologies and smart materials for the development of adaptive sonic systems for indoor and outdoor spaces. It focuses on the capacity of shape-changing structures driven by sensor–actuator combinations for use in kinetic acoustic modules to create large-scale, real-time, self-adaptive sound management systems. The goal is to design, simulate and build several prototypes of acoustic treatment elements exploring dynamic changes in texture and shape, material porosity and density to modulate their impact on absorption, reflection, and diffusion, i.e., sound propagation and perception in architectural environments. The design of systems for auditory shaping, which act on the basis of geometric and material-based principles, is intended to place sound in the category of dynamically adaptable building materials in order to be able

to exert a future-oriented and, above all, long-term adaptable influence on auditory and environmental experiences. This work will expand the existing options for acoustic modules beyond their single parameter-based application (e.g., diffusion OR absorption) by creating a system capable of transformations as dynamic as often-used multi-purpose environments such as open-plan offices and educational spaces. The work is a continuation of Schuhl's previous research into auditory environments, such as the superpose installation, which was developed and exhibited at the Massachusetts Institute of Technology (MIT) Media Lab in 2021 (MIT Media Lab 2021). The project explores the potential of interaction and experiential design to create a new understanding of how sound operates as a physical phenomenon within space.

The above-described projects represent only a glimpse of the various outcomes that emerge from the Materiability idea. Newly established labs, infrastructure, machines and spaces, and the interwoven connection between (applied) research and education, form the basis for abundant future explorations. All results will be continuously published on the research group's website (www.materiability.com) and associated media channels. In conclusion, Materiability can be understood as a shared belief and inherent motivation in the purpose and meaning of collective, unbiased efforts that unfold into something much larger than just the sum of their individual parts.

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Designing With Biomaterials: A New Form of Material Understanding

Charlett Wenig

The use of biomaterials in design calls for an approach that is conscious of the material's origin and the way it interacts with the environment. Here, tree bark is used as an example for a dialogue between design, science and crafts and how natural boundaries can be implemented in material-driven design. The use of tree bark, currently waste in the wood industry, is complicated by its natural variability and present debarking processes. The aim of this project was to create scenarios for use before combustion for energy production. The traditional method of hand-peeling was used to keep its natural structure. Similar to most biomaterials, bark changes its properties upon drying. To preserve its wet flexibility, bark was infiltrated with a water-glycerol solution which allowed to weave it into textiles. At the end of life, bark ash can be used as porcelain glazing. This approach enhances understanding and sustainability by considering material origin, processing, production, and recycling.

Keywords: Bark, practice-based research, material driven design, weaving, bark ash

Natural-grown materials force designers to look deeper into the structural understanding of biobased materials and their processing possibilities. While the properties of artificial materials – the most dominant example here is plastic – can be generated and optimized, the properties of biomaterials are, for example, determined by growth, interaction with their environment, their harvesting and storing conditions, etc. All of this has an impact on the design. This "different" and "stubborn" material requires a certain care in its selection, an understanding of its origin, the environment, the structures, and its interaction with nature. All these aspects call for a material design with care. However, this should not be seen as a hurdle or another constraint to be considered in the design process but as a potential way to enter into new dialogues with related disciplines such as the natural sciences.

Understanding the growth and form of biomaterials will open up a whole range of potential materials. These are, as in the case of bones, mushrooms, and plants, often materials that have been used by our ancestors over many generations. They are culturally deeply rooted and, in most cases, locally available.

On the example of European tree barks, scenarios in which design enters into a dialogue with science and crafts are described. It shows how naturally given "boundaries" might be addressed in material-driven design.

Utilization of Tree Bark

Current production methods substantially contribute to climate change, consume a large amount of resources, and lead to biodiversity reduction (Walcher and Leube 2017). Biomaterials are renewable resources associated with land use and thus also become subject to scarcity (Fehrenbach et al. 2017). Consequently, it is also important here to use biomaterials as long, as often, and as efficiently as possible, and to only use them for energy production at the end of their product life cycle (Fehrenbach et al. 2017).[1]

1 The passage on utilization of tree bark is part of my doctoral thesis and is used verbatim in this article (Wenig 2023).

