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From optimisation to care: ambivalent ethics in contemporary biomaterial design

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Abstract

Biomaterial design is often celebrated as a sustainable alternative to industrial material production, promising to replace extractive processes. Yet, this vision sits uneasily beside critiques that see it reproducing extractive logics through the instrumentalisation of living systems. Drawing on ethnographic research among UK-based biomaterial designers, this paper examines how relationships between biomaterial designers and organisms are lived, negotiated and ethically charged in practice. It argues that care, far from resolving tensions of exploitation, functions as a mechanism through which hierarchies of value are stabilised, justified and sometimes unsettled. Through practices of growing, attuning to and killing organisms, biomaterial designers cultivate what Donna Haraway calls non-innocent care: an engagement that acknowledges complicity in harm while sustaining responsiveness to more-than-human worlds. Attending to these ambivalent, affective and creative entanglements reveals how care in biodesign operates simultaneously as an ethical aspiration, a condition of production and a site where ecological promise and capitalist value production intertwine unevenly.

Impact statement

Based on ethnographic research and interviews, this article challenges the assumption that care stands in opposition to extraction within the context of biomaterial design. It demonstrates how care functions as a mechanism through which hierarchies of value between organisms are negotiated and stabilised, offering a new lens for understanding ethics in biomaterial design practices and surfacing further questions for biomaterial designers to navigate as they take seriously the task of growing – and killing – their organism-partners.

Introduction

Within popular media, biodesign has been increasingly lauded for its promise of sustainable innovation (Carlson 2025; Roberts-Islam 2019; Skibsted 2023). These media narratives echo the common refrain in the design community that biodesign will offer a "new industrial paradigm for the production of artefacts in the 21st century" (Karana et al. 2020, 37) and a route out of the toxicity, waste and extraction built into conventional production systems. Across presentations, pitches and publications, it appears as an alternative material producing science, enabling the replacement of conventional materials with "new" leathers, foams, plastics, etc. and the unleashing of new forms of creativity and material understanding (D'Olivo and Karana 2021; Pollini and Rognoli 2024; Rognoli et al. 2021). This is especially true of biomaterial design,[1] where there is a strong focus on sustainable replacement logics and commercial applications. Biomaterial design and the ethical ambivalence surrounding it is the specific focus of this paper. Biomaterial design offers a particularly revealing site of analysis for the ambiguous role of care because biodesigners' creative capacities to recognise and cultivate the potentials of biological materials brings previously disconnected beings into new relations.

The integration of biology into design has produced divided responses. Critics argue that the positioning of living systems as programmable, efficient and optimisable within biodesign extends extractive logics into more domains of life, turning organisms into resources and enclosing biological processes within commercial value chains (Davidov 2019; Fisch 2017). From my discipline, anthropology, the most common response to my work are suggestions that the relationships between biomaterial designer and organisms are straightforwardly exploitative. From some parts of the design community – particularly away from the more commercial side – the ambivalent potentials of biotechnology and biomaterials are often expressed. For instance, Quijano et al. (2021) describe how, within the fashion context, it may offer a "continuation of the industry's extractive status quo, albeit a cleaner, greener version, and yet it may also be imagined as the human in partnership or even kinship with the living world" (ibid.: 898). This paper explores the grounds between these poles – between exploitation, more regenerative futures and new modes of living within the world – while focusing on a particular point of ambivalence within the biodesign process: the role of care.

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I focus on care because of its curious marginality or centrality across discussions of ethics[2,3] in biodesign practice. While readings of biodesign which emphasise its extractive potentials approach biodesign at a distance through showpieces or public rhetoric and so miss the daily practices in which biodesigners grow, feed and often kill organisms, design researchers attending to these relational practices often emphasise how care and affectual relations within biodesign practice might allow for more horizontally distributed forms of power (Chen and Pschetz 2024; Guarino et al. 2025; Zhou 2025). This can lead to the sense, especially in works focused on alternate human-organism relations, that more explicit attunement or better caretaking practices within biodesign might alleviate risks of utilising organisms for human-centred ends (Bell et al. 2024; Liu et al. 2018; Zhou 2025). Yet this invites the question of what care accomplishes and for whom within the context of more commercial frames, where the caring interactions and evolving relationships between biodesigner and organism are unintended.

My aim in exploring care and the exploitation of organisms in biodesign is to highlight the lingering ethical ambivalence which arises as biomaterial designers justify their projects against wider environmental concerns. Like many writing about care within the bio-community, I ground my understanding of care through the writing of Joan Tronto (1993) and through the later exposition of care within the context of living systems by Maria Puig de la Bellacasa (2017). Care, as Tronto and Bernice Fisher write, includes "everything that we do to maintain, continue, and repair our 'world' so that we can live in it as well as possible" (1993, 103). This definition invites questions and, alongside Puig de la Bellacasa (2017), I want to draw attention to the uncomfortable open-endedness of it. "What is included in 'our' world?" Puig de la Bellacasa asks, "and why should relations of care be articulated from there?" (ibid.: 4). This ambivalence in what counts is crucial in the context of biomaterial design as different scales or orders of care might collide. As I write elsewhere (Pfeiffer 2024), care layers in biodesign practice and care for a particular organism can be in friction with more general care for an environment, pointing to the problem of which care is more fundamental in sustaining "our" world.

