Microbial revolt

Redefining biolab tools and practices for more-than-human care ecologies

Citation for published version:
Chen, Y & Pschetz, L 2024, Microbial revolt: Redefining biolab tools and practices for more-than-human care ecologies. in F Floyd Mueller, P Kyburz, JRW, C Sas, ML Wilson, P Toups Dugas & I Shklovski (eds), *CHI'24: Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems.*, 707, ACM, pp. 1-16. https://doi.org/10.1145/3613904.3641981

Digital Object Identifier (DOI):
10.1145/3613904.3641981

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Peer reviewed version

Published In:
CHI'24

Microbial Revolt: Redefining biolab tools and practices for more-than-human care ecologies

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Fig. 1. Workshop poster for Microbial Revolt

Recent work in HCI has called for deeper ethical considerations when engaging with more-than-human organisms in design. In this paper, we introduce Microbial Revolt, a provocative method to support reflection on the perspectives of organisms involved in HCI and design practice. By asking participants to consider the reality of a chosen organism in feral and lab environments and to redesign lab tools in order to account for their "non-participation", we identified the manifestation of key epistemic differences between approaches to care and ecologies in typical design and biology research - as well as the potential for design and HCI to creatively redefine power dynamics in the lab. Further interviews revealed specific challenges and opportunities that designers and HCI researchers face in adapting practices to lab standards, and lab equipment to their practices, calling for a redefinition of tools, spaces and guidance to accommodate phenomenological perspectives and multiple modes of interaction with living organisms.

CCS Concepts: • **Human-centered computing → Interaction design theory, concepts and paradigms**.

Manuscript submitted to ACM

Additional Key Words and Phrases: Posthumanism, Care Ecologies, More-Than-Human, Other-Than-Human, Ethics of Care, Multi-species Design, Bio-HCI, DIY-Bio, Microbial HCI

ACM Reference Format:

Anonymous Author(s). 2023. Microbial Revolt: Redefining biolab tools and practices for more-than-human care ecologies. In *Woodstock '18: ACM Symposium on Neural Gaze Detection, June 03–05, 2018, Woodstock, NY*. ACM, New York, NY, USA, 23 pages. https://doi.org/XXXXXXX.XXXXXXX

1 INTRODUCTION

HCI has witnessed increasing body of work geared towards engaging more-than-human living organisms in design, resulting in new areas of research that include biological HCI [20, 23, 51], microbe HCI [2, 36, 37], and renewed approaches to more traditional fields of bioart [27, 39] and biodesign [24, 50]. At the same time, we have seen an expansion of critical approaches towards decentering human-perspectives and placing greater ethical considerations towards more-than-human living organisms and species in design. Notions such as Design for Cohabitation [40, 59], Posthumanist HCI [4, 35], Multispecies Worldling [66], Multispecies Interaction Design [43], and More-than-human Participatory Design [1, 13] have emerged as attempts to invite designers and the HCI community to consider new ways of acknowledging and placing the more-than-human at the core of design practice.

In this paper, we bridge these two areas of research with a focus on revealing issues and attempting to foster reflection on practical ethical considerations in working with microorganisms in laboratory and studio practice. Similar to some of the approaches above, we draw from feminist care ethics, and the work of Tronto[62] who defines care as everything that we do to maintain, continue and repair 'the world', which includes "all that we seek to interweave in a complex life-sustaining web"[62]. Here, we refer to care ecologies as this intricate web of bodies and actions that result from interactions between living beings (human and more-than-human) who strive to sustain life in the best way possible. Although more-than-human care ethics is multifaceted and highly contextual, it orients towards the recognition of the immanent interdependence between living beings and acts of situated relationality, that is, the tangible everyday practices that strengthen (or indeed hinder) this interdependence. According to Puig de la Bellacasa, *"the ways in which we care for the everyday have a quality of 'ethicality,' embedded in processes of situated relationality [...] thinking this way follows the requirement of looking at the specificity of moments, particular relations, of ecologies where the ethical is both personal agency and embedded in the "ethos" of a community of living." (2017, p.151).* [14]

The scale, and sometimes negative connotation of microorganisms, however, can place them lower in human empathy scales [45], and provide increased epistemological-ethical challenges. As discussed by Key et al (2022) 'what and how we know (epistemology) and what and how we care (ethics) are bound together in cycles of replication.' [35]. Also due to their scales, the inclusion of these organisms in research and design practice is often mediated by specialised equipment and protocols, which are developed to safely streamline the work of culturing, managing and appropriating them for particular purposes. Departing from the notion that the tools we use to mediate our relationships with the world intrinsically affect the way we interact with the world [11], we designed Microbial Revolt, a workshop that invites people to reflect on the reality of these organisms and to redesign tools and equipment typically used in laboratory and studio practice to allow for their non-participation. The focus on revolt works as a provocation to help reveal the hidden labour of these organisms and imbue them with a sense of agency that might not align with research and design agendas. Ethics comes from evidencing their agential roles and exploring the studio or lab environment as a space for a "community of living" [14]. Acknowledgement of organisms' non-participation in the design practice becomes key to surfacing their agency and support exploration of more horizontal power dynamics between organisms and designers. The ability to leave space for them not to be involved in the design, or to consent for participation, is indeed largely neglected and sometimes made impossible by the tools, spaces and guidance that support work with living organisms. Through a collection of 16 workshop responses and 24 redesign outputs, the workshop manifested key epistemic differences between approaches to care and ecologies in typical design and biology research, and revealed the potential for design and HCI to creatively redefine anthropocentric power dynamics in the lab. Further interviews revealed the different ways designers and HCI researchers interpret and facilitate care and ecological approaches in their practice, and the multiple ways they adapt their practices to lab standards, and lab equipment to their practices, through liminal spaces and contestation. The research draws attention to the ways HCI and design is challenging a sense of remoteness characteristic of laboratory environments through intimacy and ad-hoc ecological inclusions, pointing at ways to redefine tools, spaces and guidance to accommodate such phenomenological perspectives and multiple modes of interaction with the organisms.

2 RELATED WORK

2.1 More-than-human centred approaches and methodologies

New approaches in HCI have investigated ways to best centre design on more-than-human organisms and species. For instance, by analysing two case studies that re-conceive time, space and place from more-than-human perspectives, Smith et al [59] argue for the need to support new forms of human-animal cohabitation through the concept of 'Interspecies Sensemaking' [43] Mancini et al. explore how new approaches of more-than-human semiotics and ethnography can better support 'designing for' dogs as the central users of interactive technologies. Engaging with the dialogue between Japanese philosophy and feminist techno-science theories, Akama et al. [1] explore 'more-than-human participation' in design, in the forms of creative nonfiction writing as thought experiments to reckon with differences and plurality of multispecies worlds.Some methodologies have also included specific modes of attentiveness or phenomenological methods such as the "felt experiment" [47] where researchers develop tools that directly interact with the organisms to develop ethical sensibilities towards the organisms, "designing with" [49, 65], where more-than-human things' creative capacity is engaged through approaches such as landscape description, noticing and translation; and "walking with" [19] where researchers participate in collective walking guided by local more-than-human creatures to re-construct forest data.

Drawing from these approaches, we look at ethical concerns embodied by tools, spaces and practice of involving microorganisms in design, also as a way to attend to the needs and centre design on more-than-human organisms.

2.2 Practical experiments that create a "feeling for the organism"

Designers and HCI researchers have also been developing practical work that attempts to enhance the experiential qualities and understanding of organisms, developing what feminist and biologist Fox Keller (1983) would call 'a feeling for the organism'[34]. These can be found particularly in the fields of bioHCI [16, 20, 25, 51] and microbe HCI [36, 38]. For instance, Chen et al [9] developed a human-microbial vocal interface in a fermentation bucket to 'foster human affective emotion toward fermentative microbes'. Liu et al [40] created devices for mushroom foraging that aim to 'draw the body into the environment and bring different qualities of human-fungi relationships [to the] attention of the wearer.' Ikeya et al. [31] designed silkworm-centred habitats while attempting to relinquish productionist control over them. Kim et al [37] identified a range of practices in HCI that attempt to surface the livingness of microorganisms in display interfaces at various levels, while Zhou et al. [67] investigated ways of quickly revealing states of microbe development that are only perceptible to humans after a relatively long period of time. Finally, Ooms et al. [50] reflect on a care-oriented toolkit for designers to create a bacteria-powered light installation incorporating materiality, temporality, ecology and agency from the bacteria's perspective.