Wood is considered valuable enough to be kept until it dries, but bark is typically viewed as less valuable. The amount of bark in a tree trunk is usually about 10–20% by volume (Harkin and Rowe 1971). In German sawmills, this results in the production of around 4 million cubic meters of unused bark each year (Wollenberg and Warnecke 2005). Considering these numbers, it's important to find ways to make use of this bark over the long term in order to make the most of the tree's raw materials.

Throughout human history, the material utilization of bark as a by-product of wood has been a common way to make the most efficient use of the whole tree trunk. Bark has been used for the making of cloths (Leonard and Terrell 1980), fishing items (Fletcher et al. 2018), and for the production of other everyday items like floors (Grøn 1995), roofing shingles (von Hauer et al. 1887) and boxes (Ratas and Kiudsoo 2016). Its use as a resource to extract substances probably dates back even to the Pleistocene. Archaeological records suggest that Neanderthals produced adhesive tar from birch bark (Kozowyk et al. 2017). A more prominent example is the production of leather by tanning animal skins, using the tannins naturally present in tree bark (Kite and Thomson 2006). Until the beginning of the 20th century, bark was widely used in Europe.

The devaluation of tree bark was already evident in the middle of the 20th century, however. Increasing progress in wood harvesting and processing created an enormous and problematic amount of bark. At that time, bark was mostly delivered to landfills (Feng et al. 2013). Today, the industrial application of bark can roughly be classified into three groups: bark as a material for mulching materials for horticulture (shredded into small pieces); bark as an extraction resource for biomedical applications (Schuster et al. 2020) and adhesives (Yazaki 2015); and bark as an energy source (via burning).

In many cases, the structure of the tree bark is damaged during processing. To be able to work with large pieces of bark, the first step was to peel off large, coherent pieces from felled trees. Removing the bark kills the tree, so this process can only be performed on trees that have already been cut down. Once the tree has been felled, the drying process begins, and the tree's water content decreases. This affects the properties of the material. The moisture content is a critical factor to consider when designing with biomaterials.

Influences of Water

The traditional method for removing bark from trees involves hand-peeling, which is typically done in the early spring when trees have high water content (Figure 1). This manual peeling process provided qualitative information on the peeling properties of the bark. The bark is flexible after being peeled. Both the flexibility and other mechanical properties of bark, as well as those of wood, are strongly dependent on their moisture content (Eder et al. 2021). As the bark dries, it becomes harder and more brittle. To maintain the flexibility of selected bark species, they were treated with water-glycerol solutions. This method is commonly used for preserving leaves; the glycerol

1 Peeling bark in the forest. (Photography by Florian Weisz)

replaces some of the water in the plant material and keeps it flexible (Babu et al. 2018).

The experiments showed that it is possible to flexibilize pine bark (*Pinus sylvestris*, L.) and the inner part of larch bark (*Larix decidua*, Mill.), while oak (*Quercus robur)* and birch bark (*Betula pendula*, Roth) could not be flexibilized. The differences in flexibility between the barks are related to structural heterogeneity and, in particular, to the different proportions of living bark layers.

Flexibility is an important material property for applications that involve motion, such as textiles for clothing or accessories like tents and bags. However, mechanical values are not the only relevant quality for material use. For instance, bark treated with a high amount of glycerol solution has a shiny and greasy surface, with negative effects on decorative appearance and usability for further processing (Paparozzi and McCallister 1988).[2]

2 The passage on flexibilization and weaving of bark is part of my doctoral thesis and is used verbatim in this article (Wenig 2023).

The understanding that grown materials are also always connected with water is crucial for designing with biomaterials. Using this knowledge to give the living system its own properties, or even to control them, expands the possible fields of application. Using pine bark as an example, water conservation can create a flexible material that even has improved properties (higher pliability) than fully watered bark. In addition to the properties that change through the peeling process, a symbolic transformation also occurs during peeling. If the tree is standing, the bark is part of the system and inseparable from the wood. By separating the two structures, the bark becomes its own material, standing by itself.

