Designing for the Leaky Body:
Exploring Biomaterial Absorption as Body-Material Interaction

Viola Arduini*
Critical Media Practices
University of Colorado Boulder
Boulder, CO, US
viola.arduini@colorado.edu

Eldy S. Lazaro Vasquez*
ATLAS Institute
University of Colorado Boulder
Boulder, CO, US
eldy.lazaro@colorado.edu

Srujana Golla
ATLAS Institute
University of Colorado Boulder
Boulder, CO, US
srujana.golla@colorado.edu

Mirela Alistar
ATLAS Institute & Computer Science
University of Colorado Boulder
Boulder, CO, US
mirela.alistar@colorado.edu

ABSTRACT
Leaking bodies are often concealed or disregarded in both society and design. Likewise, bodily fluids are rarely leveraged as triggers for material interaction in HCI. In this pictorial, we investigate how fluid-responsive biomaterials can enable porous, expressive, and cyclical interactions co-shaped by the body. We focus on a milk-derived bioplastic with reversible shape-changing properties, examining fluid absorption as a meaningful design affordance. Our material-led approach contributes both formulation and fabrication methods of casein bioplastic; while autoethnographic inquiry with a lactating body informed the development of Leaky Body Maps and speculative garments that position leakage as a generative site of body-material interaction. This work contributes to the discourse of feminist and posthuman HCI by centering bodily permeability, material responsiveness, and the potential of designing with—rather than concealing—leaky bodies.

Authors Keywords
Shape-changing Biomaterial; Material-led; Biodesign; Authoethnography; Body-material Interaction; Bodily Fluids.

CSS Concepts
- Human-centered computing - Human computer interaction (HCI) - HCI theory, concepts and models

---

* Both authors contributed equally to this research.

CC-BY-NC-ND

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivs International 4.0 License.
TEI ‘26 March 08--11, 2026,Chicago, IL, USA© 2026 Copyright is held by the owner/author(s).

ACM ISBN 979-8-4007-1868-7/2026/03
https://doi.org/10.1145/3731459.3774473

1. INTRODUCTION

Pregnancy and lactation are increasingly mediated through digital and interactive technologies [14]. Wearable devices promise more intimate engagement with the body [40], yet filter embodied experience through layers of sensing and interfaces. Drawing from Shildrick's conceptualization of leaky bodies [39], and Helms' explorations in design and lactation [22], we propose a shift: **from sensing the body to leaking with it.**

This pictorial explores material–body interactions with a milk-based bioplastic designed in dialogue with lactating bodies. Our casein-derived biomaterial undergoes reversible, moisture-actuated shape change. Moreover, our bioplastic foregrounds absorption not as a passive property but as an interactive, affective quality embedded in the design [1]. Situated at the intersection of feminist HCI, design research, and autoethnography, this work offers an approach for designing with and for the leaky, cyclical body.

> We ask:
>
> How can materials participate in, rather than contain or register, bodily cycles?
>
> What does it mean to design for a body that leaks?
>
> What new forms of interaction emerge when absorption itself becomes a design affordance?

Our contributions to the TEI research community include: (1) new formulation and fabrication method for a casein bioplastic that can enable interaction through reversible shape-change (2) Leaky Body Maps (LBMs), a methodological design approach for leaking bodies that reframes how HCI engages with bodily fluids and their entanglement with material interaction, and (3) speculative designs that reframe concepts of interaction and agency in bodily-material context.

2. BACKGROUND & RELATED WORK

Materials Responsiveness in Wearable Technology

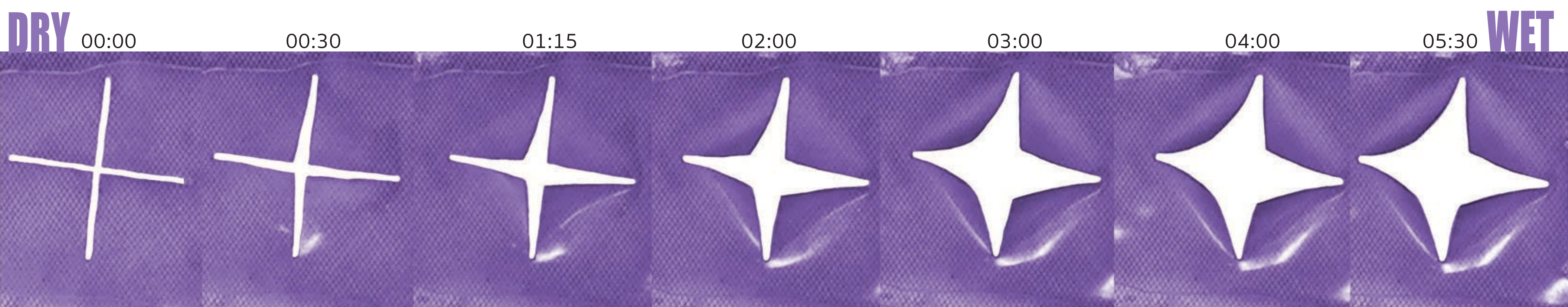
Interaction in wearable technology often emerges from the interplay between materials, electronics, and garment construction. While responsiveness has traditionally relied on electronic or digital control, a growing body of HCI work investigates how materials themselves can act as active elements [30, 42, 43]. Examples include thermochromic fabrics that shift color with temperature [12], shape-memory alloys that change form with heat [10,17], and hydrogels that swell in response to moisture [29, 37]. By leveraging their intrinsic physical and chemical properties, such materials enable low-complexity, responsive systems without electronics. Recent discussions around Wearable Bio-HCI [47] highlight efforts to integrate bodily fluids, living matter, and biomaterials into wearable interfaces — not only for sensing or responsiveness, but also to explore care, cohabitation, temporality, and nonhuman relations in design. Together, these works extend material responsiveness in wearable technology to include living, bio-based, and bodily-derived materials.

Biomaterials as Interactive Interfaces

This shift toward leveraging materials as interactive agents has led to new categories of interfaces, including those using biomaterials [34]. Biomaterials, whether living or non-living, have gained attention in HCI for their ecological benefits and ability to sense and respond to change [1, 35]. Examples include algae-based bioplastics [5] and gelatin biofoams [28] responsive to temperature or UV light, as well as living materials such as algae, plants, and bacteria explored as natural sensors and actuators [19, 31,48].

In this pictorial, we focus on casein bioplastic, a milk-derived protein, and its inherent moisture responsiveness as a body–material interaction affordance. Unlike other biomaterials, casein contracts and stiffens when wet and can be thermally or physically reset, enabling repeated cycles of passive actuation without electronics. These qualities allow us to shift the source of interaction from environmental stimuli to the body itself, reframing moisture as a bodily signal and opening possibilities for designing from and with the body.

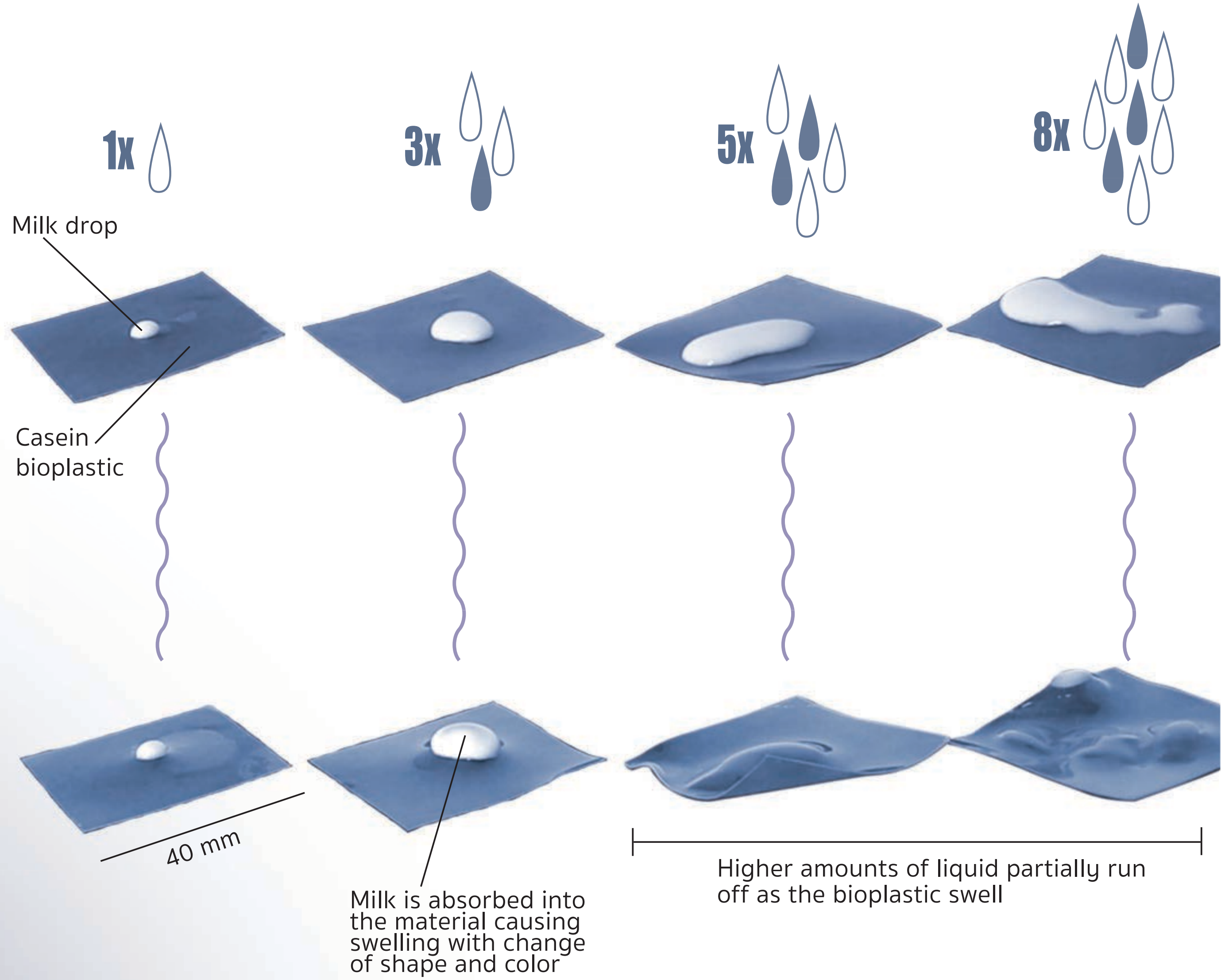
Shape-changing casein bioplastic with a laser-cut kirigami pattern triggered by moisture underneath



Designing from and with the body: milk-based bioplastic

Building on casein's ability to respond to moisture, we shift the source of interaction from environmental stimuli to the body itself. This move aligns with design approaches such as soma design [23], which re-center the body as an active site of knowledge, creation, and reflection. Soma design responds to an overreliance on data, language, and logic by foregrounding sensation, movement, and felt experience [13, 15, 27]. In this view, the body is not merely a source of measurable outputs or something to be corrected; it is a generative partner in design. From feminist and posthuman perspectives, bodies are materially entangled with their environments — porous, affective, and cyclical — and therefore central to how design can respond to lived experience.