We contribute to such forms of practical work by providing a space for designers to reflect on labour and non-participation.

2.3 More-than-human labour and non-participation

Labour is discussed in the work of Key et al [35] who draws attention to the need to recognise it outside the human-experience, exploring the many ways in which objects can labour, even in static and quiet forms. In their view, recognising this form of labour would support de-centreing the human in design. Other areas of research discuss non-participation as indeed an important way of legitimising participation. For instance, in their study on designing with yeast via directed evolution, STS researchers Szymanski et al. [61] reflect on the limitation of yeast participation by pointing out the lack of channels for the yeast to respond and express signs of non-participation towards design goals. This echoes Olsen's study on co-creation beyond humans in urban planning, which indicates the caveat of viewing co-creation as 'inherently emancipatory' without being mindful of the 'unequal distribution of power' [58].

By drawing from these notions of labour and non-participation we provide a method for designers to actively engage in such considerations in their lab and studio practice. Further, through revealing tensions generated by engaging with biolab equipment and regulations, we extend the inquiry of more-than-human participation to the level of tools, infrastructures and epistemic tensions.

3 MICROBIAL REVOLT

To better understand the nature of participation and indeed the work that organisms do through this participation, we argue for legitimization of non-participation in design activities. In this context, we use non-participation in the sense of resistance, a refusal to cooperate [29], a form of revolt, which is differentiated from other forms of non-participation that result from deliberate exclusion or alienation [32]. Revolt has long been considered a powerful way for labourers to have their voices heard [57]. Conceptualising more-than-human labour in sociology and animal geography provides insights into the agency of more-than-human labourers in shaping socio-economic processes. Porcher [54] remarks cows' labour being most visible when they refuse to cooperate, revealing the usually invisible social grooming, manoeuvre and active participation of cows that is usually reduced to 'mechanical obedience'. Despret [18] notes conflicts unravel invisible dynamics in situations where everything functions. Similarly, we argue that it's only through allowing space for non-participation that one can safeguard participation from coercion in more-than-human research.

Informed by such theories, we designed a workshop that uses revolt as a lens to invite designers and biologists to reflect upon the invisible labour of lab organisms supporting research. For example, death and contamination, could be seen as ways for microorganisms to refuse to participate in such human enterprises. We ask: what if we saw these (uncooperative) behaviours as ways for organisms with moral conscience to revolt, rather than mechanical accidents to be fixed? Despret [18] points out the constructiveness of interpreting animal 'delinquencies and uncooperativeness' as messages of suffering and revolt against abusive situations. By changing common analogies, e.g. from 'accidents', which silence organisms, to analogies that invite attention and response, the ability to revolt becomes the ability to negotiate fairer treatment.

3.1 Chindōgu and critical artefacts

We centred the workshop on the making of novel lab objects as a form of embodied reflection of participants' perceptions of organisms, lab practices and daily tools. We ask how we might redesign lab equipment, the tools putting organisms at work, into tools for organisms to voice objections towards research agendas? Redesigning lab equipment is interpreted as a form of 'critical making' [46, 56] where conceptual reflection is facilitated by the physical exploration of artefacts. Through this redesign exercise, the workshop initiates a discussion on how utilitarian equipment and organisational structures may consolidate more-than-human oppression and how such configurations could be challenged by shifting the 'end goals' of lab tools from anthropocentric production to lab organisms' rebellion.

The core workshop brief is to transform laboratory tools into Chindōgus, or unusual tools, which represents a 90s movement against consumerism and mass production [33]. Examples of Chindōgus include a tissue dispenser helmet that provides all-day tissues for people with hayfever, a pair of eye dropper glasses with funnels on top to help with applying eye drops, etc With bizarre functionalities seen as causing more problems than solving, Chindōgu provokes and unearths the preconceptions under current definitions of "utility" and "function". Rendering the lab equipment futile to humans yet useful to voicing the concern of the organisms can be seen as analogous to the practice of creating a Chindōgu.

Research in HCI has similarly explored the use of debatable and open-ended concepts as a tool for critical reflection. Vines et al's [64] created a workshop where "deliberately questionable concepts" were used to create a safe space of critique that facilitates cycles of debate and new design suggestions. In the Magic Machine Workshops[3], Anderson and Wakkary invite participants to create "non-functional and hypothetical things" as a way to materialise novel technologies through highly personal lenses while freeing participants from technical concerns. Sharing the focus on non-solutionist approaches and physicality, we argue that the hypothetical and rebellious nature of Chindogu invites creative and reflective responses unbounded by utilitarian agendas.

3.2 Microbial Revolt as a workshop method

The workshop starts with a journaling exercise, where participants are asked to choose an organism and role-play their realities and perceptions in both feral and lab environments under different themes, recording their thoughts in a template. Apart from descriptive themes such as habitats and activities, other themes were chosen based on the focus of current more-than-human design and multispecies studies literature, such as ecologies[26], temporality [48, 55], death (p81) [17], and fulfilment (p89) [17]. Participants are also invited to create their own themes. Participants are then asked to reflect on the difference between the feral and lab journals (fig 4) and potential forms of organism revolt in the lab environment, sharing thoughts with the group. This journaling exercise takes approximately 35 minutes. The aim of this exercise is to reveal participants' perception and ability to imagine the perspectives of the organism. Similar role playing methods are widely adopted in more-than-human design discourse in HCI, such as speculative participation[10], multispecies theatrical methods[58], more-than-human umwelt sketch [15] and thing-centred interview[8, 21].

In the next Chindogu design exercise, a series of prompts with lab objects (such as autoclave, cell waste jar, centrifuge and pipette, detail in fig5) and organism revolt behaviours (such as death, escape and low growth rate, fig 6) are provided for participants to draw from or randomly combine to come up with their own Chindōgus. Participants are also encouraged to create their own lab objects and revolt behaviours. Results are then sketched out or illustrated through a collage on the canvas provided beforehand (fig 3). After the design, participants are asked to share their result and discuss among the group. This exercise takes around 45 minutes, followed by a 20 minute discussion. A timeline of