Transformation of Bark into a Textile-Like Material via Flexibilization and Weaving

Bark protects the tree. It forms the interface between the environment and the vital cambium and xylem. But what does this protection feel like? Can bark take on protective functions for humans as well? These questions arise when peeling the bark off a tree for the first time. While the flexibility of freshly peeled, wet pine bark is very similar to that of textile materials, it is lost as soon as the bark dries and requires flexibilization to be maintained. The aim of creating a plain bark jacket was to explore bark as a boundary layer for humans.

The feel and color of glycerol-treated, flexible bark are like leather—animal skin tanned with substances from tree bark. Leather is an attractive material in design, with designers and scientists currently looking for replacements without animal origins (Muthu 2020). Humans often use leather as a kind of second skin and as protection from the environment, as in clothes and shoes that protect against cold or moisture. Multi-layered and based on fibrous elements, bark can be seen as the skin of woody plants, and hence as a structure that works as an enclosure as well as a connection to and trading zone with the environment.

The flexibility of the bark was highly limited. The material did not stretch at all, which is a required feature for most textiles. Consequently, the wearer could not lift their arms and found the jacket to be rather uncomfortable (Figure 2). In comparison with leather, flexible pine bark is approximately five times stiffer along the direction of the fibers. The limited mobility while wearing the jacket results from bark being highly anisotropic since the majority of its fibrous elements run parallel to each other (Wenig et al. 2021).