Extending this attention to embodiment into material practice invites working directly with substances the body produces. Bodily fluids offer a way to explore intimacy, care, and cultural meaning through material form. Prior work has engaged with the skin microbiome [6], menstruation [8], vaginal fluids [9], sweat [41, 44, 49], urination [21], and vaginal flora [7], often framing these materials through lenses of emancipation, control, or invisibility. Yet human milk — despite its cultural resonance — has been largely absent from design discourse in HCI, with the notable exception of Helms [22].



In our work, we turn to casein, a milk-derived protein, as both a biomaterial and a conceptual link to bodily fluids. Sourced as a by-product of the dairy industry and its lactating bodies, casein retains an intimacy rooted in its origin, while its responsiveness to moisture mirrors the dynamics of lactation: leaking, swelling, stiffening, and drying. Embedded into garments, the bioplastic transforms in response to bodily leakage, making visible and tangible the rhythms of maternal care. This stands in contrast to materials designed to conceal or absorb bodily fluids, instead positioning moisture as a visible, transformative interaction. Rather than concealing or containing these processes, the design invites reflection on the intertwined relationship between material change and bodily experience.

3. MOTIVATION AND DESIGN APPROACH

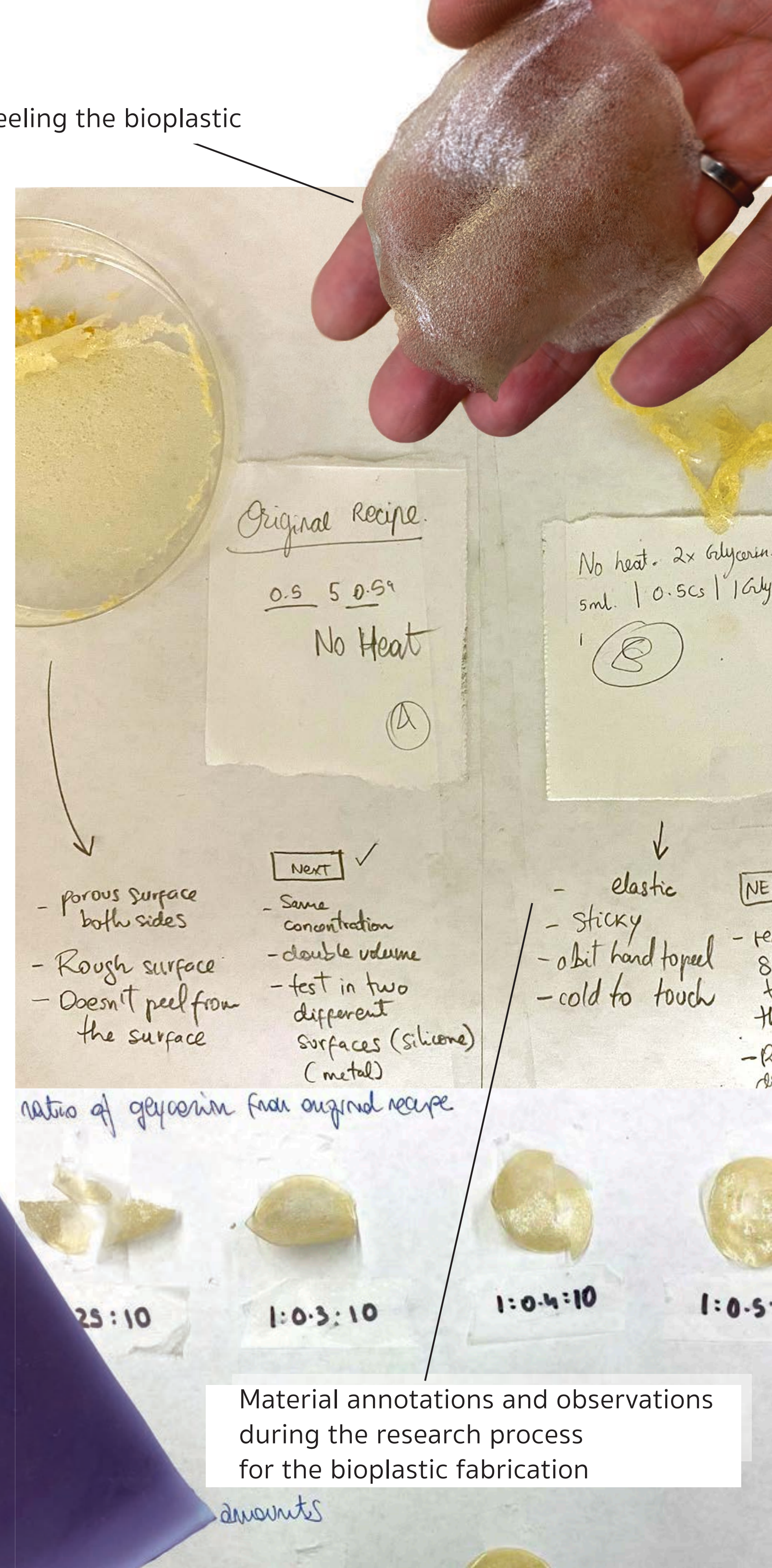
Our design practice is shaped by bodily interactions: the organic origin of the material and the principle of designing for lactating and leaking bodies, including the relationship between material and wearer. As a form of design research, this work combines making and material exploration with feminist HCI and auto-ethnographic methods. One of the authors was actively nursing throughout the research process, making this experience both a practical and poetic claim to work with and for the lactating body—its rhythms, needs, and surplus.

This situated engagement prompted us to consider bodily permeability not only as a biological condition but as a design framework. Drawing on Shildrick's conceptualization of leaky bodies as sites that challenge fixed boundaries and containment [39], we frame leakage as generative rather than problematic. This aligns with Alaimo's transcorporality —the recognition that human bodies are always entangled with material environments [2]—positioning our biomaterial not as separate from the body but as participating in its becoming. In this view, leaking bodies—bodies in flux—disrupt the idea of a sealed, autonomous subject. Leakage is not a failure of containment; instead, it reveals permeability as a condition of embodied life and a catalyst for design.

Rather than designing to conceal or manage the lactating leakage, we foreground it, emphasizing absorption, permeability, and transformation as modes of interaction between material, fluid and body. This stance informed speculative scenarios in which wearables respond to bodily leaky states through the properties of biomaterials themselves, without relying on digital sensors or triggers. Such scenarios extend the role of biomaterials in wearable design, shifting interaction toward material transformation and bodily entanglement.

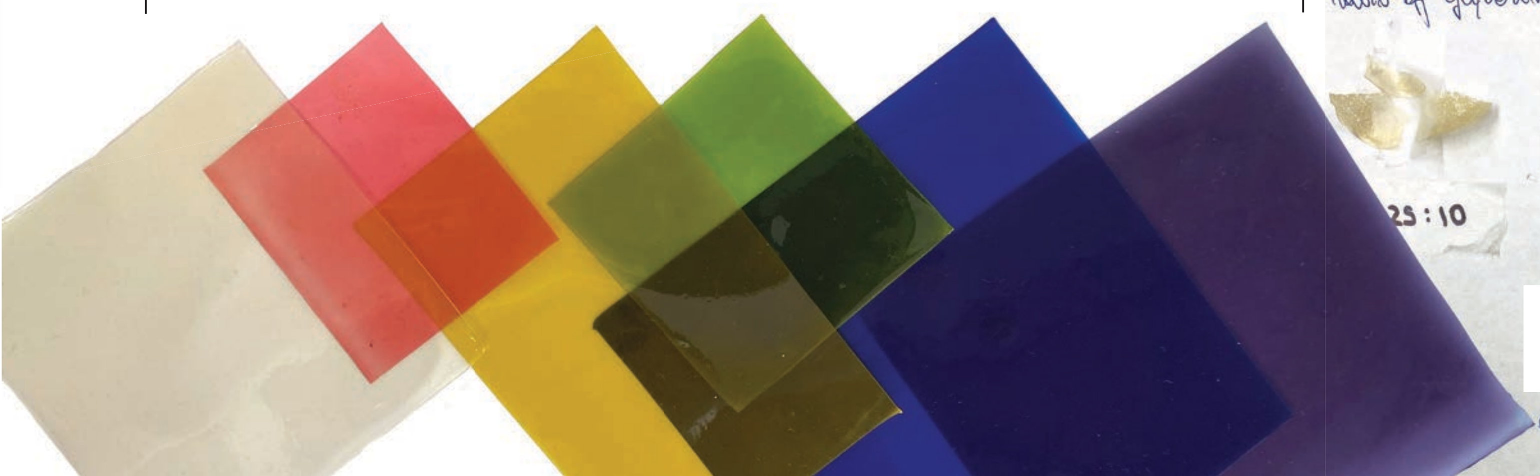
We followed a material-driven approach [26], attuning to the bioplastic's inherent responsive properties and allowing these to guide design decisions. Through this process, we witnessed the entanglement of bodily fluids and material transformation, moving beyond conventional HCI paradigms of user–device interaction toward a more diffuse relationship that extends from body–fluid–material to the wider material–environment entanglement.