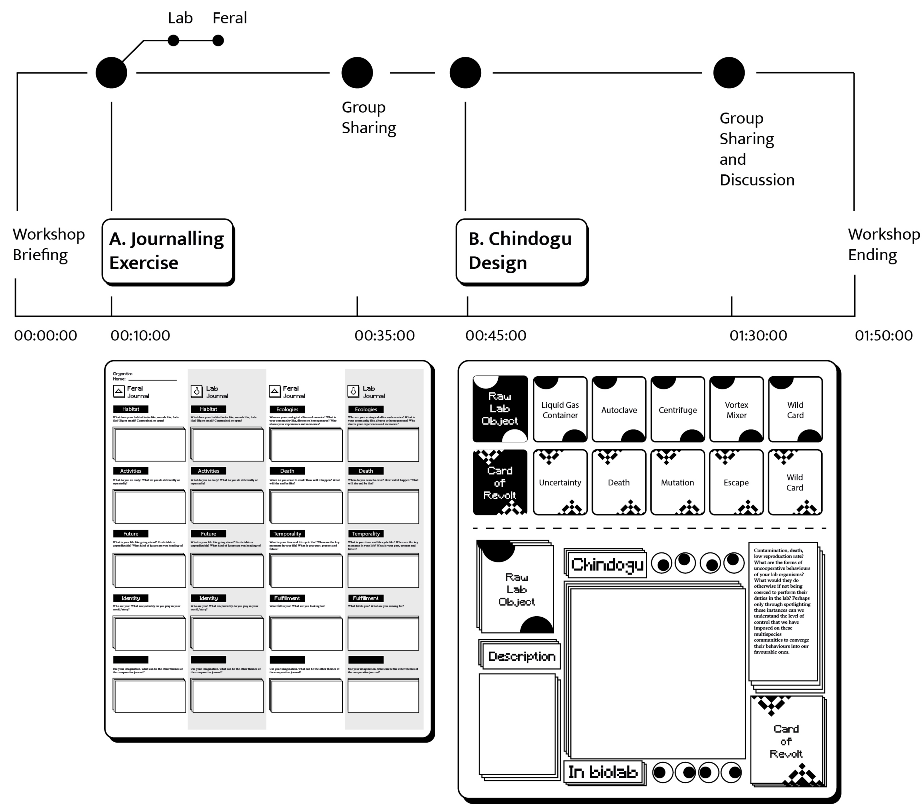

Fig. 2. Workshop timeline with respective template materials

the workshop can be seen in fig 2. As the workshop aims to guide lab Chindōgus creation based on personal experience and research with living organisms, it can be carried out both individually and in groups with similar backgrounds. The discussions have the roles of both concretising thoughts as participants externalise their views to the group, and opening up perspectives as participants leave the workshop.

3.3 Carrying out the workshop: participants and setting

Participants were recruited within the biodesign and bio-HCI communities, and included researchers working in design and biological sciences. Three workshops were conducted over two months.Overall, 28 participants took part in 3 workshops. 2 workshops took place face-to face and 1 online. Workshop sessions lasted for 1-2h.

In this paper, we report on the gathered responses, 8 of which came from biologists (4 were carried out individually and 4 in groups of 3-4) and 8 from designers (all carried out individually). One workshop was carried out only with biologists, one only with designers and one with a mix of designers and biologists.

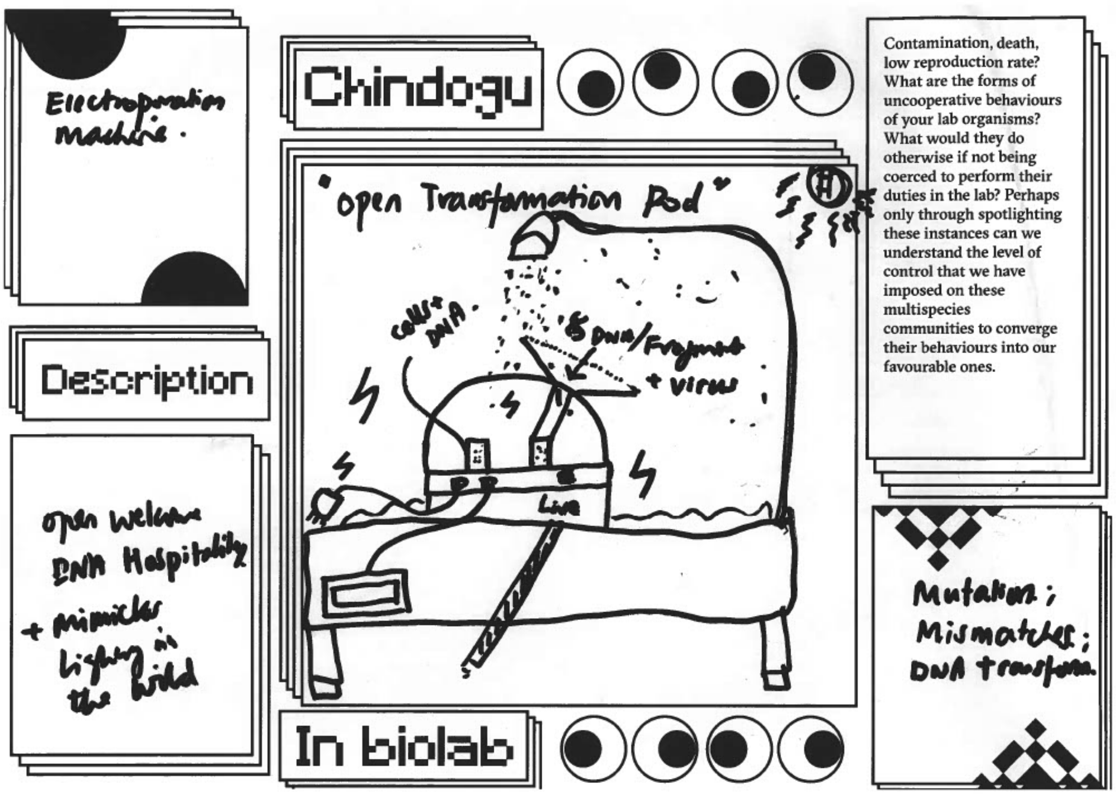

Fig. 3. A Chindōgu canvas filled by a participant

Practices of design participants were situated in the fields of biology, design and HCI and included research on biomaterials, biotic games, DIY bio, living artefacts, and more-than-human design, all actively involved in the HCI community. Biologist participants came from fields closely engaged with design communities, such as synthetic biology, molecular biology, and developmental biology. One biologist also worked as an artist. Age was not disclosed. Two thirds of the participants could be defined as early-career researchers, working as research associates or in their postgraduate studies, and one third mid-career, supervising students and leading research groups.

The sharing part of the workshops was recorded, transcribed and thematically analysed. Drawn responses were collected, scanned and analysed together with respective transcripts.

3.4 Workshop Responses

3.4.1 Responses from feral/lab journal activity. Most participants chose the organisms they worked with to carry out the journal exercise, although a few chose organisms they were familiar with without necessarily working with them in practice. Biologists mainly chose e.coli (outputs B8, B6, B4, B1), a common organism used in biological research, and two designers (D8 and D6) chose tomato plants (a creative freedom from the microbial world). All other organisms were chosen only once: Yeast (B7), Tardigrade (B5), Drosophila (B3), Menstrual Blood Cells (BA2), Mycelium (D7), Dinoflagellate (D4), Cyanobacteria (D2), Flavobacteria (D1), and the larger classes of Fungi (D3), or broadly

Fig. 4. Organism journal template with feral and lab versions

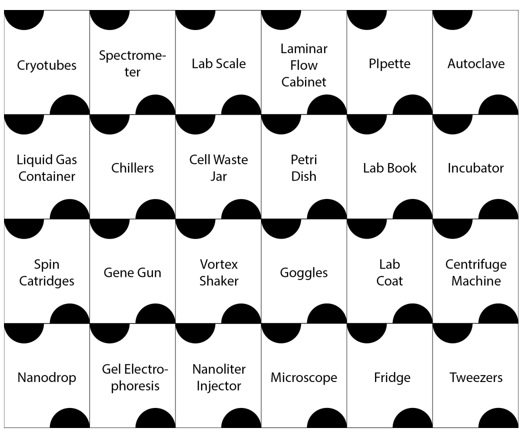

Fig. 5. Cards for laboratory tools

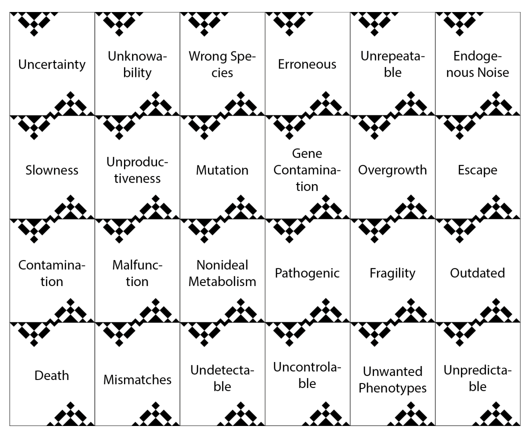

Fig. 6. Cards for organism revolt behaviours

Microorganisms (D5). In reporting the responses we use a nomenclature based on the participants' lead discipline and the chosen organism, so that D1_Flavobacteria refers to a HCI/designer-led reflection/output focused on Flavobacteria and B4_E.coli refers to a biologist-led output, focused on e.coli.

a. Habitat

Participants mainly recounted dynamic feral habitats where organisms had a more varied range of behaviours and ecological roles, with designers being particularly positive towards the feral: *"In a feral habitat, that would be* *flavobacteria chilling in a puddle on a rocky coast, which is a very dynamic habitat"* [D1_Flavobacteria]. The tendency to favour the feral habitat, however, was challenged by scientists: *"If they are better taken care of in the lab, why would they want to go to the wild?"* [B4_E.coli] *"As for the lab population, the habitat is quite comfortable. [...]"* [B8_E.coli].