The central question guiding this paper is: how do practices of caring for organisms within biomaterial design redistribute, stabilise or obscure responsibility and benefit in projects that claim ecological and ethical promise? It is an extension of the question so often raised by scholars of care – *cui bono* – who benefits? (Star 1995). Addressing this requires close attention to how biomaterial designers come to know, become attuned to and intervene in the lives of their biological partners and how these relations are situated within broader regimes of innovation and sustainability. Building upon Eva Haifa Giraud's (2021; Giraud and Hollin 2016) writings on the ambivalence of care across animal testing practices, I do not draw a strong binary between care and exploitation or see care as a moral corrective to the instrumentalisation of other beings. As Giraud and Hollin present within the context of the creation and maintenance of beagle colonies for radiation testing, care did not "combat instrumentalization through creating the space to affect and be affected" (ibid.: 5), as is often suggested by literatures on care and affect, but rather "is precisely what enables the instrumentalization of life" (2026, 7). I trace a similar relationship between care and instrumentalisation in the context of biomaterial design practice, arguing that care functions as a mechanism through which hierarchies of value are negotiated, justified and sometimes unsettled in practice. Drawing on Donna Haraway's notion of "non-innocent care" (2008), I understand biodesign as a site in which caring entanglements do not resolve ethical tensions and questions of hierarchy but make them more explicit.

The paper proceeds in three parts: first it reviews biodesign's dominant narratives and the critiques that frame it as an extension of extractive logics, then it traces how optimisation produces forms of attunement and care and finally, it considers how these relations reorganise ethical hierarchies within biomaterial design. It ends with questions which biodesigners might use to reflect on their own ethical subjectivities, on the ways in which organisms are enrolled within their material production practices and how these entanglements are communicated.

Methodology and research background

My argument develops from an ethnographic study of UK-based and UK-connected biomaterial designers,[4] largely conducted between 2021 and 2023 and in 2025. Analysis of the data, as is common in anthropological research, was recursive: initial threads of analysis were written in the field and then revisited and refined as I returned to my fieldnotes and to interview transcripts across the years.

My initial interest was in how designers navigate notions of ecological responsibility for their creations; questions of bio-utilisation and care emerged quickly as central concerns to this topic. The initial phase comprised what Sherry Ortner (2010) describes as an interface ethnography: an engagement with the public faces of a field. In the context of my work, conducting interface ethnography meant attending design shows, museum exhibitions, conferences and public talks to understand how biomaterials were being narrated and visualised to wider audiences. I complemented these observations with 68 semi-structured interviews with biodesign educators, biomaterial designers and employees from biomaterial startups. Many of these were working on projects with mycelium, bacteria cellulose, algae or other microbes with the explicit purpose of demonstrating or developing a solution for industry needs. While some of these biomaterial designers neither industrially scaled up nor commercialised their biomaterials, instead maintaining more small-scale situated practice, all framed their work in relation to degenerative conventional material practices.

Engaging with the public presentations and more private expressions of biodesign allowed me to map the discursive terrain of the field. In private, biomaterial designers often talked in the language of care and intimacy and emphasised the affective qualities of their practice. In public presentations, this was less common and more familiar narratives around production occurred. In many commercially oriented events, one often heard framings which support instrumentalist critiques as, for instance, when a prominent entrepreneur in the bio-space launched his new venture at Biofabricate 2022 with a slide announcing that it was "Creating value for all stake-holders," stakeholders defined as: "Investors," "CMOs," "Start-Ups," "FMCG Champions," "Consumers" and, finally, "Nature." This visible weighting of commercial concerns, flattening of ecological beneficiaries and erasure of organisms used within the process is a clear representation of what critics see as problematic in the field.

The second phase consisted of a nine-month corporate ethnography at a South London biomaterial start-up which was creating a new material for fashion applications, where I was employed as the company's Content Lead. This role offered

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access to the organisational culture of a small design-biotech company and to the affective, temporal and material dimensions of lab-based collaboration with living organisms. Here, I was able to see how care was practised even within strict commercial settings.

I am still engaging with biomaterial designers and regenerative designers as a postdoctoral researcher on the publicly funded Becoming Regenerative project (2024–2027). This work situates biodesign across broader debates about regenerative economies and environmental responsibility, tracking how the language of care and ethics circulates across policy, practice and pedagogy. My current position informs my analysis, though earlier work interviewing and shadowing those engaged within the lab forms the core of this paper.

The bioutilisation critique

Across many interviews with UK-based or UK-connected biomaterial designers, I encountered recurring narratives about their motivation and purpose. Few practitioners described entering the field to explore new ethical paradigms. Instead, most located their turn to biodesign with growing disillusionment with conventional design industries. When I asked my participants why they began practising biodesign at a specific point in their careers, I heard iterations on the same story: the designer, having worked in industry for a few years, became more aware of the wastefulness and pollution conventional design methods encourage. "It made me so angry," one biomaterial designer told me, "that you'd get hundreds of samples from India or China and every sample would be wrapped in plastic and there'd just be so much waste. I didn't want to do it anymore."