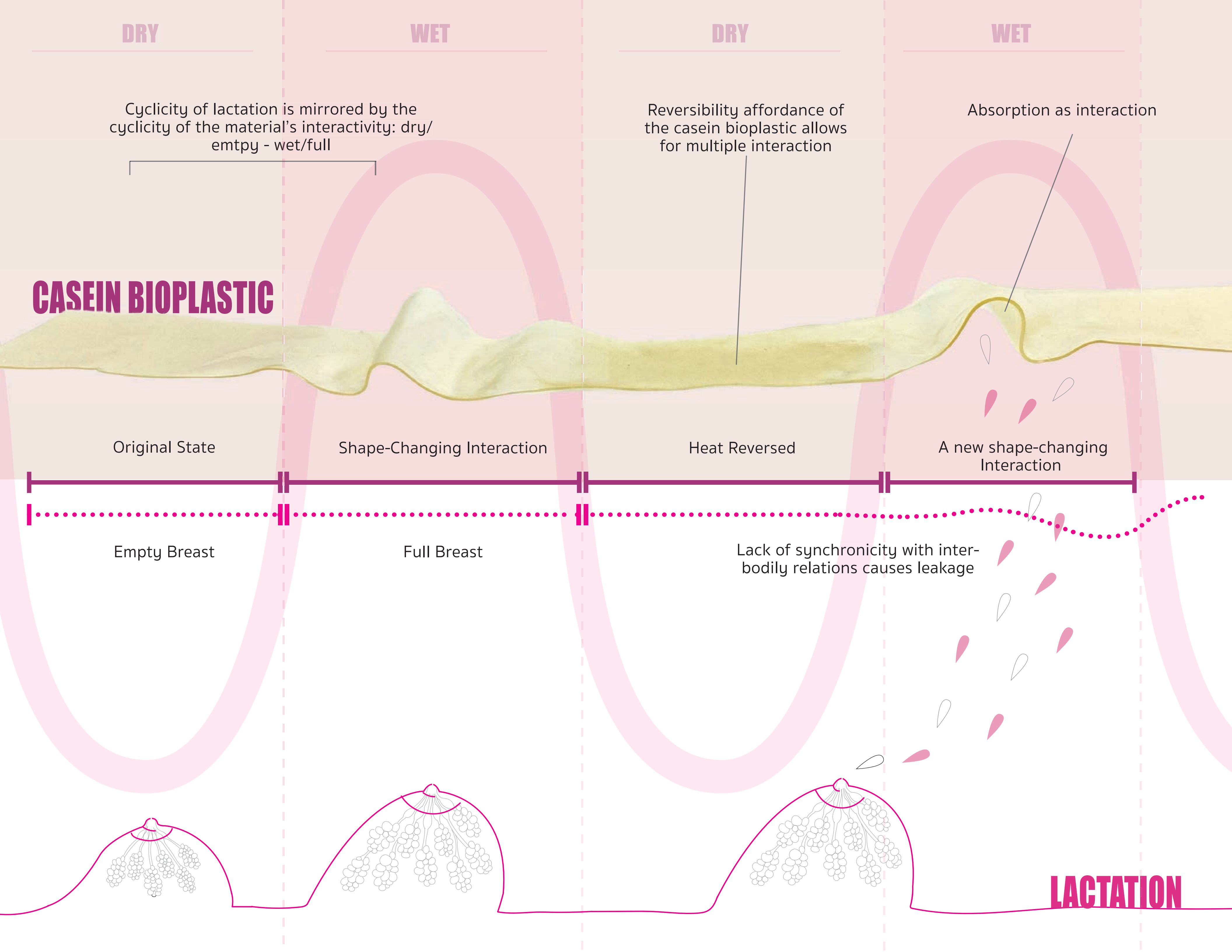
Feeling the bioplastic



Material annotations and observations during the research process for the bioplastic fabrication

Bioplastics of different colors due to the addition of food dyes




DRY
WET
DRY
WET
Cyclicity of lactation is mirrored by the cyclicity of the material's interactivity: dry/ emtpy - wet/full
Reversibility affordance of the casein bioplastic allows for multiple interaction
Absorption as interaction
CASEIN BIOPLASTIC
Original State
Shape-Changing Interaction
Heat Reversed
A new shape-changing Interaction
Empty Breast
Full Breast
Lack of synchronicity with inter-bodily relations causes leakage
LACTATION

MILK-BASED BIOPLASTICS

Casein-based materials, once used in buttons, beads, adhesives, and textiles, first emerged nearly two centuries ago during a wave of industrial experimentation with bio-derived polymers [3, 20, 38]. Casein proteins, present in the milk of all mammals, form dense micelles due to the molecule's hydrophobic and hydrophilic characteristics. These water-responsive structures give milk its opacity and thickness [24].

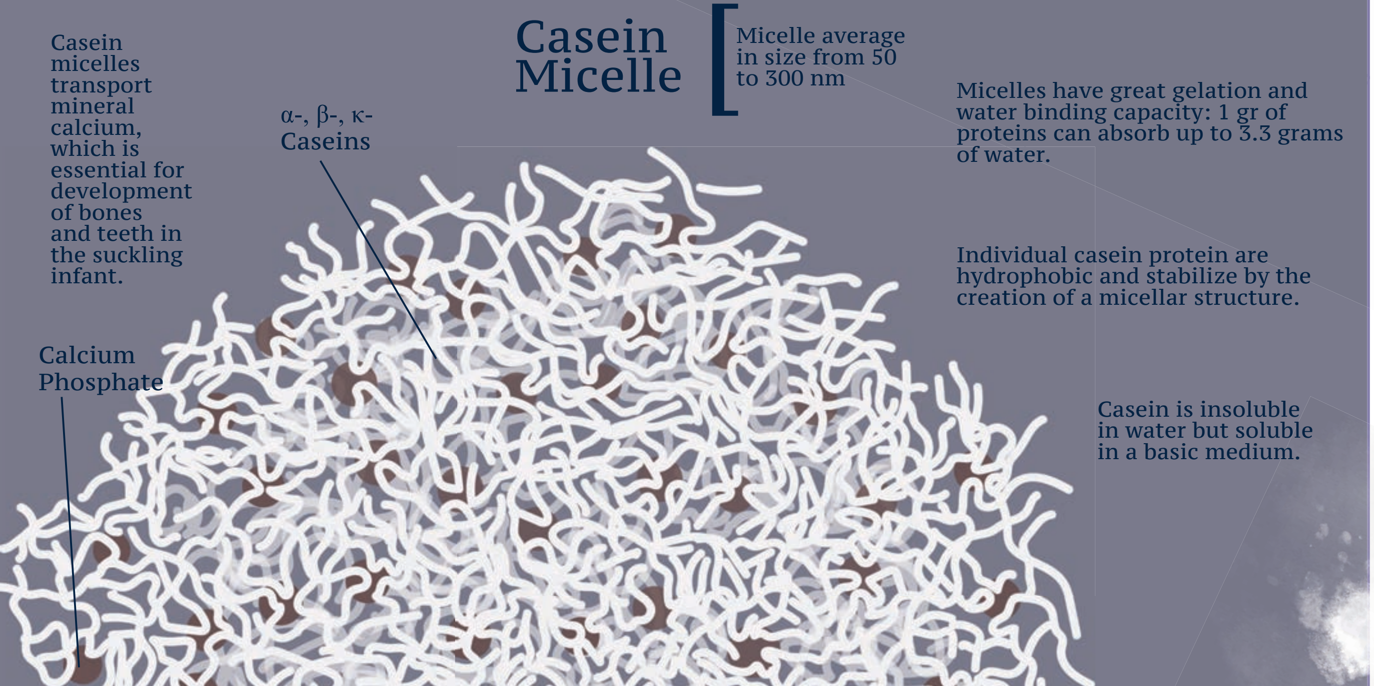
Building on this historical interest in casein's formability, we leveraged its micellar properties through design, treating reversible shape-change and absorptive capacity as interaction affordances. Rather than positioning milk-based plastic as a passive substrate, our approach activates it in relation to fluids, particularly when integrated into garments.

While it is possible to precipitate and purify casein from milk directly, for this study, we leveraged commercially available casein to focus on functional qualities while maintaining conceptual grounding in bodily processes.

The formulation presented in this pictorial, while based on existing literature, is novel in:

- The introduction of Sodium carbonate (Na_2CO_2) as a solvent instead of the commonly used ammonia, avoiding biohazardous fumes.

- A unique, tested protocol for fabrication using continuous heat to achieve greater structural homogeneity in the bioplastic



A NOTE ON AUTOETHNOGRAPHY

This project began as auto-ethnographic practice from a first-person perspective. One of the authors, a recent mother, engaged with her own lactating body as a site of inquiry, using personal experience to explore the relational, material, and symbolic dimensions of feeding and leaking. Autoethnography, as a methodology, values embodied knowledge and positions lived experience as a valid and generative source of insight within research and design [32].

Throughout the inquiry, the author employed a range of embodied and experimental practices: growing samples in agar petri dishes to culture the breast milk's micro biome (see images); recording thoughts and emotions over time; and visually mapping milk leakage through a form of visual journaling. These processes became both reflective and generative — tools to observe the body's fluid logics and to create design interactions that respond to those logics. While lactating is fundamentally a shared act, the decision to focus on the perspective of the lactating person only and not the infant was also intentional, to protect the child's own privacy and future self-determination.