In the feral journal, the organisms are portrayed as purposeful and self-directed, motivated by their own goals: *"In the wild I live or I try to live close to fruits, maybe different fruits, just trying to put my progeny there"* [B3_Drosophila] In the lab description, the habitat is "constant", "constrained" and limited to instruments used to cultivate the organism, with less description of behaviours: *"I'll be living in tubes, or bottles if I am lucky, and basically living on my food"* [B3_Drosophila].

b. Activities

Biologists often struggled to see differences in activities in feral and lab environments, out of the perspective that organism activities are mainly survival and growth related. One participant compared the feral activities and the lab activities as *"Same thing. They eat moss, they sometimes spin around"* [B5_Tardigrade]. HCI researchers saw more nuanced differences through the lens of encounters *"In the wild they have many encounters with other things and they also have interspecies conversations [...] in the labs, I think the most possibilities are intraspecies [...], and that's a bit more limited"* [D2_Cyanobacteria], and highlighted the dominance of humans: *" it's more towards changing the activities according to the person in the lab"* [D5_Microorganisms].

c. Ecologies

Most participants approached ecology in terms of interspecies relationships, which were consequently more richly described in the wild. Identified interactions included *"predation"(B3_Drosophila), "competition"(D5_Microorganisms), "symbiosis"(D2_Cyanobacteria) and "horizontal gene transfer"(D1_Flavobacteria).* In terms of lab ecology, there was again a common theme of uniformity, control and isolation. B3 narrated the loss of survival skills in the lab when deprived of predation interactions in the wild *"In the lab it is different, I cannot... I even forgot how to escape anything."*

Nevertheless, participants noticed that interspecies relationships could emerge in the lab in the form of contamination and infection. *"They will try to be sterile because when you inoculate you have to do the flame thing. But I don't think it's 100%. There would be at least few cells that could get in. So that's a possible ecology system."* [D5_Microorganisms]. Such *"ecological behaviour"* [D5_Microorganisms] was seen as particularly negative by biologists: being considered as *"the only bad thing that could have, is to get [...] this infection that will invade all the tubes in the lab that the researchers hate that will eat my protein. "* [B3_Drosophila].

d. Death

In the feral journals, death causes tended to be described as unpredictable and varied, due to competition, food depletion, environmental stress, or human encounter "My death in one case is unpredictable and I will really struggle to get old" [B3_Drosophila]. The lab journals described death as planned, controlled, and sometimes painless: "humans even planned my death before I was born [...] either I'd be drowning in ethanol that would make me sleep or I'd be burnt at really high temperatures really fast" [B3_Drosophila].

Designers tended to describe death vividly, "The food might be gone, they might get eaten, but also the habitat might turn too dry, too salty, too hot or too cold" [D1_Flavobacteria], while biologists struggled to elaborate on differences. "Death is largely the same [...] in the lab they can be heat killed or chemically terminated after an experiment, which is less likely to happen in the wild, though it's not entirely impossible." [B4_E.coli], "[in the wild] we might starve because we can't get enough food... similarly, in the lab, when our population grows to an excessive size, there is not enough food, some of us will die" [B8_E.coli].

e. Fulfilment

We introduced the theme of fulfilment to help participants see the organisms as independent teleological beings. This was captured by designers: *"I'm very central and also very discreet. [...] However, In the lab, I'm not only isolated from this ecosystem [...] maybe I will still be happy to be useful, but not as happy to be in the spotlight"* [D7_Mycelium]. However, particularly among biologists this was also interpreted from the perspective of the organism's service to research: *"When I'm in the lab, I am again part of something bigger, but it's just to make [...] some individuals happy by giving my body and my progeny to research"* [B3_Drosophila].

Interestingly for [B1_E.coli], fulfilment was interpreted in the wild as drawing attention from humans and in the lab as having their voices heard in the experiment, *"I would probably make people go a lot of times to the restroom. Yes, when I feel like it, I can be a little lethal. [...] in a lab environment, I would probably feel fulfilled if someone asked me what I want to do or what I want to produce."*

f. Temporality

Under the theme of temporality, a strong contrast between the two journals emerged. [D3_Fungi] provided a strong comparison *"[In the wild] I believe their temporalities are forever [...]. In the lab, well, a week or two weeks or more or whenever the study ends."* Time was also seen as more linear in the controlled environment: *"as a tomato [in a vertical farm], I [am] in the linear life process, not in the life cycle."* [D6_Tomato Plants]. While most responses found differences between the two contexts, some participants found it difficult to elaborate on them *"Temporality… they exist and then they don't. And in the lab they have experiments done on them, for cool reasons."* [B4_E.coli].

3.4.2 Responses chindōgu exercise. Overall we gathered 12 outputs from biologists and 12 from designers/HCI researchers (with some participants producing 2 outputs), as described below.

a. Biologists

(Figure 7)

Despite directions, only one biologist redesigned the lab equipment to support the "microbial revolt", through a **"Hallucination Microscope"** (Example 3): *"through seeing the cells into this microscope, [the scientists] start to receive messages from the cells."* [BA2_Menstruation Blood Cell]. Other 2 biologists envisioned the equipment malfunctioning, imagining a **"Broken Fridge for Yeast Escape"** (Example 10) [B7_Yeast], an **"Irritative Lab Coat"** (Example 9) *"chemical remains on the coat [...] may react with the yeast. So they may cause some sting or skin disease [...]"* [B7_Yeast], and a **"Laminar Flow Hood Escape and Outdated Lab Book"** (example 8) [B5_Tardigrade].

In all other cases, the modification would take place in the organism, which would revolt by:

a) Refusing to cooperate with the experiment - Example 1: **"Microbial sit-in protest"** *"the bacteria just decided to not do anything, be there [...] and not move at all. As you can see, well, it's just sad e-coli at the bottom of the test tube"* [B1_E.coli];

b) Killing themselves to prevent the experient or breaking the lab equipment - Example 6: **The "Uncentrifugable e.coli"** *"is incapable of spinning and withstanding centrifuge force[...] this is a special E.coli that is fighting against us."* [B4_W_E.coli] and Example 5: **"Fragile Cell Waste Jar"** *"E.coli has the capability to erode plastic containers and thus escape"* [B4_E.coli],

c) Convening with other organisms to gain back control of their genetic mutation - Examples 2: **"Black market agar plate for self directed transformation"** *"hey, take this undercover gene so that you can choose whatever you want to be and not be forced into anything."* [B1_E.coli] and Example 7: **"Non Disposable Cell Waste Jar with Mutated**

Tardigrade" *"they can take some gene from the cell waste jar and become heat resistant and can grow to a larger size when it's heated. So you cannot experiment with it nor dispose of it"* [B5_Tardigrade].

d) Destroying reproducibility of experiments - Example 4: **Unpredictable Heredity**: *"[The chindogu will] be their own chromosomes. I guess that they could somehow choose how to put the chromosomes in their nucleus [...] this will make all the results completely irreproducible [...] I think that will be the most annoying thing they can imagine"* [B3_Drosophila].

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c) Convening with other organisms to gain back control of their genetic mutation - Examples 2: **"Black market agar plate for self directed transformation"** *"I imagine [the agar plate] as the gathering place for them to plan on how their voices are going to be heard [they would say] 'hey, take this undercover gene so that you can choose whatever you want to be and not be forced into anything.'"* [B1_E.coli] and Example 7: **"Non Disposable Cell Waste Jar with Mutated Tardigrade"** *"they can take some gene from the cell waste jar and become heat resistant and can grow to a larger size when it's heated. So you cannot experiment with it nor dispose of it"* [B5_Tardigrade].