Fuelled by this frustration, they began seeking alternative production methods that appeared more circular or regenerative. Biofabrication arose at that point as a viable solution and a means of substituting or eliminating toxic or petrochemically derived processes from conventional design. Across these narratives, biomaterials are consistently framed in relation to a material crisis. Greener, ideally cheaper, more localised and, perhaps, more efficient, they are presented as being able to solve multiple problems simultaneously. This approach entangles organisms used within biodesign practices in spanning systems, supply chains and challenges.

The goal of working with biology, as presented in these narratives, is highly functional. As one panellist at the 2022 Bio-Futures for Transplanetary Habitats symposium observed, "biology does the hard work for us." It is a positioning of biodesign's role supported in academic discourses. Alexandra Daisy Ginsberg (2014), an early and prominent thinker on biodesign, argues that in it biology becomes "more than a material ripe for exploitation; it becomes both software and hardware for manufacturing; a toolbox for a new generation of designers mixing and matching components more akin to computer programs and components" (ibid.: 52). Living systems are positioned here as programmable, optimisable and productive, qualities which prove attractive within existing industrial and commercial logics – and creative practices.

Academic critiques of biodesign have tended to focus on this instrumental framing and argue that the practice risks extending capitalist logics of extraction into more and more of the biological domain, positioning increasing numbers of organisms as resources to be optimised. A small but illustrative example of this comes from design researcher Svenja Keune's (2021) analysis of language used in biodesign write-ups. She notes how life itself becomes a material quality in biodesign theorising instead of its own dimension of being. She writes how living organisms become "living *things* that can be collaborated with" (quoting Karana et al. 2020, emphasis mine) with the end result that "living organisms such as fungi, algae, plants, or bacteria mainly serve the production of materials that are seen as alternatives to petroleum-based materials or materials of animal origin" (2021, 13). Critiques like this bring to light the common but problematic slippages between the organism and object. Indeed, many of the metaphors employed within biospaces set up organisms as just another technology ripe for use as they are described as "chassis" or "micro-factories" for production and their value presented in terms of their "efficiency" and "output." Downgrading organisms from being to object and framing their living processes as outputs reinscribes them inside conventional, extractive logics.

Recent critical work has moved beyond discourse level by tracing the wider ecologies of labour implicated in biodesign and biofabrication practices. For instance, Chen et al. (2025) explore the activities of organisms within the lab through the metaphor of more-than-human labour, situating organisms within networks of production, subsumption and value creation. By foregrounding the hidden work performed by microbes, plants, animals and other biological entities, this approach productively complicates celebratory narratives of bio-sustainability. They further trace the spanning connections between activities in the lab and the processes and supply chains which enabled their production, highlighting the connection, for example, between E. coli bacteria being cultured in a lab and palm oil production or red algae cultivation to provide a growing medium or preservation.

These are valuable perspectives in thinking labour, provenance and the extension of extractive logics into the biological domain and in considering what organisms do for production systems – and what these systems do to them. This can lead to ethical questioning, as the authors of the above paper suggest, by focusing on the quality of "labour" relations and whether "the level of control over organisms is commensurable to the consequential benefit and what could be done to improve conditions within these practices" (Chen et al. 2025, 18). Ethics here relates to the conditions of "work" for the microbes but less to the subjectivities and hierarchies crafted in relation to uneven claims to care. Further, they do not account for the fact that care and evolving ethics run both ways; as Yee and Sharp (2023) argue in their work on insect growing for consumption in New Zealand, affectual relations, even in the context of instrumentalised labour, change both care-receiver and care-giver.

Attending to caretaking practices within biodesign, I critically ask what working with organisms does to biomaterial designers and argue that closer attention to care opens new avenues for approaching biodesign and bioutilisation, grounding implication, ambivalence and self-critique as central ethical and political stakes of the practice.

From optimisation to attunement

This section explores how care emerges as an ambivalent, situated effect of optimisation and bioutilisation. From attempts to optimise living processes appear relations of attunement and responsibility as a condition of the work itself.

A desire to maximise design outputs paves the way for entanglements, as "high-quality" biological output demands sustained attention, sensitivity and responsiveness to an organism's

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needs. Take, as an example, biomaterial designers looking to grow mycelium for commercial purposes. Before they can scale, they would need to intimately understand the needs of their mushroom partners. As one of my participants put this, this is a particular challenge because of the amorphous potentials and "transformational dynamics" of mycelium: it can grow in so many ways, with different characteristics. Accordingly, these biomaterial designers working with mycelium must pay close attention to their fungi's responses to different stimuli and conditions in order to direct their growth in a desired way; mushrooms will grow as they wish, otherwise.[5] Biodesigners "direct" rather than "control" growth because biodesign entails action at a remove. As Camere and Karana (2018) present, there is a "temporal division between the moment of making and the evaluation of the outcome [. . .], intermediated by the organisms" growth which "breaks the flow of question and answer that normally occurs between makers and materials in the crafting process" (2018, 579). As such, the designer's actions become input in a two-way process and not linearly tied to a result. From desires for material optimisation and creative expression attunement emerges. Camere and Karana write that biodesigners must learn to "anticipate the material" without being able to directly "feel the effects of their making onto the material; their practice must rely on observations, as they watch and look after the organisms' growth" (2018, 579).