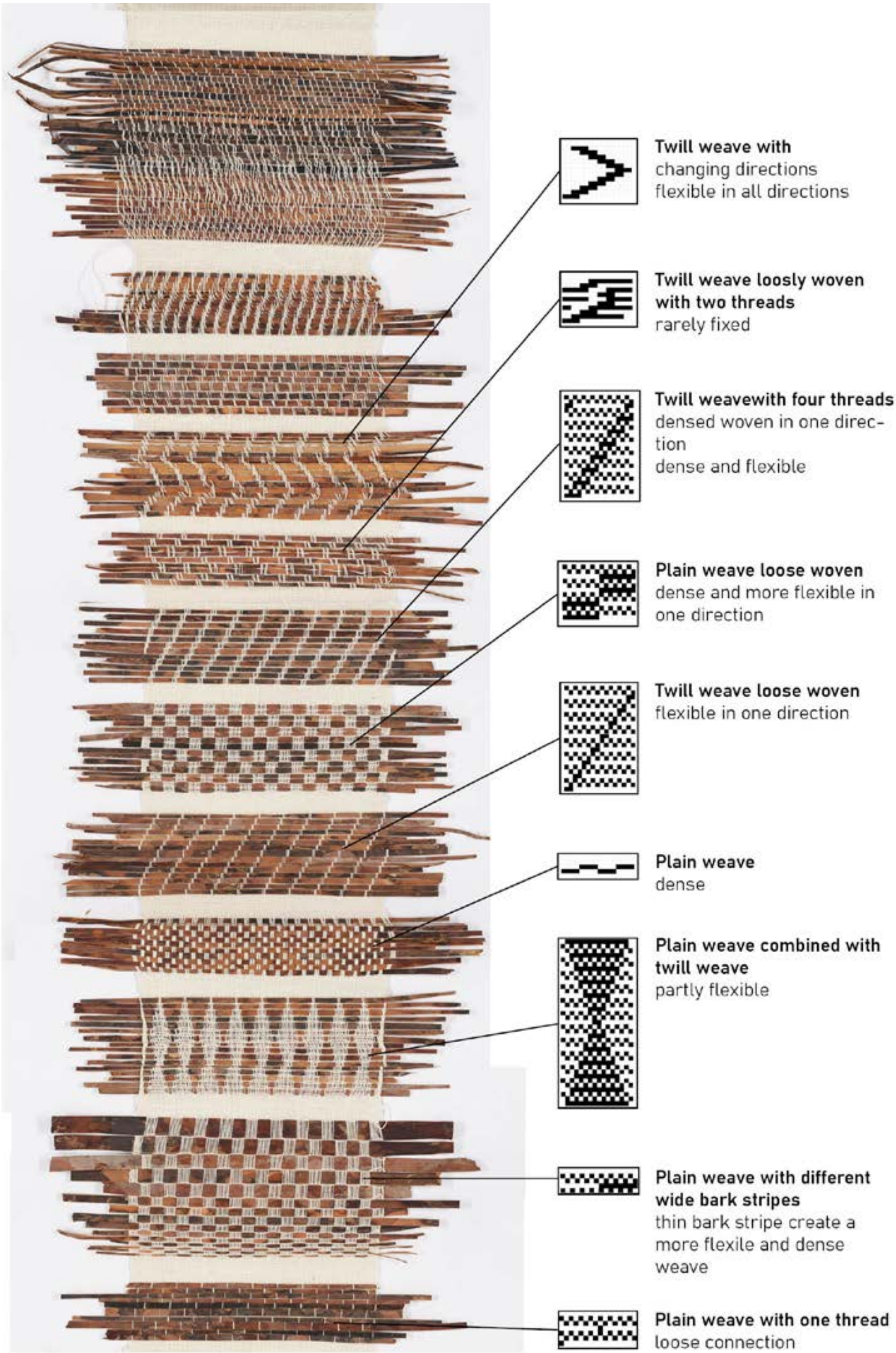
In the context of this project, the first prototype's lack of flexibility, the bark's anisotropy, and the amount of waste material resulting from the production were addressed by weaving techniques (see Figure 3). Weaving is one of the most ancient crafts. Even older than ceramics, the fundamental principle of weaving remains essentially unchanged (Albers 2017). Whether woven by hand or by machinery, two fibers or threads are interlaced in a rectangular pattern, which can be used to either support or impede the different threads' material characteristics (Albers et al. 2017). Different techniques resulted in different textile characteristics. For example, higher flexibility was achieved when applying a twill weave, while a plain weave created a very sturdy and tear-resistant textile. It was not only the weaving pattern that influenced the textile; its properties were further changed by the width of the strips and the combination of strips with different widths within one sample. The narrower the bark strips, the firmer the weaving bond and the greater the flexibility that could be created by weaving. Furthermore, by combining different weaving patterns (see Figure 4), it was possible to modulate strength and flexibility and to join bark textiles without the permanent incorporation of other substances such as glue. The possibilities of other processing techniques such as knitting, knotting, or combinations with other materials have not been tested further in this work.

What all the mentioned techniques have in common is the use of fibers. Tree bark is cut into strips/fiber-like forms whereby the material is not chemically modified and, despite the width

2 Image of the finished bark jacket, front (Image copyright by Studio Patrick Walter and Max Planck Institute of Colloids and Interfaces)

3 Close-up of finished woven bark jacket (Image copyright by Studio Patrick Walter and Max Planck Institute of Colloids and Interfaces)

4 Evaluation of the woven bark carpet. Different weaving pattern tested with bark (Image copyright by Charlett Wenig)



5 Results of combustion test with robinia bark (Robinia pseudoacacia) at the University of Arts in Bremen (Image copyright by Charlett Wenig)

reduction, also long coherent pieces remain. By changing the geometry – the structure in space – the properties of the bark are improved by weaving. By knowledge of the anisotropic structure of the bark, this property can be used in the process of weaving. The material will improve in its properties without changing itself much. This type of modification allows for a long value chain in which the woven bark can be shredded after use and then used for horticulture or chemical extraction. The very last step should then be incineration. However, this does not have to be the final scenario for all types of bark.[3]

3 The passage on weaving techniques of bark is part of my doctoral thesis and is used verbatim in this article (Wenig 2023).