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b. Designers (Figure 8)

In contrast, designers tended to actively challenge the original purpose of the equipment by changing its form, structure, scale or material. One designer imagined a **"Squirting Pipette"** (Example 9) *'I imagine you can squeeze and then you let go, which sucks microbes in and propel them away. And the escaped microbes can try out their luck in the real world.'* [D1_Flavobacteria]. Another participant designed a **"Multi-channel Contamination Pipette"** (Example 7) with an inserted bioreactor in the middle to produce bacterial contamination. *"The idea is to contaminate [...] these*

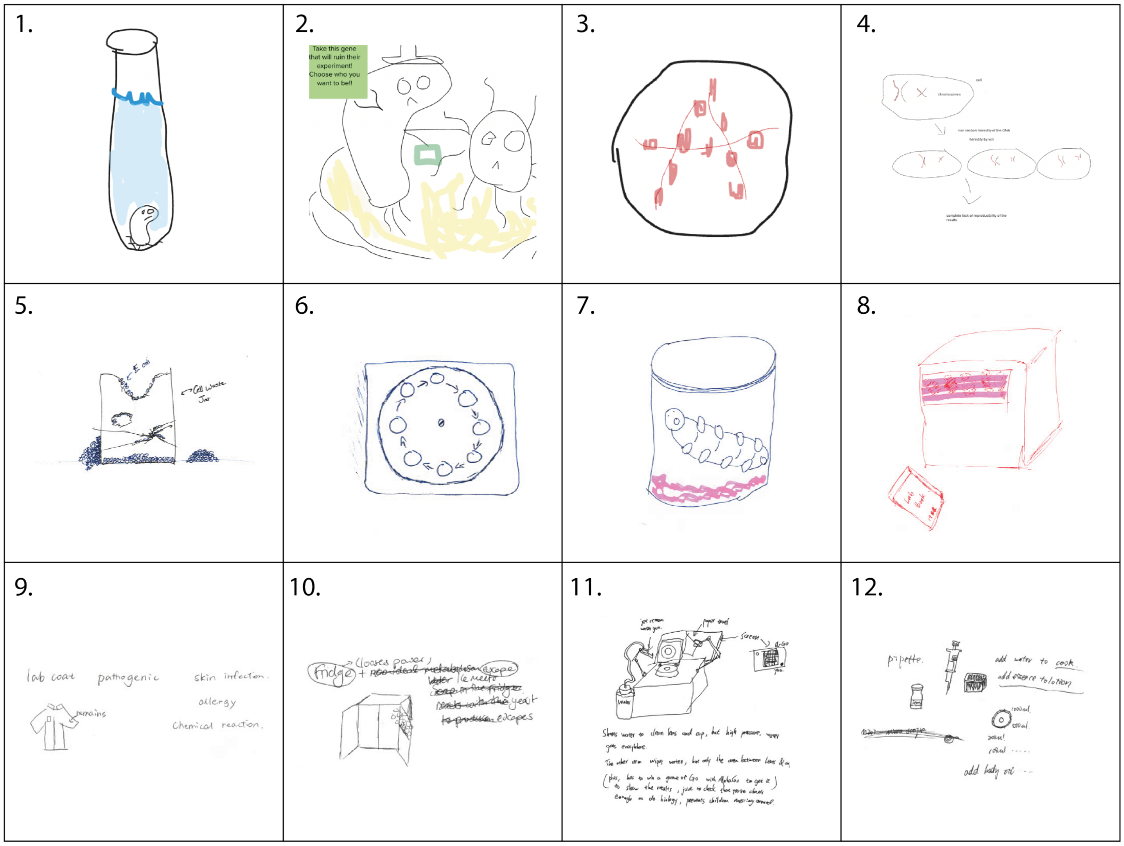

Fig. 7. Biologist participants' chindōgu design

samples with either the microbes or the genetic or molecular proteins that's been generated in the bioreactor. [...] to propagate and contaminate as much as possible." [D5_Microorganisms]; D1_Flavobacteria created a **"Biodegradable Petri Dish"** with biodegradable materials that can be eaten by the microbes (Example 8). *'When you forget to feed your cells then they can also escape.'*

Another mode of revolt looked into the suppressed characteristics or ecological interactions of the organisms in a lab setting. One participant came up with a **"Flexible Petri Dish for Rhizomatic Growth"** (Example 11) *"how to connect my intrinsic features back to what I would like to be, rather than what designers would like me to be. I thought about this petri dish which will have loads of connectors that would somehow account for my rhizomatic nature"* [D7_Mycelium]. Another example is the **"Friend smuggling tool"** (Example 1) *"I am designing these clothes for the scientists [...] that attracts the insects, but also provides camouflage for them. [...] Then the scientist will wear the contaminated clothes back to the greenhouse lab to meet with the tomato plants."*

Designer responses were underlied by questions towards production-driven control on organisms in the lab. For example D5_Microorganisms designed an **Open Transformation Pod** (Example 6) that mimics the natural conditions for horizontal gene transfer to create randomised genetic alteration in bacteria: *"it's not really a controlled transformation.*