In biodesign, an emphasis on nonhuman agencies directly shapes the understood relationship between designers and the organisms they work with. Many describe their relationship to their organisms as "conductors" or "microbiofarmers." At the company I worked for, lab technicians used a running metaphor when presenting their work of acting as shepherds and the microbes as their "herds." These analogies speak to directional influence but not direct control. "I try to get the best out of each sort of actor," one biodesigner explained to me, "but I don't necessarily feel I must engineer it, you know?"

Engaging with organisms within biodesign – coming to understand their preferences and needs inside their environment – involves honing one's senses. It requires learning what their signs of comfort or discomfort are and how to engage with them accordingly. I understand this refinement of sensibilities as the process of creating an "interested body" (Latour 2004) which can pose "interesting questions" (Despret 2004). An interested body is a body which has learned "to be affected, meaning 'effectuated', moved, put into motion by other entities, humans or non-humans" (Latour 2004, 205). Within the context of biodesign, honing an interested body means making sense of organisms' signs in different situations. These signs can be subtle, but to the trained eye, hand and nose, they become clear. For instance, I was told by a biodesigner working on a photosynthetic coating for fabrics that microorganisms can "find a way to talk to you in a very powerful way" either through "colour change, potentially smell, potentially texture . . . It's not necessarily something that – they are microbes – so it's not something crazy jarring." This was often repeated by other interlocutors; smells became a sign of how "happy" (or not)[6] their organisms were, and even unpleasant smells (like ammonia) came to be a positive cue, a sign of thriving life, and was something to be savoured. Through gradual attunement, biodesigners build an intimate understanding of the organism's responses to stimuli and come to create conditions in which the organism produces their desired effects like density of growth, colour changes, surface textures and so on.

By honing an interested and attuned body, many biodesigners can start asking "interesting questions" to their biological partners. Interesting questions, Despret writes, are framed in a way that the organism can understand and freely respond. Rats navigating a maze for rewards are asked interesting questions, but those pinned down for experiments are not. In Despret's examples, the animal subject asked interesting questions can influence the design and outcome of the experiment itself: asked an interesting question, organisms might produce interesting responses in turn. To ask interesting questions, the experimenter must rely on the "availability" of the organism and present themselves as a "care-taker, as someone interested in its possible becoming" rather than a "judge or master" (ibid.: 124).

Bringing this back to biodesign, materials and organisms capable of "acting back" in unexpected ways set limits to human control and allow for interesting responses, which many of my interlocutors embrace as positive. As I was told by a department head for a bio-architecture course which taught synthetic biology, practitioners should consider themselves to be closer to "gardeners" than "gods." His takeaway was that one should not strive for ultimate control with biology, though one could prune and guide. Such metaphors point to a recalibration of roles and refinement of sensibilities, as biodesigners come to position their actions in terms of co-production, care and direction. Here, one can trace the connection between honing an interested and attuned body and leaving open possibilities for surprise and difference based upon a flow of influence, agency and perhaps empathy between experimenter and subject.

Such an open-ended approach is explicitly called for within biodesign circles as it allows for novel emergences. For example, Ramirez-Figuroa (2018) directly advocates for probes which do not presuppose what an organism is "good" for or encourage a deterministic outcome. Rather, organisms may have capabilities not yet explored or understood and these capabilities might yet be valuable to people too. Though such an approach may seem at odds with the productive, maximising drive behind much biomaterial design exploration, this kind of free exploration and creative probing underpins much of the practice. Allowing for contingency and "happy surprises" is understood as "part of the process" when exploring a particular organism or living systems' potential, especially in the early days of a project. For instance, at a talk an employee from Faber Futures, a research-based design studio in London, explicitly called for designers to "slow down." "Don't try to take the organisms, drop them into a system and force an output," they said: "you need to build a relationship" which enables different kinds of possibilities first.

The following section considers the consequences of this relationality, yet before moving on I wish to draw attention to two points. First, the care and attunement emerging within the field cannot be extricated from the simultaneous reality that such practices improve productivity and expand what these beings might become good or useful for, thereby extending the range of relations into which they may be enrolled. Second, this enrolment of organisms into new, productive forms drives biomaterial designers to draw hierarchical relations *between* organisms. While organisms become physically enrolled in the creation of biomaterials (either directly or subordinately through supporting infrastructures like Chen et al.'s (2025) palm oil), they are also brought into new conceptual frameworks that arrange them differently in relation to each other and other distributed beings. Thus, a fungus bred for its capacity to remediate nitrate run-off, for instance, is physically enrolled in relation to the other organisms it is grown alongside in the lab *and* is simultaneously enrolled conceptually in relation to the cattle whose slurry produces that

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run-off, the waterways it pollutes and the agricultural systems that sustain the cycle. Organisms are rendered as nodes within distributed lifeways and forms extending far beyond their immediate remit, valued for their potential to intervene in entangled systems. The ethical tension here occurs because of biodesigners' creative capacity to identify and cultivate the potentialities of different organisms: to perceive of these organisms not simply as living beings, but as latent solutions to systemic problems.

This process establishes hierarchies of value between beings, insofar as some lives, capacities or ecological relations are rendered worthy of protection or optimisation in service of broader goals, while others become secondary or expendable. This differs from more mundane forms of bioutilisation such as yeast in breadmaking, a comparison raised by Zhou (2025), because the enrolment of organisms in biomaterial design is explicitly framed through ethical and care-laden justifications. Where the use of yeast in baking rarely requires moral articulation, biomaterial design foregrounds claims about environmental repair, sustainability or collective flourishing, thereby making ethics itself a central stake of the endeavour. As one participant suggested, "biomaterials are materials with more ethical considerations, generally."