Designing with Residuals by Understanding the Origin

Another use for bark is as an alternative in the porcelain glazing process. Ash is a crucial ingredient in ceramics and glassmaking (Wolf 2012). The use of ash for glazing has a long history, dating back to 1500 B.C. in China (Tichane 1998). Different plants were burned in specific ways to produce ash, which, depending on its chemical composition, can provide various colors and surface qualities in the glazing process (Bezborodov 1975). Characterizing bark as a material in general is difficult, as the ash content and number of elements in bark are much higher than in wood (Kurth 1947; Fengel and Wegener 2011).

A main chemical component of bark ash is calcium, which can serve as a flux in the glazing process (Lehnhäuser 1985). Other minerals in bark could also be used to replace the chemicals for colors in glaze. Conventional glazing relies on metal oxides to create color, such as cobalt blue, green from chrome oxide, and brown tones from manganese and iron (Matthes 1985). Bark ash (see Figure 5), a locally available by-product, can replace these metal oxides. In the first experiments, all bark ash glazes resulted in colors ranging from yellow and brown to blue-green tones. These colors are also mentioned in historical literature as being present in antique glass production (Tichane 1998) due to the presence of copper, iron, and manganese oxides (Wolf 2012).

The color of a glaze can vary depending on the firing method and is not always predictable (Figure 6). This problem is not a special case for bark glazes; it is a common issue in traditional ceramic production. To overcome this “problem,” a design concept that prioritizes other aspects besides color is necessary. The variability in color can also be seen as an opportunity to create a unique product. By utilizing bark ash, even the residual waste has a new purpose as a glaze additive for ceramics. If the ceramic object is broken, it can still be recycled and used in road construction.

Cooperation Between Science and Design is Essential to Unlock the Full Potential of Biomaterial for Future Applications

The low perceived value of tree bark as a waste material is due to several reasons, including limited production facilities and a lack of knowledge about the material compared with wood. This issue is usually approached by a single profession (e.g., wood engineering, product design, biology, etc.), leading to narrow and one-sided solutions. By combining science and design, the motivation for understanding the structure of waste materials like bark and discovering new applications for them converges. Scientific methods can be used to characterize the properties of tree bark, which can then be applied in various fields of architecture and design.

Combining basic material characterization with application scenarios requires upscaling approaches from micro- to macrostructures. Upscaling is often the point at which it becomes clear whether biomaterials, as well as other material developments, can be incorporated into the currently predominant production culture and whether they are valid materials for individual pieces, small series, or mass products. The issue here is not only if the production of large quantities is possible but also what the consequences of upscaling are. Of course, it can be argued that the use of biological materials is preferable to materials that consume limited resources and require a lot of energy. However, any biomaterial is also subject to the structures of today's industrial processes. The consideration of the material origin, the processing method, the production processes, and its recycling are potential aspects that make a biomaterial sustainable or not. Consequently, also for the establishment of (grown) materials, the inclusion of multiple sources of knowledge is necessary to obtain a comprehensive understanding of our future (bio)materials. To fully understand the potential of bark (and other materials), collaboration between different disciplines, including science, the humanities, and design, is crucial. By combining existing practices and knowledge, these fields can inspire each other and lead to new research questions. This could potentially revolutionize the way we use raw materials that are currently considered as waste.

6 Glazing results. The left column shows glazed bowls before firing, the right column shows glazed bowls after firing (Image copyright by Charlett Wenig)

Glaze before firing | Glaze after firing

No Bark

Robinia

Larch

Glaze before firing | Glaze after firing

Birch

Spruce

The research on tree bark described in this article was done as part of Charlett Wenig's doctoral thesis. Parts of the thesis were used verbatim or in terms of content. The direct text passages are marked in the article.