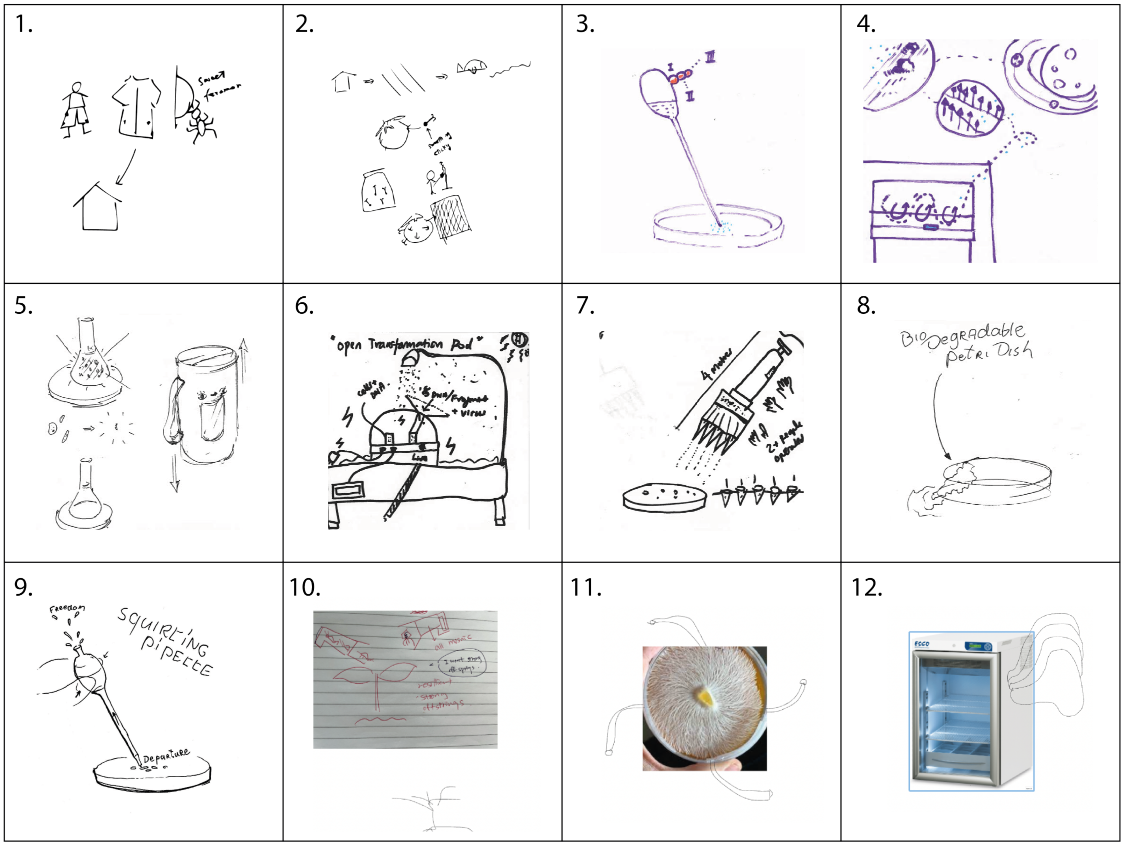

Fig. 8. Designer participants' chindōgu design

[...] It would be something like an open transformation pod, so just like a transformation festival for microbes within this container". A similar response was the **Suicidal Pipette'** (Example 3) by D2_Cyanobacteria *"So in this pipette there are three chambers where the microbe can go for different levels of euthanasia. So in the first one, it's a long one and then the second one is a slightly shorter one. The third one is like immediate death."* D8_Tomato Plants speculated about the design of a **Hook Spray for Free-Ride Escape** (Example 2) *'Tomato fruits often have a bit of hair on them. So something nice would be really tiny objects that have a bit of a hook and they will be able to attach to [the hair] [...] the tomatoes with the little hooks will attach to your clothes and then it goes with the person back home, outside'.*

3.5 Initial Insights

While most designers/HCI researchers saw the lab as restrictive to organisms agency and wellbeing, biologists tended to portray it as a safe and meaningful environment, where organisms could be shielded from natural threats and engage in fulfilling missions through the research.

Similarly, while both groups acknowledged the intrinsic ecological decontextualisation of lab environments, biologists didn't necessarily see this as negative and tended to place less emphasis on differences between feral and lab environments (such as in the death and activities themes). This reflects different epistemic cultures [7]: for biologists, the need to generalise results encourages control, replication, and viewing organisms through the lens of the experiment at hand. This is evident in the Chindogu example where destroying reproducibility became "the most annoying thing [the organisms] can do". In contrast, the tendency of Design to situate the complexity of phenomena through concepts that embody aspects of this complexity, e.g. in the ways it is seen as tackling 'wicked problems' [5, 30, 44], makes it less prone to generalisations (practice that has been enriched by the increased exploration of participatory multispecies approaches, as discussed in the Related Work section)

Despite adoption of the first person role play as an attempt to help participants recentre perspectives, the will of organisms in the lab was still often connected with the aims of the human researchers, as seen in responses from both biologists and designers when talking about organisms' fulfilment, although the theme of revolt also helped to surface levels of oppression within this fulfilment.

While biologists tended to view 'microbial revolt' as anarchist threats addressed to the scientist, designers interpreted it as an expression of unmet needs which can still be accommodated through mutually beneficial arrangements. Nevertheless, biologists' questioning of standardised manipulations like pipetting could spur reimagining alternatives to organisms' mechanical obedience in day-to-day streamlined manipulations. Overall designers were more inclined to contextualise organisms within ecological and socio-economic perspectives.

Overall, within the realm of "secluded" [6] biological research, care was restricted to the relationship between researcher (as caregiver) and organism (as care receiver). The high level of control of biological research leaves little space for the organism to "care" in ways that go beyond compliance and obedience. Therefore, in this case, care ecologies (as we define earlier in the paper) are still centred on the human: organisms' activities, death, and sense of purpose comes from the researcher and the research community, in which the organism is deeply implicated. Designers' position, in turn, reflects a broader perspective on care ecologies, where there is an attempt to focus on relationships beyond the researcher. The loser scope and tendency to focus on wicked problems allow designers to embrace revolt within their research agenda that allows experiments to be more insightful than representative.

These differences raise several questions. How are these epistemic cultures negotiated by practitioners engaging with spaces, tools, and guidance that originate in biology research? What are the perceived power dynamics? How can ecological perspectives be expanded? As we interviewed practitioners in biodesign and bioart, we aimed to further investigate how one might navigate these issues and balance secluded versus ecological research approaches in future biodesign practices.

4 INTERVIEWS

To expand points of tension and further explore the creative potential and ecological thinking behind HCI and design practice, we carried out 16 semi-structured interviews: 5 with previous workshop participants and 11 with newly recruited ones, that is 9 biodesigners working across HCI, and 2 bio-artists. The interviews lasted around 30-45 minutes and were carried out online. Their focus was the participants' practices, ways of accessing institutionalised lab resources and technical knowledge, the challenges posed by lab management, and tactics adopted to navigate safety regulations and creative freedom in their projects, and how they envision biodesign labs mediating more-than-human care ecologies in the near future. Interview recordings were anonymised, transcribed, and thematically coded with open and axial coding processes. Through this thematic analysis, we defined four themes as follows:

4.1 Biolab tools and spaces as constraining perspectives

Most designers saw traditional biolab environments and practices as narrowing the scope of work and even creative capacities. *"They are way stricter with the rules. [...] You have to know everything before you enter it. [. . .] there's no real creative freedom anymore"* [DF1]. The suppression of creativity was linked to the lab environment itself: *"[in the lab] I will probably see them as more experimental subjects maybe because of the atmosphere that the lab has"* [DF2]; and to the equipment at hand. *"I think in the lab there are quite limited things you can do to really care besides keeping them alive"* [DF13]. Equipment was in fact seen as a way to restrict the range of organisms studied in traditional labs when it comes to working with complex samples. *"They don't want you to bring in other types of organisms [. . .] because they need to get more equipment to handle [them]. "* [DF3]. Moreover, the biosafety standards often pose challenges to designers when introducing new tools, as described by [DF1], who could not bring their tools to a Biosafety Level 1 (BSL 1) biodesign lab.[1] *"The catcher tools are made of wood and you cannot properly clean them according to the rules in the lab"* [DF1]. Some responded with provocative actions as a way to challenge the conventional use of lab equipment, *"One of the artists in residency researching the impact of vibrations on growth put two dildos into the incubator"* [DF8]

The importance of compliance with safety guidance in the lab was acknowledged by giving examples of bad conduct. *"They didn't clean the hood properly after the use. And then another student came in [...] immediately that bacterial culture got contaminated"* [DF3], while another interviewee argued that such conduct could be connected to a lack of guidance for more experiential approaches. *"the physicality, the materiality is an important element in art and design, but [...] there's no biosafety data of whether you can let this organism be touched by someone or not"* [DF16]. Others described the need for new guidance to accommodate creative practices. *"I think biolab regulations don't really cover all the potential scenarios and risks that can occur in a biodesign lab. And I think it's very important to think about how to balance creative freedom and safety"* [DF3].

4.2 Care practices in the lab

While some did think about the biolab environment as facilitating care and attention, they also acknowledged limitations of the nature of care in lab settings. *" if you talk about other types of care like affection or emotional level or ethical level, it's really something different and there is nothing you can do in the lab itself as a researcher"* [DF13]. Other participants reflected on the productionist nature of the criteria used to evaluate organism wellbeing in the lab: *"They should grow well, we want them to prosper and we define prospering as a good thing"* [DF16]; *"traditional lab protocols or standards [...] that aim to maximise productivity are making the organisms very lazy and passive, or they are depriving the liveliness of the organisms"* [DF9].

On the other hand, designers also framed care practices as the cultivation of intimacy with the organism, both in physical and emotional terms. DF1 states,*"I'm working on [...] experimenting with direct interactions [...] like with less forms of mediation, I'm trying to see how we can have a more intimate experience [with the organisms]"*. In another example the researcher saw the creation of alternative sensory experiences as a way to empathise and become more attentive to microorganisms: *"I think all my tools are about sensing microbes or becoming microbial in a new way [...] it's fun to make [...] tools that allow you to spend more time with these organisms"* [DF6].