The fact that attunement emerges from optimisation and the creative questing for useful capacities sets the stage for deeper shifts in perception. As biodesigners learn to read their organisms' signs and ask interesting questions, they expand their perceptual worlds to include bacterial, fungal and algal lifeways. The next section traces this movement from sensory intimacy to shared worlds, showing how attunement generates new forms of implication and responsibility alongside new biomaterials.

From attunement to shared worlds

As biomaterial designers deepen their relationships with their organism-partners, many begin to imaginatively project themselves into the worlds and experiences of their co-creators. As scholar of care Nel Noddings explains, contractual reciprocity – a willingness to care based on valued services – can give way to a more affective connection. She contrasts one's willingness to let spiders, toads and king snakes live in their garden because "they serve my purposes: they eat marauders" to the admiration and wonder one might begin to experience when one appreciates the worlds of the other in their own terms (2013, 158). I see a similar journey in biomaterial design where maximising productive outputs paves the way for and is complicated by careful attention and growing care within bio-practices.

Caretaking and caring for an organism in a biolab have inherent challenges. Noddings writes that when we care for another person, we step outside of our personal frame and "consider the other's point of view, his objective needs, and what he expects of us" (Noddings 2013, 24). When one tries to relate to organisms such as mycelium, cyanobacteria or slime mould in the lab, stepping into the organism's point of view poses difficulties. To begin relating, many biomaterial designers imaginatively project into the world and experiences of their co-creators. At first, this often takes the form of anthropomorphic empathy. Helena, a biomaterial designer working on degradable clothing inoculated with mycelium, described that when she first started working, she felt "like to understand it I had to become its friend. I wanted to understand how it was working and growing and creating all these networks . . . I think it helped me to communicate with the mycelium a lot when I humanised it." I heard a similar impulse expressed frequently by biodesigners who attributed human-like attributes and abilities to their organisms. An organism could "misbehave," for instance or "betray" their human partners, and they also often acquired names and genders. Yet, there are clear limitations to such a humanising approach, and Helena acknowledged this. She mentioned that her opinion on how best to try to relate changed as "humanising things is actually pretty limiting – only understanding things in human forms limits us from seeing what it is actually capable of."

While Helena found that humanising the organism ultimately was an unproductive means of relating to it, her empathetic stance points us to the fact most biodesigners need for their organism to feel "real" to them. I had this need described to me by Marlene, a well-known biodesigner who works with insects and is particularly respected for her work with propolis, a resin-like material made by bees. The daughter of a beekeeper, Marlene described how the lives of insects are very real to her and she talked at length to me about their needs. With microorganisms like bacteria, however, she said that one must "develop an imagination with them. They are very imaginary . . . I'm not attracted to it. Maybe because it's not real to me, it's not in my worldview for now."

Together, these accounts show that making organisms "real" is a precondition for care: becoming "real" makes things matter in new ways as organisms must exist within one's perceptual and moral field and enter one's world. Yet things do not become "real" equally and not all organism lives are rendered as affective and entangling as others. There are lasting hierarchies in who or what becomes "real" inside the lab, mediated by what technologies and collaborations render microbial, algal and fungal lives perceptible and significant. In my interviews with biodesigners, many described the importance of talking to scientists and reading academic papers to better understand the "worlds" of their co-creators and the biological processes they are manipulating. Marin, a fellow at Newcastle's Hub for Biotechnology in the Built Environment, put this explicitly. She told me that by deeply engaging with their scientific colleagues biodesigners could "sort the signals from these so-called black boxes [and] speculate intensely on what's going on in their little samples." Marin said that such apparatuses become biodesigners' fingers and legs and extended eyes. This kind of research, which is extended through technologies and explained by scientific partners, is helpful in making sense of their organisms' behaviours and making organisms more "real." Doing so contrasts with the projective and humanising approach that Helena described.

For many of my interlocutors, the experience of engaging with organisms in their own terms and in their own worlds (however partial) was revelatory. A lab technician working at Central Saint Martin's wet labs told me he was shocked when he first started in the lab at how frequently designers shrieked with delight as they looked into microscopes. The liveliness, unpredictability and surprising multiplicity of their partners was enchanting. Indeed, many of my participants expressed delight at their newfound sense of life's proliferation. Nicole said that "when I first saw the bacteria on the microscopic level and I could see they were moving, I realized that there were hundreds and hundreds of them. I had thought of colonies as single beings, but it's like a whole world."