This situated approach informed both the selection of a milk-based bioplastic and the development of the Leaky Body Maps presented in this paper. In both cases, the design process emerged from a desire to follow the body's own expressions of permeability, excess, and transformation. By grounding material design in lived experience and autoethnography, this work contributes to feminist and posthuman design practices that challenge the separation of researcher and subject, material and meaning, body and environment. In doing so, it invites further exploration of how auto-ethnographic methods can attune us to the porous bodies and becoming-with materials.

4. MATERIAL FABRICATION

The casein bioplastic was created by combining casein powder (biopolymer) with washing soda solution (solvent) and glycerin (plasticizer). We tested over 20 ratio variations of the recipe to refine strength, malleability, and flexibility. At the end, two formulations were finalized: a softer one with higher glycerin content that allows maximum actuation as woven structures, and a recipe with a lower glycerin ratio for the material acting on its own, such as in sequins. The fabrication protocol is the same for both formulations, the only variable is the amount of glycerin added to the mixture. Both formulations can be laser-cut and present shape-shifting interaction with moisture.

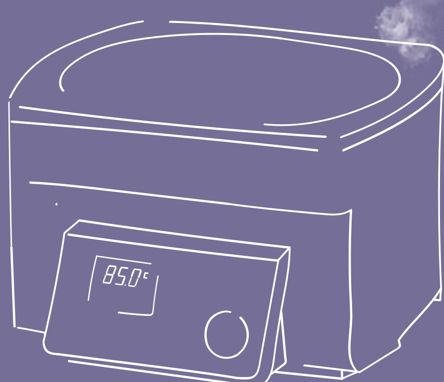
FORMULATIONS (RATIO CASEIN : GLYCERIN : SOLVENT):

1:0.5:10 = slightly harder, lighter, flexible, more responsive when used as isolated material

1:1:10 = a more elastic, softer, sticker formulation, best for woven implementations

1. MEASURE & MIX INGREDIENTS

(1) To obtain a 1% solution, dissolve 2.5 g of Na_2CO_3 (from common washing soda) in 250 mL of tap water. Sprinkle 25g of casein powder onto the solution's surface to ensure even suspension without clumping. Using a hand whisk, gently incorporate the casein powder in the solution until the mixture reached a semi-solid, viscous consistency. Add glycerin in a 1:1 or 1:0.5 ratio with the casein, depending on the formulation chosen.



2. HEAT BATH

(2) Heat the mixture in an 85 °C water bath for 15 minutes, stirring every 3 minutes, then skim off the top foam with a spatula, and sieve the solution. After a second 5-minute heating, the solution is sieved again.

3. MOLDING & CURING

(3) We poured the mixture into a flat silicone mold to cure at room temperature (22–25 °C) for 3-4 days in a low-humidity environment, but drying time can vary greatly based on environmental factors. This amount of mixture cures into a translucent, 25 cm x 30 cm sheet with a thickness of 0.5 mm, and is flexible enough to be laser cut.

5. PRELIMINARY TECHNICAL EVALUATION

We conducted a series of preliminary tests to assess the bioplastic's performance during fabrication, moisture-triggered shape change, and reversibility.

Mass Loss During Fabrication Drying Process:

The curing step (drying) is critical as it influences mechanical properties such as adhesion (stickiness) and tensile strength. Experimentally, we measured an average mass loss of 88% from the initial liquid (wet) formulation. We determined this corresponding formula that calculates the resulted material mass:

$$DryMass = 0.12 \times WetMass$$

where constant 0.12 is determined experimentally.

Absorption test

The bioplastic leverages the highly absorptive properties of casein to enable interactive, moisture-responsive behavior. It is established that one gram of protein can absorb up to 3.3 grams of water [36]. We conducted tests to evaluate the water absorption of the bioplastic based on different periods of exposure to moisture. A minimal mass loss was found in the dried material, suggesting that a small fraction of the material is solved and removed by water. We also found water absorption to increase proportionally with exposure time, exceeding 400% of the initial dry weight in long exposures. Interestingly, results show a proportionality between the amount of water absorbed and the final mass loss after absorption (see graph).

Thickness and loss of volume in drying:

We measured thickness and volume reduction during drying to estimate the wet mixture needed for a desired final dry volume.

Shrinkage ratios were measured to be in the range of 10-13% of the wet material, with a loss of approximate 87% of the thickness in the drying process. This allows for a simple checkpoint: the poured wet mixture should measure approximately 10 times thicker than the desired final dry thickness.

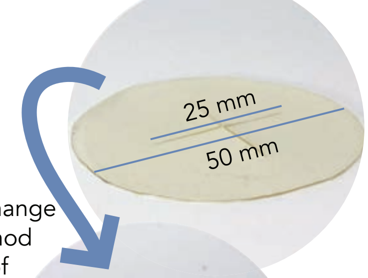
Additional data provided us with the information needed to determine a general formula that calculates the wet mass needed per desired surface area and thickness:

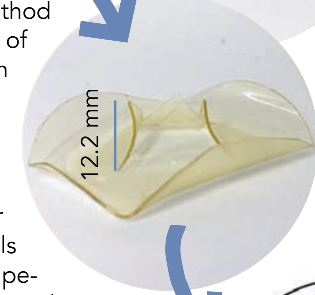
$$WetMass = A \times T \times 0.70 \frac{g}{mm^3}$$

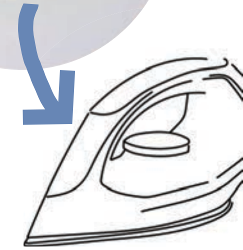
where A is the final area and T is the desired thickness of the dried material. The experimentally determined constant 0.70 g/mm3 represents the required wet mass to yield 100 mm3 volume (e.g., 1 cm² dry bioplastic of 1 mm thickness).

Timing of shape-changing interaction:

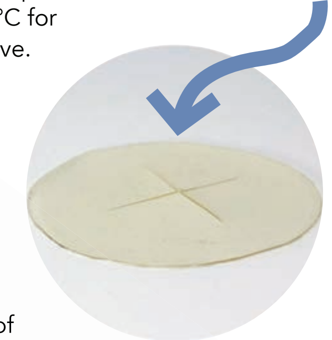
We measured time intervals needed for the casein bioplastic to change shape after being triggered by moisture. We found that different variables contribute to the total time needed for the material to change shape, such as thickness, method used for moisture it, and size of the material. Overall though the interaction is quite fast, spanning from 2 to 10 minutes with an average of 4 minutes. In general, thinner and smaller samples present faster interactions, while higher levels of moisture trigger larger shape-changing movement in the material.





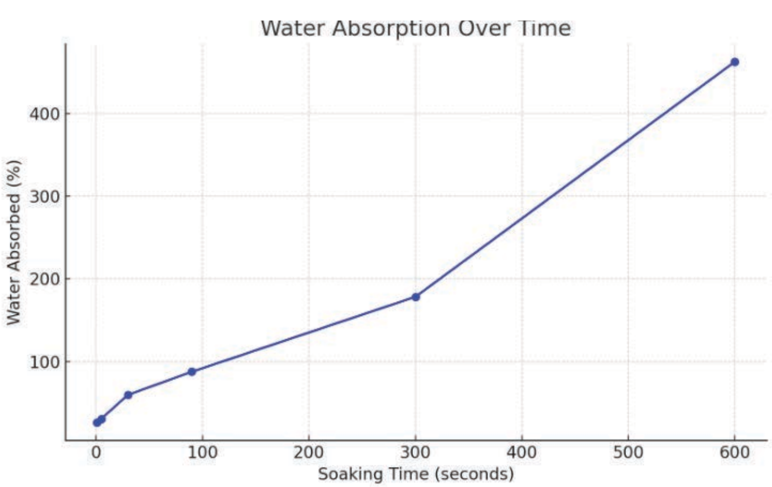


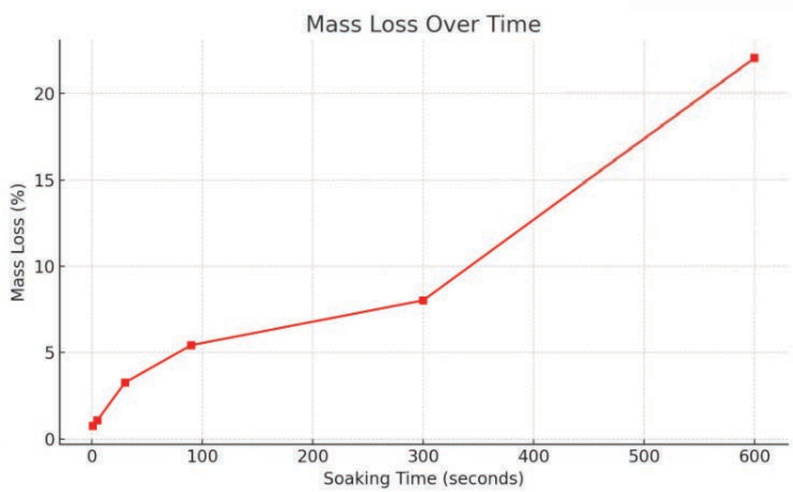
110°C for 30"