Some designers saw that integrating the organisms in their lives or studio practices facilitates ways of attending and caring for the organism. *"It's good to come home [with the flavobacteria]. And it felt more personal and explorative in a*

[1]Biosafety level (BSL) is a common regulatory standard for biolab to establish biocontainment precautions such as personal protective equipment and facility access control according to the level of risk posed by the organisms and agents present in the lab. The BSl ranges from the lowest level (BSL-1) to the highest (BSL-4).

way" [DF1]; *"Working with organisms at home, our lives are affected by their presence more. [...] When I had silkworms at home, they were a part of my life. I was even worried during cooking if smoke and smells would disturb them"* [DF2]. However, another response also pointed out the risk of uninformed actions that are seen as caring in non-regulated studio practice. *"When he finished the project in the UK, he didn't want to kill the Madagascar cockroaches, so he released them in Hyde Park. It sounds like an ethical decision when you have no knowledge of ecology"* [DF16].

4.3 Designers/HCI researchers facilitating ecological thinking

One participant pointed out that designers might be uncritically adopting life sciences knowledge into the design field. *"We are learning the expertise and all the ways of practice from their domain. That also means we brought in the ethical issues or concerns that emerge in their practices"* [DF14]. This was seen as promoting de-contextualisation and human domination: *"It's so removed from the actual organism that they don't even think about it"* [DF10]. *"When you are in the wild, [...] you cannot have your control there. But the lab is the stage of humans"* [DF9].

Some tried to counteract such effects by recontextualising the organisms. DF10 recounted their effort to counteract the decontextualisation of tissue culturing. *"We would take them touring the animals in the animal facilities. So bring it back to them to understand that they are actually working with living materials. [...] They are those suffering and you know, it's a violent act, but basically it's biotechnology"* [DF10]. Other responses show the growing trend in biodesign to adopt a more naturalistic approach, to follow the organisms. *"If you want to investigate what is really happening, you need to follow the flow of the natural world [...] you give [the organism] more freedom [...] and then they will grow their own way [...] to me that is more collaborative"* [DF3].

On the other hand, some expressed concerns that the positive emphasis on out-of-lab practices might obscure important issues of responsibility. *"[...] People do dangerous things outside of the lab where lab rules don't really cover. "* [DF16]. *"[...] Sometimes people think, 'Oh, I'm out of the lab now.' [...] then they think the safety precautions inside the lab don't apply outside the lab.[...] For example, they will not understand why they need to wear gloves when they handle environmental samples. "I don't wear gloves when I touch dirt. Why now?"* [DF3].

4.4 New tools and protocols

Despite the tensions, participants saw the value in engaging with different discourses. *"If you do biodesign or bioart in a laboratory, it's not just about the artwork or the product. It's a lot about actually the culture of science, and the focus is [...] on the interaction between science and non-scientists"* [DF10].

Some responses provided examples of tactical approaches adopted to develop their practice within current regulatory frameworks, by creating a 'liminal zone' between lab space and the studio. *"Actually, we now have the bio lab and then there's a space in between, outside the bio lab, where we keep our self-made tools that are more challenging to clean"* [DF1]; or proposing alternative tools to accommodate working with environmental samples in more naturalistic ways. *"A lot of people use agar in petri dishes but agar is very specific for monoculture in the lab [...] why not research other ways of being more selective with the growth media, for example, in fermentation such as kombucha or kimchi, they are already very salty and sour, which make much more of a selective medium for growing specific types of microbes"* [DF6]. Another response shows the possibility of working with unconventional practice responsibly in a semi-controlled way. *"Working with something with unknown contents is a big risk. But then [the lab managers] accepted in a kind of a controlled way, they first suggested I put [the tank] in the outdoor environment [...] So once we have a look and we are confident that we couldn't find anything that causes harm, then I start bringing more into the fish tank"* [DF3]. Notably, DF8 proposed a more cooperative attitude when negotiating with safety or ethics regulators *"We should treat them as a structure that* *would allow us to do things that otherwise we will not be able to. If you think about them as enablers rather than restrictors [...] you can actually get much better results."*

While calling for a new regulatory framework to better manage the risk of unconventional practices, some participants pointed out that accidents and contamination could also be perceived in a new light. *"We had so many issues of contamination, but this is kind of an unintentional agency in which we often celebrate it in our work [...] We would set up the device, but life would take its course [...] a lot of our work is just about an illusion of control"* [DF10]; *"They never follow the plan. You can really feel in these processes, their strong liveliness, I call it revolt. And this revolt inspires you."* [DF9].

5 DISCUSSION

5.1 Practices of resistance and microbial revolt

Although speculative, the angle of revolt serves as a critical tool to reflect on the power dynamic between humans and more-than-humans in their lab practices. Thinking about non-participation and revolt helped to direct participant's attention to the characters of the organisms, ultimately exposing and/or reimagining utilitarian tools and modes of working.

For biology participants, the revolt exercise helped to expose the level of manipulation on lab organisms and that it could be contestable, e.g. through 'Un-centrifugable e.coli' (B4_E.coli), or the control driven by research agenda can be challenged through 'Unpredictable Heredity' (B3_Drosophila) and 'Laminar Flow Hood Escape and Outdated Lab Book' (B5_Tardigrade). From the perspective of design participants, their responses showed a designerly reflection on the possibilities of knocking down anthropocentric controls in the structures, and materials, and in standardised lab tools to shift power dynamics towards the organism, e.g. by allowing organisms more freedom to behave as they would in nature, e.g. through 'Open transformation pod' (D5_Microorganisms) and accommodating their ecological relations in the lab such as 'Friend smuggling tool' (D8_Tomato Plants).

While biologists viewed revolt as oppositional, designers saw as something that could be embraced in their practice, reflecting the value of what Haraway (1998) called "partial perspective" [28] - meaning that those who are marginally connected to a context are potentially more able to expand it into new perspectives. For example, we can find a sense of anarchism in the biologists' outputs such as in 'The Irritative Lab Coat' (B7_Yeast) where the yeast would cause skin irritation on the wearer, or the 'Microbial Sit-In Protest' (B1_E.coli) where microbes simply refuse to work. Designers' outputs embraced the notion of revolt as a space for mutual needs to be met. Such as the "Squirting Pipette" (D1_Flavobacteria) enabling partial experiment participation; or a tool that allows free form growth in 'Flexible petri dish for rhizomatic growth' (D7_Mycelium).

In biodesign context, resistance can provide opportunities for negotiating mutuality and embracing organismal agency. As DF10 noted, organisms' 'unintentional agency' via contamination could be celebrated. DF9 described how viewing 'organism revolt' as inspirational as it transcends limited human perspectives. This shifts focus from using organisms to achieve one's goals to collectively shaping the agenda of the creative practices with the unique autonomy of living organisms.

5.2 Epistemic remoteness vs intimacy and care ecologies

Lab environments, while providing controlled conditions that eliminate noise, can hinder contextualising the experiments within wider ecological and social scenarios. As DF14 noted, uncritically adopting knowledge from fields with different ethical standings risks perpetuating problematic assumptions. DF9 described labs as 'the stage of humans', where organisms are solely identified by their utility to human researchers. Such an environment eliminates the ecological and historical context of an often "purified" monoculture organism, by physically and epistemologically secluding their space as the space of the experiment. This is exemplified in participants' recognition of the temporal and metabolic domination of lab organisms, with lifespan determined by research timelines.

The highly mediated interaction between organisms and researchers promotes a culture of objectivity and rationality that creates distance and hinders alternative engagement modes or deeper ethical relations. This distancing is reinforced by safety regulations and initiatives that position humans as prime decision-makers. Ecofeminist Val Plumwood [53] correlated a sense of remoteness with the crisis of rationalist culture that underlies ecological destruction. Such remoteness distances researchers from interpreting experimental choices from organisms' and the wider ecosystems' perspectives, and might have hindered biologists from considering organisms' standpoints in depth during the workshops.