As their microscopic partners are rendered "real" within the lab, many biodesigners note their expanded awareness of bacteria, algae, mycelium and other organisms in the world generally. This sense of excitement at the proliferation of life and growing interspecies awareness is noted by others writing on biodesign. Myers (2021) suggests that biodesign "cultivates interspecies empathy while building knowledge of biological systems and the intricate interdependencies in the environment" with the result

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that biodesigners "imagine an ecosphere simply bursting with undiscovered opportunity for collaboration and integration." While this has clear resonances with this paper's argument, his second conclusion – that from biological awareness biodesigners espy "opportunity" (which I interpret primarily as productive and financial opportunity in new outputs) – misses the bigger point. Nature, in his framing and in many other biodesign or biomimicry discourses, comes to appear in its proliferation as a "huge R&D lab" (Blok and Gremmen 2016, 205) brimming with creative possibilities. Such sentiments reframe the wonder and entanglement emerging from biodesign in exploitative terms as plants and other organisms become "evidence of nature's 'genius', a repository of skills" which can in turn be patented and enclosed within intellectual property rights (Goldstein and Johnson 2015, 390). This logic is articulated by actors within the biomaterial community, as when Suzanne Lee asked "how do we go from 5,000 microbial solutions used in the bioeconomy to billions?" during a panel conversation at Biofab Fair 2025, arguing that "it's almost infinite what's possible out there" with different organisms as "we don't know what their capabilities are yet."

Yet, I argue that there's more at play here. Though in my conversations with biodesigners I've often heard similar sentiments, the wonder often expressed by biomaterial designers at life's proliferation is not *just* with a view of expanded resource imaginaries. The natural world, for them, is not simply full of solutions to be commodified as potential capital. Instead, biodesigners' expanded awareness involves a broader perspective shift and has consequences for how they relate to the world, even when no immediate design application follows. For instance, Liene, a biodesigner dyeing fabric by growing blue elf cup mushrooms directly onto them, told me that she had a new wonder for her body after practising biodesign. She had become aware of how we "breathe spores in every day, all day, but that's just normal . . . I think about humans, breathing spores, and how I don't get mouldy because of my immune system. It just makes everything seem a bit more magical." Ultimately, Liene said, "once you start to realize that everything is alive on a very small level, that everything is alive constantly, you have a very different world." My participants' descriptions of discovering "new" and "different worlds" points us to the fact that such expansions of awareness involve an ontological shift as much as an epistemic one. Caring entanglement, as Haraway proposes, "pepper[s] its partners with attachment sites for world making" (2008, 26).

While this expansion of perceptual and imaginative worlds is often described by biomaterial designers in terms of wonder, delight or even enchantment, such affectual relations should not be read as ethical consolation. Care deepened through wonder heightens emotional acuity to the consequences of one's actions, making questions of justification and responsibility more pressing rather than less. As a result of this expanded awareness of life, many biodesigners come to see themselves as a responsible part of a network of beings whose lives will be affected by the choices they make. This extends over time, with actions leading to consequences that spiral out in unpredictable ways. Liz, an educator and researcher, connected this to the lasting discomfort she felt with biomaterials, saying, "as we are manipulating nature, and we don't know where that leads, there's always the question of the unknown."

From shared worlds to non-innocent care

This section examines how biodesigners explicitly recognise, teach and cultivate what Donna Haraway terms "non-innocent care" – an orientation that acknowledges responsibility across relations that necessarily involve harm and death (Haraway 2008). I show how recognition of non-innocent care is the first step in remaining accountable to the lives one takes but also to the hierarchies one establishes between lives. Overall, I see this articulation of value between lives as central to teasing out the ethical ambivalence at the heart of contemporary biomaterial design practices.

As biodesigners become more aware of the organisms present in their daily and professional lives, they begin to feel their participation in these livelier worlds more acutely, recognising that their actions and activities directly affect an increasing number of lives. Attunement brings obligation as much as wonder. A central tension arises here: if biomaterial designers care deeply for their organisms, if they imagine themselves as participants in broader ecosystems and if they frame their work as non-human-centred, how do they reconcile this with the fact that their practices depend on using and killing organisms for distinctly human ends?

Some biomaterial designers end up questioning the legitimacy of bioutilisation for design purposes altogether. For instance, a biomaterial designer I interviewed working with mycelium, Aurelie, told me that the first thing she realised is "it's not just you working in your studio with some fabric or some clay or something that doesn't impact the world. You actually have a direct intervention in an ecosystem." As such, she emphasised the need for biodesigners to avoid doing "what we've always done . . . ecological colonization – we just go into ecosystems and take things from it, regardless of the consequences. How do we avoid that?" The desire to avoid replicating degenerative processes informed her decision to source fungi from her local forest to ensure that if some of her samples escaped the lab, they would not disrupt the balance of her environment. Yet she still questioned whether it was even right or justified to "kill this living thing for the sake of design?" and argued back and forth for a while on the issue, describing it as an ethical choice akin to veganism: tied up in personal ethics and influenced by broader considerations of environmental impact. Such practices make clear that attunement not only intensifies responsibility across existing ecosystems but extends it across newly assembled and speculative ones.

The resulting ambivalence often distinguishes biodesigners from scientists with whom they collaborate. Victoria, then a biodesign lecturer at Central Saint Martins, told me that while scientists may understand organisms such as mycelium or slime mould as non-sentient (and may see the moral conflict that biodesigners feel in their making process as naïve), she understands and encourages her students' impulse to develop empathy for their living co-creators. She said that she invited them to seriously question the ethics of what they were doing – and to determine, for themselves, whether it was appropriate to use other beings for design or art practices. Feeling for microbes was not naïve or romantic, Victoria said, as empathy was needed to grapple with the ethics of using and ultimately killing their living collaborators. Carolina, a biodesign lecturer at the Royal College of Art, expressed a similar commitment in an interview. She tried preventing her students from disassociating and no longer noticing the deaths of others in the lab, even if those deaths were necessary for experiments. She said she wanted them to feel the consequence of what they were doing.