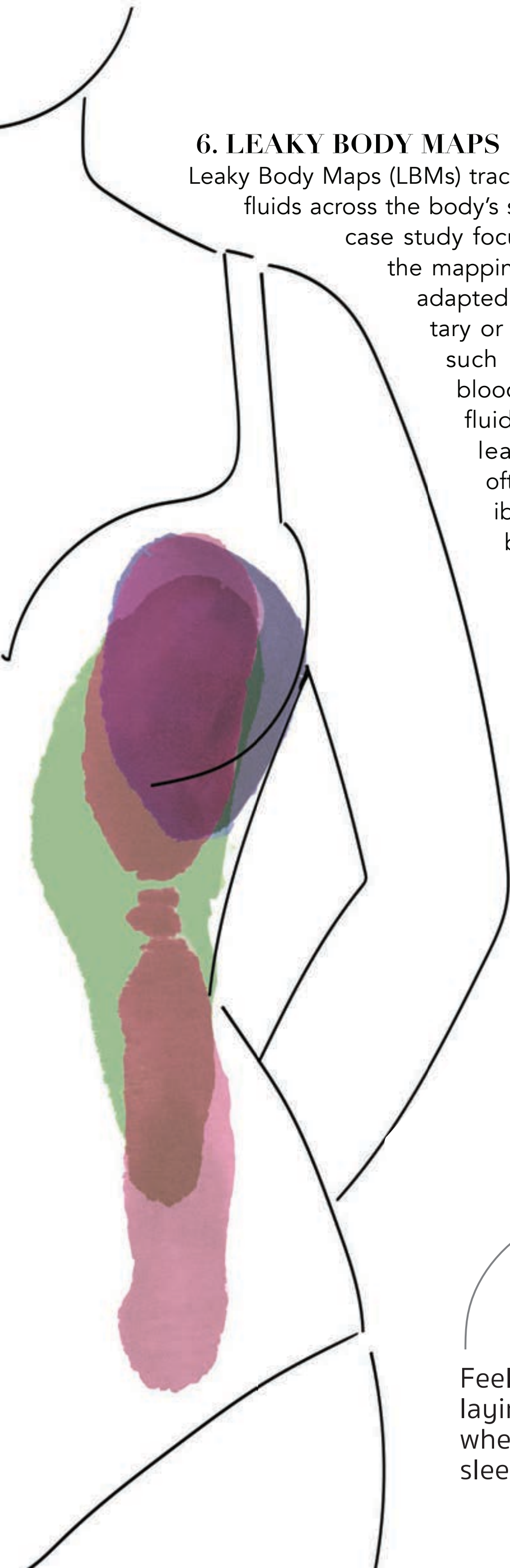


Reversibility of shape-changing:

We tested tension, heat, and weight as methods to reverse shape change in the material, with heat yielding faster, more consistent results. We found the bioplastic to be thermo-reversible, with 110°C for 30 seconds being the most effective. We used a household iron on its lowest setting, with a cotton cloth placed between the iron and the textile. This process restored the material to its pre-moisture state, suggesting the removal of moisture as the main factor in reversing interaction. We repeated this test for a minimum of five cycles on the same swatch, indicating that multiple interactions are possible without significant material degradation.







6. LEAKY BODY MAPS

Leaky Body Maps (LBMs) trace the pathways of fluids across the body's surface. While our case study focuses on lactation, the mapping process can be adapted to other involuntary or rhythmic releases such as sweat, urine, blood, tears, or vaginal fluids. LBMs visualize leakages that are often hidden or invisible, functioning as both analytical tools and prompts for designing with, rather than around, bodily processes.

Body Mapping

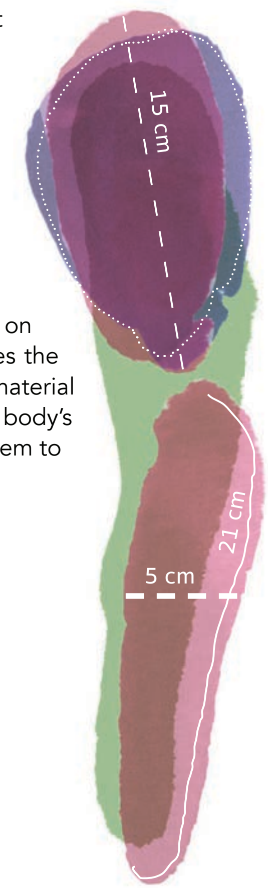
Existing wearable body maps often position the body as a site of functional optimization and usability-focused placement (16, 46). Biomedical mapping likewise prioritizes measurement and monitoring, framing the body as an object of sensing, control and optimization. Feminist body cartographies instead foreground lived experiences of pain, pleasure, trauma, and memory [33], while Soma Design maps capture emotions and embodied sensations that resist verbalization [11]. LBMs build on these, reframing the body as a leaky, affective, situated terrain, materializing interaction through fluid exchange, permeability, and cultural tension.

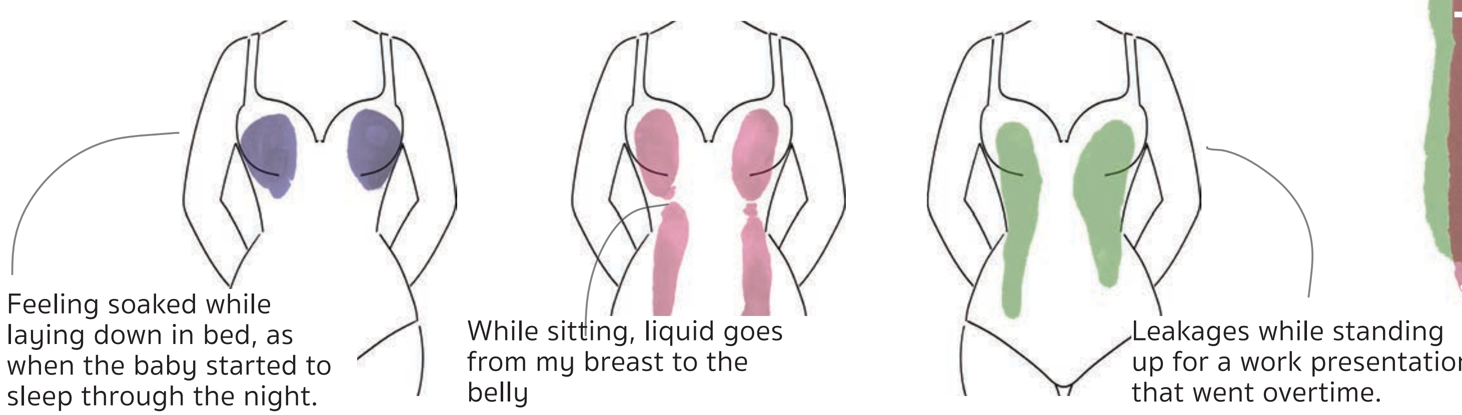
Methodological Origin: Autoethnography

LBMs emerged from a first-person, embodied, autoethnographic process in which one of the authors mapped her own fluid patterns during lactation. Milk release occurred for diverse reasons: emotional triggers (e.g., hearing the baby cry), shifts in feeding schedules due to the infant's growth needs or sickness, or situational constraints such as work running overtime [45]. Leakage patterns were documented by releasing 15 mL of dyed liquid from a needleless syringe onto a white t-shirt while in varied body positions. The stains, shaped by gravity and body contours, were traced and digitally rendered by the co-author. These maps became artifacts for reflecting on what it means to inhabit a leaky body, how to trace fluid movement, and how to design for such embodiment.

From Functionality to Relationality

Though it began as a personal exploration, LBMs offer an invitation for others to trace and reflect on their own body's fluid patterns. Each map is unique, shaped by the particular rhythms, contours, and circumstances of an individual body. Rather than producing standardized templates, LBMs suggest an approach to attending to bodily leakage that others can adapt within their own contexts. For designers, these mappings can inspire wearable concepts that respond to leaky bodies by positioning actuators or sensors in relation to lived experience and fluid flow, shifting emphasis from functional optimization toward relational engagement. By focusing on the dynamics of fluidity—what leaves the body, when, and how—LBMs open material design possibilities that honor the body's own rhythms without constraining them to monitoring or performance metrics.





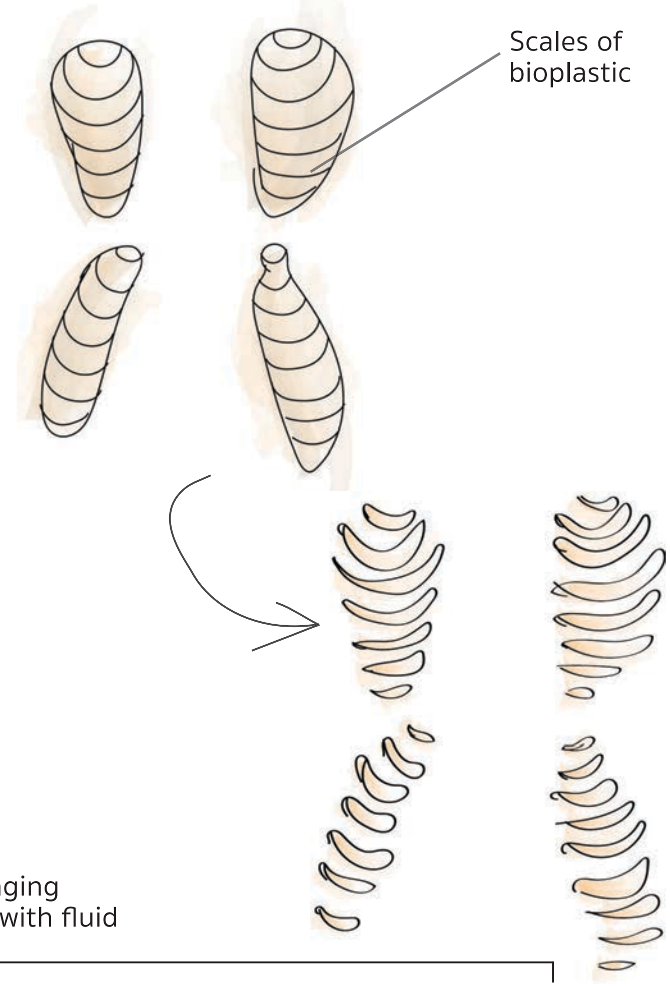
7. SPECULATIVE SCENARIOS: DESIGNING FOR THE LEAKY BODY

These two speculative scenarios explore how fluid-responsive biomaterials can enable porous, expressive, and cyclical interactions co-shaped by the body. Informed by Leaky Body Maps (LBMs), they treat fluid not as mess or malfunction but as a trigger for embodied interaction. Rather than using electronics to monitor or correct, the garments allow tears and milk to directly transform form and surface through slow, situated material responsiveness. Each design invites a reconsideration of what it means to leak, to feel, and to wear one's own rhythms openly.