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Authors

Sename Koffi Agbodjinou is an author, tech activist, and award-winning entrepreneur. With a background in industrial design, architecture, and anthropology, he now curates exhibitions and gives lectures and workshops worldwide. He is co-founder of Africaine d'architecture, a collaborative platform for experimentation and research on L'African architecture and urbanism, and of HubCity/WoeLabs, a network of Togolese technology hubs. He works with concepts that incorporate indigenous elements into modern design, at the level of product, building, and urban planning. His work develops alternative visions around issues of holistic architecture, primitive computationalities, democracy in technology, and urban sustainability.

Viola S. Ahrensfeld, born and raised in Cologne, is a designer and design researcher currently pursuing her PhD at Bauhaus-Universität Weimar. Her research interests focus on how design practices help shape human existence and social worlds, and the related ethical issues of design as a practice of the everyday life.

Joanna Boehnert is senior lecturer at the Design School at Bath Spa University. She is currently working on two UKRI research projects on net zero transitions and Gregory Bateson's ecological aesthetics. She is author of *Design/Ecology/Politics: Towards the Ecocene* (2018) and a fellow at the Centre for the Understanding of Sustainable Prosperity (CUSP). She is originally from Canada and tweets @ecocene.

Jessica Bulling studied Product Design (BA) and Strategic Design (MA) at HfG Schwäbisch Gmünd. Building upon her master's thesis on "Vegetarianism and Veganism – Potentials for Design," she is currently pursuing her PhD on "Materials as Carriers of Meaning – Perception and Impact in the Context of Leather Substitution" at TU Dresden and HfG Schwäbisch Gmünd. Her work focuses on material design, material semantics, and ecodesign. Additionally, Jessica Bulling serves as a lecturer at HfG Schwäbisch Gmünd.

Michaela Büsse is a postdoctoral researcher at the chair of Digital Culture at Technische Universität Dresden and associated investigator at the Cluster of Excellence "Matters of Activity. Image Space Material" at Humboldt-Universität zu Berlin. In her research she focuses on socio-material transformations in the context of speculative urbanism, climate change mitigation, and energy transition. Drawing on elemental anthropology and feminist science and technology studies, she investigates how design practices and technologies govern environments and define who and what is being rendered inhuman.

Emile De Visscher is an engineer, designer and researcher exploring new materials and manufacturing methods. Through this practice-based research, he questions the political role of technology and its underlying concepts like productivity, functionalism or efficiency in regards to current social and environmental changes. Emile De Visscher was a research associate at the Cluster of Excellence “Matters of Activity”, Humboldt-Universität zu Berlin from 2019-23 and now holds the Chaire Professeur Junior “Design for ecological transitions” at ENS Paris Saclay.

Matthias Held studied product design in Germany and in the US. After working as a design consultant for the German Society for International Cooperation (GIZ), including in Africa, he was a co-founder of the quintessence design studio in Stuttgart. In 2006, he was appointed professor at the HfG Schwäbisch Gmünd, heading research projects in the field of sustainability, regenerative energy and medical technology. He currently serves as prorector for research and transfer. Held is member of the German Society for Design Theory and Research (DGTF), of the Design Research Society UK and jury member of the Bundespreis Ecodesign.

Roman Kirschner is a designer, artist, researcher, and teacher working across disciplines. After studies of philosophy, art history and audiovisual art, he completed a PhD on “the paradigm of material activity in the plastic arts.” He was the project leader of the arts-based research project “Liquid Things” (FWF, AT) and the editor of *Raw Flows: Fluid Mattering in Arts and Research* (2017). Currently he is the Co-PI of the research project “Interfacing the Ocean” (SNF, CH). His current research revolves around metabolism and ecologies, fluid material systems, spatial strategies, research methods and the mutual influence of material, imagination and epistemology.

Manuel Kretzer is professor for Material and Technology at the Dessau Department of Design, Anhalt University of Applied Sciences and director of the Materiability Research Group. The group’s work focuses on exploring novel material properties in unison with digital design and fabrication processes. A particular emphasis is on adaptive or smart technologies as well as biological materials as sustainable alternatives to synthetic, petroleum-based resources.