This pedagogy of responsiveness is not confined to classrooms. At the Biosummit 5.0, a global conference for bioartists, academics, biohackers, biodesigners and citizen scientists in 2021, there was a ceremony which involved thanking the various actors which were sacrificed in experiments. Animals, plants, cells and bacteria were acknowledged and thanked in turn. Such performances and

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teachings radically and in some cases playfully query the remit of one's concerns and care. They put into stark focus the question of where concern ends – which organisms' deaths are worthy of concern and question and which are not. "Every decision has consequences," I was informed, and "you need to know them in order to proceed." I see these pedagogical efforts as an expression of non-innocent care: teaching students to live with the necessity of killing organisms for material production without rendering their deaths invisible or ethically neutral. The point is not that care resolves the violence of instrumentalisation, but that it renders biodesigners accountable for the hierarchies through which some lives are protected, cultivated or mourned while other deaths are justified.

The willing participation in the death of another exposes the limits of collaboration. This is an obvious point, but it is worth stating plainly that an organism's co-involvement in the design process does not mean equal investment or benefit in the design outcome. Shared worlds do not mean shared stakes. Did the organism sign off for its life to be put to such ends after all? Does that even matter? Leigh Star's question resurfaces: who exactly is benefitting here?

Daisy Ginsberg and Natsai Chieza, two pioneers in the bio-space, make this explicit as they ask: "if good biodesign today asks: 'Can biology do this better? How will this change things for good?', then we propose a third question that addresses others: For whom, or for which other species does this matter?" (Ginsberg and Chieza 2018). I suggest that there is an additional and perhaps even more difficult question: which species for whom it might matter can be ignored?

As Giraud (2021) cautions, "the recognition that no form of relation is innocent is insufficient in accounting for the exclusions that are bound up with any form of relation" (ibid.: 4). Recognising noninnocence, she argues, "does not get to the root of things"; care is not inherently disruptive of anthropocentric or ethical hierarchies and may instead reproduce or stabilise them (2021, 117). This is particularly important in biomaterial design, where structured exclusion is a necessary feature of practice. Some lives are recognised as lively, valuable and worthy of care while nevertheless being judged expendable for the preservation or flourishing of others. From this perspective, speculative suggestions like Zhou's that future ethics committees might "scrutinize projects for their impact on microbial lives, ensuring that no harm comes to these living participants" (2025, 279) do a disservice to the practical ethics and challenge of exclusion within the lab. Harm will necessarily be done, so the question is not whether biomaterial production can ever become fully non-exploitative or harm-free. Such a framing risks reproducing fantasies of innocence that obscure the constitutive exclusions involved in any material practice.

Instead, the ethical challenge concerns how harms are ordered and legitimised: which organisms are positioned as sacrificable for particular sustainable or regenerative futures, which forms of flourishing are prioritised and who decides these relations of value.

As biomaterial designers become more attuned to the lives they work with, they simultaneously refine the distinctions through which some organisms are protected, cultivated, optimised or mourned while others are rendered killable. These distinctions are justified in multiple ways. For instance, the death of some microbes may be framed as necessary to protect others in the lab. This is common practice, as most laboratory work requires aseptic techniques that eliminate all life except the selected organism under study. Even the act of choosing one organism necessitates the eradication of others in that controlled space. Such exclusions are procedural requirements and are rarely foregrounded in ethical discussions about caring for or killing the "chosen" organism. In this sense, laboratory monoculturing is inherently discriminatory, structuring in advance which forms of life are permitted to live and which are rendered expendable. Care does not stand outside processes of instrumentalisation here; it becomes one of the mechanisms through which biological value is differentiated and organised in practice.

In justifying certain deaths as necessary, biomaterial designers echo what Thom van Dooren (2014) calls the "violent-care" of conservation in which preservation of some species requires the death of others. However, within conservation or environmental care narratives, such practices typically operate in a relatively bounded ecological frame: decisions about who lives and who dies are justified in relation to the integrity of a particular ecosystem understood as an organism's "natural" world. Care and killing are often articulated within an environmentally delimited network of relations, as predators are eliminated to preserve the ecological assemblage deemed worth sustaining. In Yee and Sharp's account of care within insect farming in New Zealand, for instance, care for a particular grub was intimately tied to its fern host and the soil conditions that sustained it, but also in the fact that their interlocutors could be explicitly "un-caring towards others (i.e., 'getting rid of weasels, rats, stoats')" (2023, 92).

Such bounded relationships certainly persist in biodesign (as the example of Aurelie's mycelium above shows) and care (or its withdrawal) is enacted through them. Yet biodesign also extends these relations beyond conventional ecological frames. While violent care in conservation is justified in the name of maintaining ecological integrity, in biodesign, organisms are cultivated, modified and relocated across contexts, generating connections that are creative, engineered and often unpredictable. The justification needed to account for specific harms, then, is grounded in imagined futures and spanning relations across material and ecological systems.