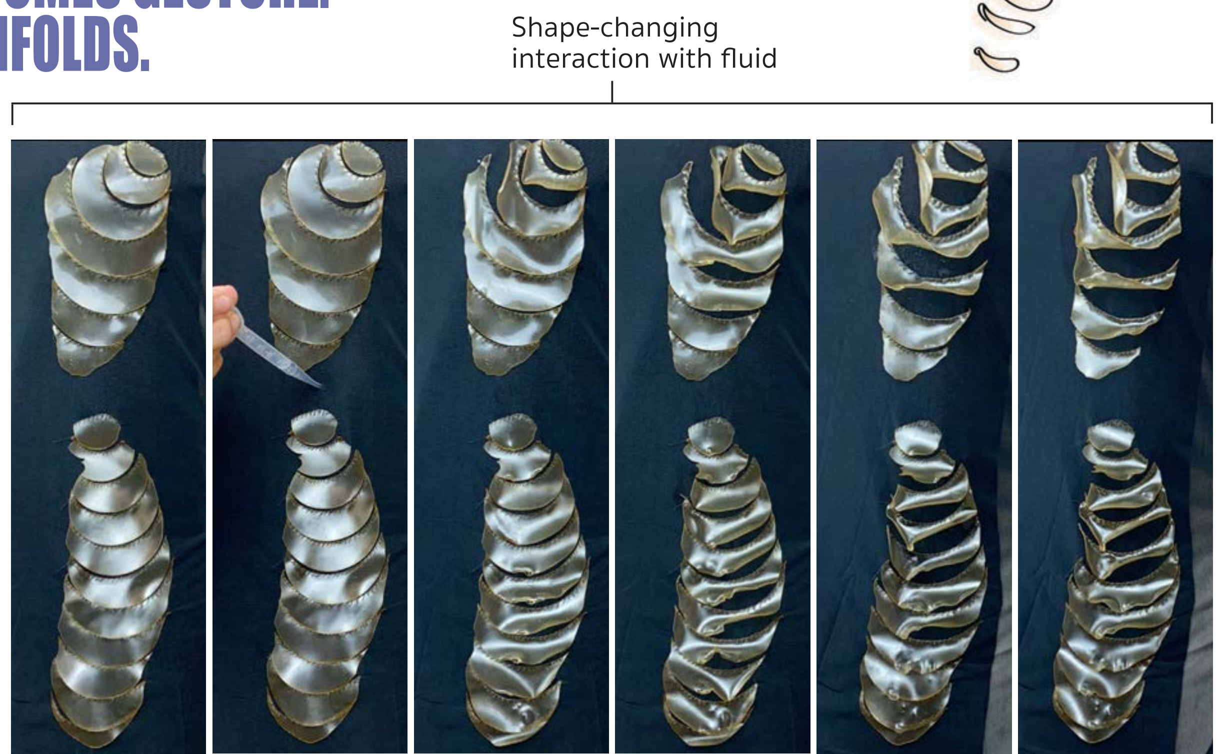
SCALES OF OVERFLOW:

This black mesh tee integrates an exoskeleton of casein-based bioplastic scales in the regions where LBMs registered milk leakage. The scales change shape—lifting or curling—when absorbing breast milk. As the wearer leaks, the material responds—not digitally, but physically—transforming visibly through moisture-induced interaction.

Milk no longer disappears into absorbent fabrics; it activates, traces, and informs. The pattern of movement maps the body's fluid rhythms over time—responding to hormonal fluctuations, emotional triggers, or embodied labor. Through cycles of wetting and resetting, the garment becomes a material diary of lactation, turning personal leakage into visible, embodied knowledge. Rather than concealing the leaky body, this garment reveals it as an interface of presence, timing, and care.



HARNESS OF SCALES, LEAKAGE BECOMES GESTURE. PRESENCE UNFOLDS.



A GARDEN IN MOTION

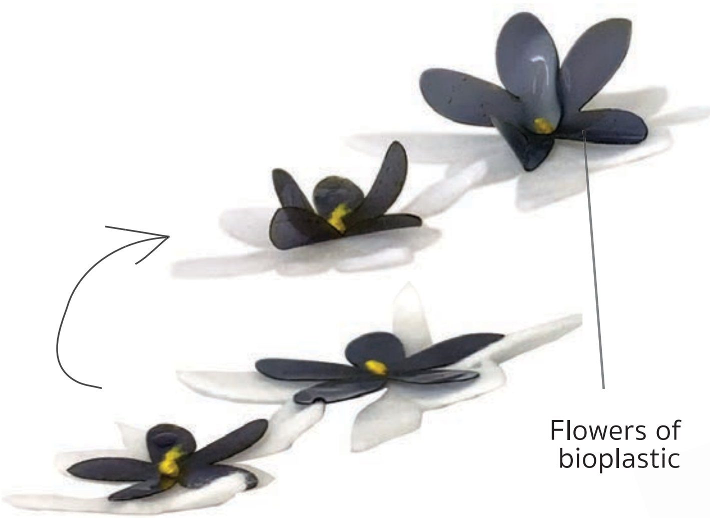
In this scenario, tears and milk become entangled expressions of the body's overflow in early motherhood. As the wearer cries—whether from joy, exhaustion, or intensity—butterflies on a delicate tulle veil flutter in response to the moisture. At the same time, flowers beneath the breasts begin to bloom, actuated by milk leakage. Though these fluids do not often meet, their co-activation creates a visual and symbolic choreography across the body.

The garment doesn't conceal but reveals—making public what is often kept private. It embodies the ethics of affective intra-action [4], where body, fluid, and material co-produce an experience of vulnerability as agency. This duet across face and chest transforms leakage into expression. Tears and milk—typically shrouded or suppressed—become communal, visible, and materially affirmed, offering a wearable ecology of feeling, care, and relational presence.

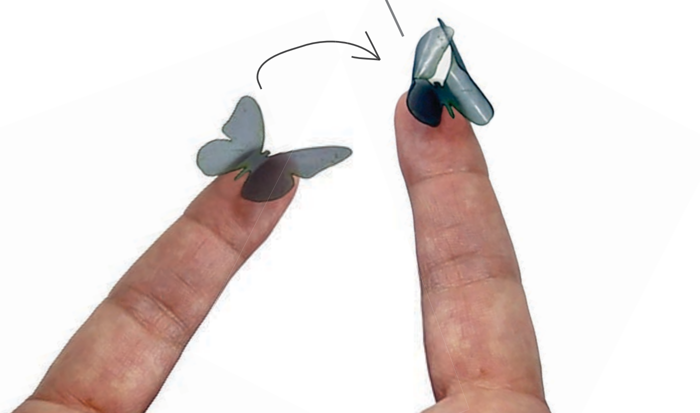
A garden streaming from head to legs for leakages of various nature: tears, milk, and potentially menstrual blood

A TEAR GLIDES DOWN. A WING SHIVERS.

FLOWERS OPEN WITH THE HUM OF MILK.



Flowers of bioplastic



Bioplastic butterfly rising its wings after be moistened

8. DISCUSSION AND CONCLUSION

Reframing Interaction through Bodily Fluids:

The shape-change mechanism of our casein bioplastic offers a distinct form of engagement, as the material itself becomes an interface that responds physically to bodily fluids. Lactation and leakage become visible as the material absorbs and transforms. Moving beyond the means of electronics to visualize interaction, our biomaterial itself enables the lactating body to have a generative role and serve as both context and active participant, shaping the experience through its rhythms. Instead of extracting data or optimizing performance, the design embraces situated responsiveness as surfaced in the Leaky Body Maps (LBMs).

Our approach renders bodily knowledge as lived experience: sensed, felt, and co-constituted through material engagement, making leakage physically present. Our speculative garments, such as *Scales of Overflow*, are designed as sites where bodily rhythms can be encountered in real time, illustrating how material responsiveness can sustain intimate, reflective interaction. Contributing to feminist and critical design discourses that center embodied knowledge in interaction [25], our work expands HCI's engagement with bodily fluids from a focus on sensing and data extraction toward designing with material agency, where the fluid itself initiates and shapes interaction.

Biomaterials Beyond Sustainability: Sensory and Temporal Interfaces

While prior design research has engaged with bodily fluids, our work foregrounds absorption within a fluid-responsive biomaterial as the primary site of interaction. Biomaterials are positioned not simply as sustainable alternatives to synthetics, but as enablers of interactions that emphasize bodily presence and material responsiveness. The casein-based bioplastic interacts with bodily fluids such as breast milk, contracting, stiffening, and resetting through repeated cycles of interaction and transformation. Absorption becomes an interaction that both originates from and culminates in the presence of a leaking body. LBMs guide material placement in garments; water-based fluids trigger changes in texture, form, and surface. These transformations engage the senses beyond vision, drawing attention to tactility, moisture, and even smell, as explored in the speculative scenarios. Such interactions unfold over time, following the body's rhythms rather than pre-defined inputs or outputs. The bioplastic's reaction to water-based liquids fosters sensory experiences that are both intimate and culturally situated, allowing for new ways of relating to bodily processes through time, touch, and transformation. In this, we also recognize that practices of breastfeeding, crying, and bodily leakage are deeply shaped by cultural norms and values. Our work emerges from Western feminist contexts; future explorations should examine how bodily leakiness translates across diverse frameworks.

Tensions and Ethical Entanglements of Bodily Materials

Working with biomaterials that originate from bodily fluids raises tensions around provenance, ethics, and symbolism. One tension involves the use of commercial casein, derived from cow's milk, as a proxy for human breast milk. This decision preserved the conceptual link to lactation without consuming a limited and medically significant human fluid, while enabling exploration of lactation-related interactions. Yet, the substitution risks reinforcing hierarchies in which nonhuman bodies are treated as more expendable, even as the work seeks to elevate the significance of bodily materials more broadly.