Anupama Kundoo is an architect whose practice, established in 1990, focuses on environmentally conscious architecture suited to the socio-economic context. She is currently professor at FH Potsdam, Germany, and has taught in a variety of cultural contexts and institutions across the world. Her research-oriented work has been showcased at the Venice Architecture Biennale twice, with installations in 2012 and 2016. Kundoo is the author of *Roger Anger: Research on Beauty/Recherche sur la Beauté, Architecture 1958-2008* published in Berlin by Jovis Verlag in 2009 and has actively assisted chief architect Roger Anger with the development of the city plan of Auroville, an international city-in-the-making in South India founded in 1968 as a prototype for future cities.

Claudia Mareis is a design researcher and cultural historian. After initial training in Graphic Design, she studied Design, Art and Cultural Studies in Zurich, Berlin, and Linz. Since 2021, she has been professor of Design and History of Knowledge at the Department of Cultural History and Theory at Humboldt-Universität zu Berlin, where she is also the co-director of the Cluster of Excellence “Matters of Activity. Image Space Material.” Besides, she is a lecturer at the Institute for Experimental Design and Media Cultures (IXDM) at the FHNW Academy of Art and Design in Basel, where from 2013 to 2021 she has built up an interdisciplinary research group converging design, media arts, anthropology, historical studies, and technology. Her research interests include history, theory and methodology of design in the 20th century, knowledge cultures in design, experimental design and media practices, cultural history of creativity, design and material politics.

Martin Müller researches and teaches at the Cluster of Excellence "Matters of Activity. Image Space Material" at the Department of Cultural History and Theory at Humboldt-Universität zu Berlin. His research is located at the intersection of cultural history and theory, media studies, history of knowledge and science, and design theory. Together with Léa Perraudin, he leads the experimental laboratory for knowledge exchange and speculative design "CollActive Materials" – a joint project of the Clusters "Matters of Activity" and "Science of Intelligence," funded by the Berlin University Alliance. He has recently published *Leben machen. Die Zoëpolitik der synthetischen Biologie* (Berlin: De Gruyter, 2023).

Fara Peluso is a Berlin based artist-designer which through a speculative methodology pursues a deep research on algae poetic and agency. Peluso, investigating possible closer relationships between human beings and algae organisms, wants to raise critical questions about human and more-than-human coexistence. In 2022 she was nine months in residency at Ars-Electronica, regional S+T+ARTS center in Linz, with the collaborative project "Circular Records" about LP bioplastic manufacturing. In March 2023 she showed the project "Tecuitlatl" at Weltmuseum Vienna, an algae sound installation in collaboration with the sound composer Hüma Utku and in research collaboration with Prof. María Antonia González Valerio.

Léa Perraudin is a postdoctoral researcher at the Cluster of Excellence "Matters of Activity. Image Space Material" at Humboldt-Universität zu Berlin. Her research is concerned with (media) infrastructures of the Anthropocene, experimental cultures in media, art and design, as well as practices of knowing, writing and making in the realm of environmental humanities and queer feminist technology studies. Léa is currently working on an extensive media theory of phase transitions, investigating the material ties of media infrastructures in contemporary technocapitalist environments through situated phenomena of transience, dispersal, abundance and solidification. Together with Martin Müller, Léa leads the experimental laboratory for knowledge exchange and speculative design "CollActive Materials," funded by the Berlin University Alliance.

Wolfgang Schäffner, a historian of science and media technologies, has been professor of the Cultural History of Knowledge at the Department of History and Theory of Culture at Humboldt-Universität zu Berlin since 2009 and is director of the Cluster of Excellence "Matters of Activity." His main research fields are the development of a Geist- and Material Science / Material Humanties, with special focus on analog code, active matter, intercultural and transdisciplinary knowledge production (collaborative projects with Universidad Nacional de Colombia and Universidad de Costa Rica), and design as interdisciplinary practice-oriented research. He has also been permanent guest full professor at the Universidad de Buenos Aires since 2005 and head of the Master's degree program "Open Design" of the

Humboldt-Universität zu Berlin and Universidad de Buenos Aires.