This sense of remoteness also simplifies care practices, situating them within productionist models that hinder ecological perspectives. Tronto [63] defines four basic elements of ethics of care, that is: attentiveness, responsibility, competence, and responsiveness. While the lab can be seen as catering for all these elements, zooming out allows us to be critical about established care relationships, particularly in relation to the nature of the "life-sustaining web" [63] that surrounds lab organisms. While DF16 pointed out the underlying productionist ideology in using 'growth rate' as the measure of organism wellbeing, DF13 argued that the discussion of organism ethics and welfare beyond production-driven standards is not really supported in lab context. For DF9, such utilitarian care is even seen as harmful to the organisms by making them 'lazy and passive'. As critical theorist Giraud [22] noted, care can be implicated in unethical ends if anthropocentrism is not contested in both the means and ends of the project. This is echoed by feminist STS scholar Cooper's insight in Life as Surplus[12], that the welfare maintenance for reproduction can be a means for biopolitical agendas to maximise life's value extraction.

Designers from the interview shared efforts to counteract remoteness and support more nuanced practices of attentiveness, responsibility and responsiveness, which are closely related to the nature of their design competences DF10 drew visibility into organisms' origins, surfacing ecological violence in projects. Some focused on phenomenological interactions, like DF6's microbial tactile interface, to spur ethical reflection. While studios can enable more obvious care relationships, as DF1/DF2 recounted, decontextualized relationships of care can be problematic. Without greater understanding and engagement of ecological relationships it might become either unilateral or dangerous. As DF16 described, an individualistic "act of care" like releasing imported Madagascar cockroaches without considering ecological impacts reflects one's distance to potential consequences at an epistemic and temporal level .

Overall, the controlled nature of labs risks perpetuating extractive approaches by hindering contextual, ethical engagement with organisms and ultimately simplifying care practices. While care can be seen as a situated act between a giver and a receiver it is when we expand it to an ecological perspective that we can better understand risks of isolated acts and open up possibilities for new practices to emerge.

5.3 Laboratory protocols vs. creative freedom

In the interviews, concerns were raised about tensions between laboratory protocols and creative freedom, and more-than-human care ecologies. Both conventional biolab and more DIY lab spaces/studios are being increasingly established for working with living organisms in HCI and design. While conventional biolabs guarantee greater safety, more streamlined resource supply and what could be seen as "higher standards", they are also connected to stricter rules and potentially more conflicts with creative practices. On the other hand, DIY labs and more studio-based spaces, can provide a higher degree of freedom, but such freedom can carry more unknown risks, brought by new tools, practices, and a diversity of species.

For example, DF1 described her un-autoclavable wood tool being banned from using in their BSL 1 lab, while DF16 described the lack of safety guidance regarding sensorial exploration such as touch and smell typical in design when working with living organisms. Furthermore, as mentioned by DF3, due to the diversity of organisms that designers seek to interact in their work, particularly in a more ecological approach, and the fact that these cannot be supplied form standardised sources (as is usually the practice in conventional biolabs) new techniques are needed to create the capacities to work with multiple organisms or be selective to the organisms in complex environmental samples.

In essence the creative agency might come in tensions with lab safety regulations at various levels, which include a) the risk and contamination management of non-standardised tools with diverse shapes and materials, b) challenges that arise from a tendency to prefer more close interaction with the organisms, and c) increasing attempts to work with complex environmental cultures in the wild instead of monoculture lab organism, which leads to consideration of multiple rather than single species and their interactions.

While bio-related practices should still be closely monitored, they require a framework that is more suitable for tools and practices in creative settings than conventional biolabs can offer. Between the two extremes of not allowing alternative tools.

6 PRACTICAL IMPLICATIONS FOR DESIGN AND HCI: REFRAMING TOOLS, SPACES AND GUIDANCE

Building on the ideas of balancing safety, responsibility and creative freedom in design-driven lab practices, we concluded four suggestions for practice moving ahead:

1) Re-framing sterilisation

As the interviews showed, common lab techniques for sterilisation can subjugate researcher-organism relations to those mediated by highly controllable lab devices. They can restrict the use of self-made tools in biolabs, also limiting possibilities to explore more feral practices. This suggests a need to increase flexibility of sterilisation mechanisms for appropriation in design contexts e.g by integrating techniques that allow for sterilisation of larger pieces of equipment or spaces (such as portable UV-C and ozone sterilisation device designed by Lopez et al [41]), and the use of varied equipment materials (such as microwave for wood or food based materials [68]), or by adopting naturalistic, probiotic approaches to create selective environments in collaboration with microbial communities as mentioned by DF6, when discussing the issue with agar plates being typically designed to work within monoculture organisms in contrast to other media for growth that are naturally selective and facilitate work with mixed cultures (also see Paxson[52] and Lorimer[42] for other approaches). Furthermore, rather than thinking about sterilised contexts that simply isolate individual species we should consider spaces of limited contact for multispecies encounters, as discussed below.

2) Designing new 'contact zones'

Designers described the process of creating a liminal space, an 'in-between room' between a typical design studio and a conventional biolab for practices that don't fully fit in any of them. DF1's lab, for instance, created a liminal zone that connects the resources of the biolab, and at the same time, allows for a higher flexibility of tools, methods and modes of interaction with organisms. Another example was provided by DF3, where wild samples were treated with openness and care in an intermediate environment to eliminate potential risks.

In essence, we identify opportunities in the concept of liminality – the creation of new 'contact zones' between spaces with different protocols. By assembling new spaces that fuse the benefits of design studios and biolabs, while circumventing their limitations.

3) Increase and systematise documentation of design-based practice

Following the attitude of viewing regulators as enablers instead of restrictors proposed by DF8, we propose creating better documentation of novel lab practices in design as a strategy that informs practitioners, provides more tangible material for discussion of different practices, and may assuage regulators' concerns over safety risks or bioethical issues. By transparently capturing methods, experiments, and interactions with organisms via detailed documentation, designers/HCI researchers can discuss, agree and provide regulators with evidence of thoughtful and well-managed procedures. For example, a diagrammatic explanation of organisms and biowaste traffic routes in labs/spaces with different BSLs could clarify potential risks at different levels and guide safety measures accordingly. Overall, careful documentation helps establish ongoing accountability, and support greater creative licence.

4) New risk management frameworks specific for biodesign labs

Researchers in biosafety governance have already called for a reevaluation of appropriating biolab regulatory frameworks in managing unconventional practices, such as DIY biolabs. [60]. Our research echoes this call by drawing attention to the need for new guidance that accommodates ecological perspectives, phenomenological practices and sensibility, and more varied ways of engaging with the organisms specifically in design scenarios. For instance, developing a biosafety database for material-driven exploration with living organisms mentioned by DF16, or establishing a step by step process of considering biological, chemical and mechanical risk in a lab-based design project as standard practices as well as providing guidance for respective control measures.

7 CONCLUSION

We propose a workshop method that explores practices of resistance, non-participation and revolt as a lens to scrutinise more-than-human participation in biology and bio-related HCI practices. Participants were guided to write a comparative more-than-human journal from the perspective of a lab organism in lab and feral environments, and subsequently asked to redesign lab equipment into futile objects (Chindōgu) to facilitate revolt of the role-played organism. By doing so, the workshop surfaced key epistemic differences between designers and biologists, mapped their different approaches to more-than-human care and ecologies, and revealed the potential for design to challenge the secluded and productionist culture in biological laboratories. Insights from workshops were deepened by interviews with HCI researchers and designers focussing on concerns surrounding design-driven lab practices and the delicate balance between standardised laboratory protocols and creative freedom in working with living organisms.

Based on data from both workshops and interviews, we discuss the need to: 1) embrace revolt as a means of exposing and/or reimagining utilitarian tools and modes of working; 2) address the sense of remoteness and enhance the notions of ecology in care practices; 3) reframe tools, spaces and guidances for design-driven lab practices. We finally draw four practical implications for Design and HCI to negotiate creative freedom for alternative modes of interaction with living organisms, and indeed, to enable a tactic of resistance, while navigating safety, responsibility and the productionist culture in and beyond a laboratory space. We argue that it is only by accepting potential resistance that one can create space for negotiation, adjustment and consideration of wider care ecologies within bio-related HCI practices.

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Received 20 February 2007; revised 12 March 2009; accepted 5 June 2009