A further tension involves the cultural framing of breast milk as precious and emotionally charged. Although the project sought to center lactation as a meaningful and visible interaction, it also had to navigate the ethical and practical limits of using a substance that is often associated with care, nourishment, and scarcity. These decisions required balancing conceptual exploration with ethical responsibility, while also confronting the difficulty of accessing certain bodily materials for design purposes. Rather than resolving these tensions, the project foregrounds them as sites for critical reflection, revealing how working with bodily materials can complicate consent, value, and interspecies entanglement. We suggest that future work should treat sourcing ethics, interspecies relations, and consent as integral to the design process.

Absorption as Theoretical Reframing

We reframe casein-based biomaterials not simply as sustainable alternatives to petroleum-derived ones, but as sites for new relational experiences between body, its surfaces, and the environment, as enacted in the speculative scenarios. This shifts HCI's typical focus on user-device interaction for wearable technology. Absorption becomes a posthuman feminist ethics of care—not a passive state, but an embodied and relational act. Drawing on Barad's concept of intra-action [4], we understand absorbing, leaking, and form-making through material agency as processes that emerge through entanglement and challenge containment and hierarchy. This extends the notion of interaction to include vulnerability, reciprocity, and cyclical flows between body, material, and environment.

In this, we challenge the norms of concealment, particularly around lactation in public and professional spaces, as surfaced in the autoethnography of one of the authors. We propose a shift from containment to expressive visibility and sensory interaction. This reframing invites further aesthetic and ethical inquiry; particularly into what it means to use material from one body to interact with another, and how to define the intersubjective materiality of a leaking body engaging with another. For designers, this suggests opportunities to use fluid-responsive biomaterials to make bodily processes perceptible and participatory without electronic translation. Our speculative garments foreground bodily leakage to open conversations, yet raise questions about comfort, smell, and social legibility. Future work should engage crip theory on discomfort and queer theory's explorations of visibility and disclosure, to critically examine how designs might embrace bodily messiness and risks of making intimate experiences publicly legible.

Conclusion

This pictorial explored how fluid-responsive biomaterials can enable interactions shaped by the body's own rhythms, using lactation as a situated case. Through the formulation of a reversible, moisture-actuated casein bioplastic, the development of Leaky Body Maps, and speculative garment scenarios, we reframed leakage as a generative site of interaction. Grounded in feminist HCI, autoethnography, and design research, this work expands HCI's engagement with bodily fluids by situating material agency, sensory responsiveness, and relational entanglements at the center of interaction.

REFERENCES:

[1] Naseem Ahmadpour, Danielle Lottridge, Jonas Fritsch, Corina Sas, Marta E. Cecchinato, Daniel Harrison, Kristina Höök, Pin Sym Foong, Kiran Ijaz, Phillip Gough, Yidan Cao, Xuefei Li, Shaimaa Lazem, and Thida Sachathep. 2025. Affective interaction and affective computing - past, present and future. In *Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '25)*. Association for Computing Machinery, New York, NY, USA, Article 768, 1–6. https://doi.org/10.1145/3706599.3706743

[2] Alaimo, Stacy. 2010. *Bodily Natures : Science, Environment, and the Material Self*. Bloomington: Indiana University Press.

[3] Jean-Luc Audic, Bernard Chaufer, and Georges Daufin. 2003. Non-food applications of milk components and dairy co-products: A review. Le Lait 83, 6 (2003), 417–438. https://doi.org/10.1051/lait:2003027

[4] Karen Barad. 2003. Posthumanist performativity: Toward an understanding of how matter comes to matter. *Signs: Journal of Women in Culture and Society* 28, 3 (2003), 801–831. https://doi.org/10.1086/345321

[5] Fiona Bell, Latifa Al Naimi, Ella McQuaid, and Mirela Alistar. 2022. Designing with Alganyl. In P*roceedings of the Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction (Daejeon, Republic of Korea) (TEI '22)*. Association for Computing Machinery, New York, NY, USA, Article 2, 14 pages. doi:10.1145/3490149.3501308

[6] Fiona Bell, Michelle Ramsahoye, Joshua Coffie, Julia Tung, and Mirela Alistar. 2023. μMe: Exploring the Human Microbiome as an Intimate Material for Living Interfaces. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference* (Pittsburgh, PA, USA) (DIS '23). Association for Computing Machinery, New York, NY, USA, 2019–2033. doi:10.1145/3563657.3596133

[7] Nadia Campo Woytuk, Fiona Bell, Joo Young Park, Mirela Alistar, and Madeline Balaam. 2024. A Plurality of More-than-Humanness: Feminist Speculations for Designing with the Vaginal Microbiome. In *Proceedings of the Halfway to the Future Symposium (HttF '24)*. Association for Computing Machinery, New York, NY, USA, Article 20, 1–10. https://doi.org/10.1145/3686169.3686170

[8] Nadia Campo Woytuk, Marie Louise Juul Søndergaard, Marianela Ciolfi Felice, and Madeline Balaam. 2020. Touching and Being in Touch with the Menstruating Body. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3313831.3376471

[9] Nadia Campo Woytuk, Joo Young Park, Jan Maslik, Marianela Ciolfi Felice, and Madeline Balaam. 2023. Tactful Feminist Sensing: Designing for Touching Vaginal Fluids. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference (Pittsburgh, PA, USA) (DIS '23)*. Association for Computing Machinery, New York, NY, USA, 2642–2656. doi:10.1145/3563657.3595966

[10] George Chernyshov, Benjamin Tag, Cedric Caremel, Feier Cao, Gemma Liu, and Kai Kunze. 2018. Shape memory alloy wire actuators for soft, wearable haptic devices. In P*roceedings of the 2018 ACM International Symposium on Wearable Computers (Singapore, Singapore*) (ISWC '18). Association for Computing Machinery, New York, NY, USA, 112–119. doi:10.1145/3267242.3267257

[11] Karen Anne Cochrane, Kristina Mah, Anna Ståhl, Claudia Núñez-Pacheco, Madeline Balaam, Naseem Ahmadpour, and Lian Loke. 2022. Body Maps: A Generative Tool for Soma-based Design. In *Proceedings of the Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '22)*. Association for Computing Machinery, New York, NY, USA, Article 38, 1–14. https://doi.org/10.1145/3490149.3502262

[12] Laura Devendorf and Chad Di Lauro. 2019. Adapting Double Weaving and Yarn Plying Techniques for Smart Textiles Applications. In *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction (Tempe, Arizona, USA) (TEI '19)*. Association for Computing Machinery, New York, NY, USA, 77–85. doi:10.1145/3294109.3295625

[13] Jonas Fritsch, Kristina Höök, Claudia Núñez-Pacheco, Pedro Sanches, Anna Ståhl, and Vasiliki Tsaknaki. 2025. Estrangement through Silence. In *Proceedings of the 2025 ACM Designing Interactive Systems Conference (DIS '25)*. Association for Computing Machinery, New York, NY, USA, 929–943. https://doi.org/10.1145/3715336.3735711

[14] Mafalda Gamboa. 2023. My Body, My Baby, and Everything Else: An Autoethnographic Illustrated Portfolio of Intra-Actions in Pregnancy and Childbirth. In *Proceedings of the Seventeenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '23)*. Association for Computing Machinery, New York, NY, USA, Article 26, 1–14. https://doi.org/10.1145/3569009.3572797

[15] Mafalda Gamboa, Claudia Núñez-Pacheco, Sarah Homewood, Andrés Lucero, Janne Mascha Beuthel, Audrey Desjardins, Karey Helms, William Gaver, Kristina Höök, and Laura Forlano. 2024. More Samples of One: Weaving First-Person Perspectives into Mainstream HCI Research. In *Companion Publication of the 2024 ACM Designing Interactive Systems Conference (DIS '24 Companion)*. Association for Computing Machinery, New York, NY, USA, 364–367. https://doi.org/10.1145/3656156.3658382

[16] Francine Gemperle, Chris Kasabach, John Stivoric, Malcolm Bauer, and Richard Martin. 1998. Design for wearability. Institute for Complex Engineered Systems, Carnegie Mellon University, Pittsburgh, PA. http://www.ices.cmu.edu/design/wearability

[17] Alireza Golgouneh, Brad Holschuh, and Lucy Dunne. 2020. A Controllable Biomimetic SMA-actuated Robotic Arm. In *2020 8th IEEE RAS/EMBS International Conference for Biomedical Robotics and Biomechatronics (BioRob)*. 152–157. doi:10.1109/BioRob49111.2020.9224371

[18] Philip Gough, Soojeong Yoo, Martin Tomitsch, and Nasim Ahmadpour. 2021. Applying Bioaffordances through an Inquiry-Based Model: A Literature Review of Interactive Biodesign. *International Journal of Human–Computer Interaction* 37, 17 (2021), 1583–1597. https://doi.org/10.1080/10447318.2021.1898846

[19] Eduard Georges Groutars, Carmen Clarice Risseeuw, Colin Ingham, Raditijo Hamidjaja, Willemijn S. Elkhuizen, Sylvia C. Pont, and Elvin Karana. 2022. Flavorium: An Exploration of Flavobacteria's Living Aesthetics for Living Color Interfaces. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems(CHI '22)*. Association for Computing Machinery, New York, NY, USA, 1–19. https://doi.org/10.1145/3491102.3517713

[20] Ahmed Hassabo, Nada Khaleed, Shaimaa Shaker, Nehal Abd El-Salam, Nesma Mohamed, Nahla Gouda, and Eman Abd El-Aziz. 2024. Significance of casein fiber in textile technology. J*ournal of Textiles, Coloration and Polymer Science* 21, 1 (2024), 63–73. https://doi.org/10.21608/jtcps.2023.221107.1212

[21] Karey Helms. 2019. Do You Have to Pee? A Design Space for Intimate and Somatic Data. In *Proceedings of the 2019 on Designing Interactive Systems Conference (DIS '19*). Association for Computing Machinery, New York, NY, USA, 1209–1222. https://doi.org/10.1145/3322276.3322290

[22] Karey Helms. 2021. Entangled Reflections on Designing with Leaky Breastfeeding Bodies. In *Proceedings of the 2021 ACM Designing Interactive Systems Conference (DIS '21)*. Association for Computing Machinery, New York, NY, USA, 1998–2012. https://doi.org/10.1145/3461778.3462048

[23] Kristina Höök. 2022. Soma Design – Intertwining Aesthetics, Ethics and Movement. In *Proceedings of the 2022 International Conference on Advanced Visual Interfaces (AVI '22)*. Association for Computing Machinery, New York, NY, USA, Article 3, 1. https://doi.org/10.1145/3531073.3538400

[24] David S. Horne, Chapter 6 - Casein Micelle Structure and Stability, Editor(s): Harjinder Singh, Mike Boland, Abby Thompson, In *Food Science and Technology, Milk Proteins (Second Edition)*, Academic Press, 2014, Pages 169-200, ISBN 9780124051713, https://doi.org/10.1016/B978-0-12-405171-3.00006-4.