Lea Schmidt is a research associate at Lucerne University of Applied Sciences and Arts and a doctoral candidate at TU Dresden's chair of Industrial Design Engineering. Her research focuses on sustainability, design, and technology, with a particular interest in material circularity and its design implications.

Maxie Schneider is an architectural design researcher and lecturer. Her work combines physical and digital prototyping to develop textile building techniques and fibre-based material systems. She has collaborated on various design-build projects and advanced material experiments into structural implementation. As a research associate and PhD candidate at the Cluster of Excellence "Matters of Activity. Image Space Material," Humboldt-Universität zu Berlin and TU Berlin, she investigates adaptive textile structures and the functionalization of softness in architecture.

Emilia Tikka is a designer and researcher working in the intersection of speculative design practices, feminist science and technology studies and novel bioscience research including genome-editing technologies and epigenetics. Her current research focuses on re-imaging human-nature-technology relations through situated and collaborative practices of designing and storytelling. She is currently a PhD candidate at Aalto University, School of Arts, Design and Architecture in Helsinki, where she is a member of the research group Empirica. Emilia is also an associated member at the Cluster of Excellence "Matters of Activity. Image Space Material" at Humboldt-Universität zu Berlin.

Ebba Fransén Waldhör is a designer and lecturer in the fields of spatial installation and textile research. As a design researcher she investigates adaptive materials in textiles and how they function in architectural contexts. In her independent practice, she develops experimental spatial concepts for artists and institutions. The materiality of textiles as soft barriers provides a material ground from which she explores questions of spatial boundaries and their permeability.

Charlett Wenig is an industrial designer (MSc) who did a dissertation on tree bark in the discipline of materials sciences. She is a researcher with a keen interest in biomaterials and sustainable design practices. With her background in both science and design, she specializes in exploring the potential of natural materials and their applications in various fields. In the "Matters of Activity" research group "Adaptive Fibrous Materials" at the MPI for Colloids and Interfaces she aims to bridge the gap between science and design, promoting a research approach that considers material origins, processing methods, and environmental impact to create innovative and sustainable solutions.

Clemens Winkler is a postdoctoral design researcher at the Cluster of Excellence "Matters of Activity. Image Space Material" at Humboldt-Universität zu Berlin. His work relates environmental concerns with social, scientific and technological development. By questioning atmospheric control with its epistemic foundations and institutional affiliations, he, for example, puts clouds into boxes to show what cannot be contained and therefore explores the human obsession with controlling the environment. Opening up participatory and playful frameworks through material transitions becoming intellectual and intimate markers led to his current position as visiting professor for the MA studio “Spiel und Objekt” at the University of Theatre Arts Ernst Busch Berlin.

Susanne Witzgall holds a PhD in art history and is senior lecturer for transdisciplinary studies at the Academy of Fine Arts Munich, where she has directed the cx centrum for interdisciplinary studies since 2011. She is the author and editor of numerous books and essays on contemporary art, on the relationship between art and science, and on current interdisciplinary discourses. These include among others the anthologies *Power of Material / Politics of Materiality* (2014, with K. Stakemeier), *Hybrid Ecologies* (2019, with M. Kesting, M. Muhle, and J. Nachtigall) and *Human after Man* (2023, with M. Kesting).

Material Trajectories: Designing With Care?

Edited by
Léa Perraudin, Clemens Winkler,
Claudia Mareis and Matthias Held

Material Trajectories: Designing With Care? turns towards material-driven design processes with the aim of relocating technoscientific trajectories. Concerned with new forms of caretaking, it combines positions from the extended fields of design research and humanities scholarship including practice-based approaches. The contributions explore current ecological conditions through multiple acts of making-with and seek to complicate questions of sustainability, livability, and cooperation. In reassessing the status quo in design and architecture as material practices, they provide outlines for a nuanced reading of these world-making processes and ask what different ways of designing with care and complicity might entail.

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