It is often noted and considered integral to design that it connects previously disconnected things, and design practice brings new worlds into being (Fry 1999; Simon 1969). This ability to imagine otherwise, to intervene creatively in entrenched material and ecological arrangements is precisely what makes biodesign compelling, yet it is also what intensifies the ethical burden borne by biomaterial designers. Organisms are not merely enrolled into existing ecological orders but repositioned in newly configured assemblages oriented toward particular problems and futures. For example, a fungi might "need" to be sacrificed to prevent some broader environmental harm, as when mycelium is grown to substitute for conventional petrochemical foams, thereby displacing potential toxicities released into an environment. These sorts competing sorts of care, in which fungi are cultivated as alternatives to petrochemical foams or insects are bred for material experimentation, draws beings into hierarchies that privilege certain lives, environments or temporal horizons over others. This is not to say that these hierarchies are inherently wrong or that the benefits of mitigating this or that ecological harm might not be "worth it," but that the ethical stakes of biodesign lie in more than simply acknowledging the presence of harm or death – it lies in justifying them vis-à-vis others.

Conclusion

Through sustained ethnographic engagement, I have shown that working with living organisms reshapes biomaterial designers' ethical orientations, bodily routines and senses of responsibility. This article has argued that care in biomaterial design is not opposed to instrumentalisation: the two are co-constitutive. The very practices through which biomaterial designers learn to

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notice, respond to and care for organisms are also those through which organisms become enrolled in systems of production, optimisation and value creation. Care does not stand outside extraction as its ethical corrective; instead, it reorganises the ethical life of extraction from within. Organisms become simultaneously "interested" actors, responsibilities, experimental subjects and material resources.

Recognising this complicates accounts that position care as inherently resistant to bioutilisation. In biodesign, care can coexist with processes structured around scalability, innovation and optimisation. Indeed, caring attentiveness often expands capacities to perceive new productive possibilities in living systems and to justify the incorporation of organisms into newly configured assemblages.

The ethical significance of non-innocent care, then, lies in rendering the tensions in biomaterial design perceptible and contestable. As biomaterial designers become more attuned to the lives with which they work, they are compelled to articulate why some organisms are protected while others are sacrificed; why some ecological relations are preserved while others are disrupted; and how particular harms come to be justified in the name of broader environmental or social goods. Care then becomes ethical work and not a resolution to ethical questions.

The implication is not that biodesign should abandon care, nor that care can redeem it. Recognising the co-constitution of care and instrumentalisation opens further ethical and political questions for biomaterial designers. If care inevitably participates in the production of hierarchies between lives, then the task is to remain accountable for the exclusions, distributions and futures one helps bring into being. Asking not only what a biomaterial does, but for whom, at whose expense and through which assumptions and infrastructures is key to exploring one's own ethical positioning here. Does one's practice (or the language used to frame it) trouble epistemological, ethical or anthropocentric hierarchies, or does it redistribute and stabilise them in new forms? Who counts in maintaining one's world "as well as possible" (Tronto, 1993)? What kinds of exclusions become thinkable, necessary or morally acceptable across frameworks of care oriented toward optimisation, regeneration or repair? While these questions are deliberately theoretical, they are intended to invite biomaterial designers to pause and reflect on the underlying assumptions behind what they understand to be care within their practice.

Practically, implementing this sort of reflection may require creating explicit moments in biomaterial workflows, such as sourcing decisions, organism selection, contamination protocols, scaling discussions and end-of-life planning, where exclusions and hierarchies of care are collectively reflected upon rather than naturalised as technical necessities or obvious justifications. Such moments of reflection are relevant within small-scale practices and in large-scale biomanufacturing, as both involve navigating the ambivalence of designing in shared, lively worlds where care is real but unevenly distributed, implicating and never innocent.

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Notes

1 I primarily use "biodesigner" and "biomaterial designer" to refer to practitioners working with living organisms in material development contexts, though many participants also identified simply as designers due to their training in fashion, product or speculative design. The biomaterial designers I worked with sometimes made products themselves or created textiles or other materials to be inputted into established supply chains for fashion or interior design, for example.

2 By bringing ethics and care together, I am thinking through the lens of feminist care ethics and everyday practice, rather than through explicit lab protocols and regulations.

3 Bioutilisation refers to the use of biologically derived materials or the services of living organisms in a designed product, process or system.

4 Most typically, biomaterial designers who had been trained in the UK but who had since moved outside of it.

5 This is true generally: as a biodesigner starts working with a new organism, they will need to refine their technique, their methods for preparing, processing and acting on their organism's environment. Many design researchers working within the space have aimed to enhance the ability of designers to become attuned to organisms (Bell et al. 2024; Kim et al. 2024).

6 This invites a question: how are physical cues – cues interpreted by the designers' 'interested bodies' – understood as signs of the organisms' happiness? There is always a level of uncertainty as to what an organism's signs might mean and a level of conjecture in uncoding them, as designers will readily acknowledge. In the end, power relations determine what signs come to matter at all. I see parallels here to Eva Hayward's ethnography of coral cups in a lab in California. Hayward (2010) notes that "crosspecies sensations are always mediated by power that leaves impressions, which leaves bodies imprinted and furrowed with consequences. Animal bodies – the coral's and mine – carry forms of domination, communion and activation into the folds of being" (ibid: 592). A similar exchange of power takes place between designers and organisms with a biodesign lab as the ability to identify and assume happiness is implicated in power relations.

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