[25] Cayla Key, Cally Gatehouse, and Nick Taylor. 2022. Feminist Care in the Anthropocene: Packing and Unpacking Tensions in Posthumanist HCI. In *Designing Interactive Systems Conference (DIS '22)*, June 13–17, 2022, Virtual Event, Australia. ACM, New York, NY, USA, 16 pages. https://doi.org/10.1145/3532106.3533540

[26] Elvin Karana, Bahareh Barati, Valentina Rognoli, and Anouk Zeeuw van der Laan. 2015. Material driven design (MDD): A method to design for material experiences. I*nternational Journal of Design* 9, 2 (2015), 35-54.

[27] Pavel Karpashevich, Pedro Sanches, Rachael Garrett, Yoav Luft, Kelsey Cotton, Vasiliki Tsaknaki, and Kristina Höök. 2022. Touching Our Breathing through Shape-Change: Monster, Organic Other, or Twisted Mirror. ACM Trans. Comput.-Hum. Interact. 29, 3, Article 22 (June 2022), 40 pages. https://doi.org/10.1145/3490498

[28] Eldy S. Lazaro Vasquez, Netta Ofer, Shanel Wu, Mary Etta West, Mirela Alistar, and Laura Devendorf. 2022. Exploring Biofoam as a Material for Tangible Interaction. In *Proceedings of the 2022 ACM Designing Interactive Systems Conference (Virtual Event, Australia) (DIS '22)*. Association for Computing Machinery, New York, NY, USA, 1525–1539. doi:10.1145/3532106.3533494

[29] Eldy S. Lazaro Vasquez, Ali K. Yetisen, and Katia Vega. 2020. BraceIO: biosensing through hydrogel dental ligatures. In *Proceedings of the 2020 ACM International Symposium on Wearable Computers (Virtual Event, Mexico) (ISWC '20)*. Association for Computing Machinery, New York, NY, USA, 87–89. doi:10.1145/3410531. 3414290

[30] Xin Liu, Chengkuo Lee, Clement Zheng, and Ching Chiuan Yen. 2025. Designing Physical Interactions with Triboelectric Material Sensing. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems (CHI '25)*. Association for Computing Machinery, New York, NY, USA, Article 683, 20 pages. doi:10.1145/3706598.3714194

[31] Jasmine Lu and Pedro Lopes. 2022. Integrating Living Organisms in Devices to Implement Care-based Interactions. In *Proceedings of the 35th Annual ACM Symposium on User Interface Software and Technology (Bend, OR, USA) (UIST '22)*. Association for Computing Machinery, New York, NY, USA, Article 28, 13 pages. doi:10.1145/3526113.3545629

[32] Andrés Lucero, Audrey Desjardins, Carman Neustaedter, Kristina Höök, Marc Hassenzahl, and Marta E. Cecchinato. 2019. A sample of one: First-person research methods in HCI. In *Proceedings of the 2019 ACM Conference on Designing Interactive Systems Companion (DIS '19 Companion)*, June 23–28, 2019, San Diego, CA, USA. ACM, 385–388. https://doi.org/10.1145/3301019.3319996

[33] Tamar Luckett and Jen Bagelman. 2023. Body mapping: Feminist-activist geographies in practice. *Cultural Geographies* 30, 4 (2023), 621–627. https://doi.org/10.1177/14744740231179479

[34] Timothy Merritt, Foad Hamidi, Mirela Alistar, and Marta DeMenezes. 2020. Living media interfaces: a multi-perspective analysis of biological materials for interaction. *Digital Creativity* 31, 1 (2020), 1–21.

[35] Pat Pataranutaporn, Todd Ingalls, and Ed Finn. 2018. Biological HCI: Towards Integrative Interfaces

Between People, Computer, and Biological Materials. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems (CHI EA '18).* Association for Computing Machinery, New York, NY, USA, Paper LBW579, 1–6. https://doi.org/10.1145/3170427.3188662

[36] Chathuranga S. Ranadheera, Wasantha S. Liyanaarachchi, Jayani Chandrapala, Muditha Dissanayake, and Todor Vasiljevic. 2016. Utilizing unique properties of caseins and the casein micelle for delivery of sensitive food ingredients and bioactives. Trends in Food Science & Technology 57, Part A (2016), 178–187. https://doi.org/10.1016/j.tifs.2016.10.005

[37] Michael L. Rivera, Jack Forman, Scott E. Hudson, and Lining Yao. 2020. Hydrogel Textile Composites: Actuators for Shape-Changing Interfaces. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems (Honolulu, HI, USA) (CHI EA '20).* Association for Computing Machinery, New York, NY, USA, 1–9. doi:10.1145/3334480.3382788

[38] Carlo Santulli. 2024. Beyond buttons: Repurposing of Casein-Based Materials in Education and Industry — a Review. Academia Materials Science 1 (2024). https://doi.org/10.20935/AcadMatSci7286

[39] Margrit Shildrick. (1997). *Leaky Bodies and Boundaries: Feminism, Postmodernism and (Bio)ethics* (1st ed.). Routledge. https://doi.org/10.4324/9781315004952

[40] Ayoung Suh, Ruohan Li and Lili Liu. 2016. The Use of Wearable Technologies and Body Awareness: A Body–Tool Relationship Perspective. In: Stephanidis, C. (eds) HCI International 2016 – Posters' *Extended Abstracts. HCI 2016. Communications in Computer and Information Science,* vol 617. Springer, Cham. https://doi.org/10.1007/978-3-319-40548-3_65

[41] Shuyi Sun, Alejandra Ruiz, Sima Pirmoradi, and Katia Vega. 2023. BioSparks: Jewelry as Electrochemical Sweat Biosensors with Modular, Repurposing and Interchangeable Approaches. In *Adjunct Proceedings of the 2023 ACM International Joint Conference on Pervasive and Ubiquitous Computing & the 2023 ACM International Symposium on Wearable Computing.* 315–320.

[42] Michael R. Vinciguerra, Dinesh K. Patel, Wuzhou Zu, Mahmoud Tavakoli, Carmel Majidi, and Lining Yao. 2023. Multimaterial Printing of Liquid Crystal Elastomers with Integrated Stretchable Electronics. *ACS Applied Materials & Interfaces* 15, 20 (May 2023), 24777–24787. doi:10.1021/acsami.2c23028 Publisher: American Chemical Society.

[43] Lining Yao, Jifei Ou, Chin-Yi Cheng, Helene Steiner, Wen Wang, Guanyun Wang, and Hiroshi Ishii. 2015. bioLogic: Natto Cells as Nanoactuators for Shape Changing Interfaces. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (Seoul, Republic of Korea) (CHI '15).* Association for Computing Machinery, New York, NY, USA, 1–10. doi:10.1145/2702123.2702611

[44] Meredith Young-Ng, Grace Chen, Danielle Kiyama, Anna-Sofia Giannicola, Erkin Şeker, and Katia Vega. 2023. Sweatcessory: a Wearable Necklace for Sensing Biological Data in Sweat. In *Adjunct Proceedings of the 2022 ACM International Joint Conference on Pervasive and Ubiquitous Computing and the 2022 ACM International Symposium on Wearable Computers (Cambridge, United Kingdom) (UbiComp/ISWC '22 Adjunct).* Association for Computing Machinery, New York, NY, USA, 141–143. doi:10.1145/3544793.3560342

[45] World Health Organization. 2009. Infant and young child feeding: Model chapter for textbooks for medical students and allied health professionals. Session 2, The physiological basis of breastfeeding. World Health Organization, Geneva. https://www.ncbi.nlm.nih.gov/books/NBK148970/

[46] Zeagler, Clint. 2017. "Where to Wear It : Functional , Technical , and Social Considerations in On – Body Location for Wearable Technology 20 Years of Designing for Wearability." In *International Symposium on Wearable Computers.* Maui, Hawaii. doi:10.1145/3123021.3123042.

[47] Jingwen Zhu, Fiona Bell, Katherine W Song, Katia Vega, Aditya Shekhar Nittala, Mirela Alistar, Leah Buechley, and Cindy Hsin-Liu Kao. 2025. Wearable Bio-HCI: Challenges & Opportunities. In *Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '25).* Association for Computing Machinery, New York, NY, USA, Article 866, 1–5. https://doi.org/10.1145/3706599.3716295

[48] Jingwen Zhu, Samantha Chang, Ruth Zhao, and Cindy Hsin-Liu Kao. 2025. LivingLoom: Investigating Human-Plant Symbiosis Through Integrating Living Plants Into (E-)Textiles. In P*roceedings of the 2025 CHI Conference on Human Factors in Computing Systems (CHI '25).* Association for Computing Machinery, New York, NY, USA, Article 773, 18 pages. doi:10.1145/3706598.3713156

[49] Jingwen Zhu, Nadine El Nesr, Christina Simon, Nola Rettenmaier, Kaitlyn Beiler, and Cindy Hsin-Liu Kao. 2023. BioWeave: Weaving Thread-Based Sweat-Sensing On-Skin Interfaces. In *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology (San Francisco, CA, USA) (UIST'23).* Association for Computing Machinery, New York, NY, USA, Article 35, 11 pages. doi:10.1145/3586183.3606769