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Living Bits and Radical Aminos

A Workshop on Bio-Digital Interfaces for Human-Computer Interaction

Forman, Jack; Pataranutaporn, Pat; Gough, Phillip; Kim, Raphael; Bell, Fiona; Ofer, Netta; Lu, Jasmine; Vujic, Angela; Bai, Muqing; More Authors

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Living Bits and Radical Aminos: A Workshop on Bio-Digital Interfaces for Human-Computer Interaction

Jack Forman*
Pat Pataranutaporn*
jackform@mit.edu
patpat@mit.edu
MIT Media Lab
Cambridge, MA, USA

Phillip Gough
phillip.gough@sydney.edu.au
Design Lab, School of Architecture Design and Planning, The University of Sydney
Australia

Raphael Kim
r.kim@tudelft.nl
Delft University of Technology
Netherlands

Fiona Bell
fiona.bell@colorado.edu
ATLAS Institute, University of Colorado Boulder
Boulder, Colorado, USA

Netta Ofer
netta.ofer@colorado.edu
ATLAS Institute, University of Colorado Boulder
Boulder, Colorado, USA

Jasmine Lu
jasminelu@uchicago.edu
University of Chicago
Chicago, IL, USA

Angela Vujic
avujic@mit.edu
MIT Media Lab
Cambridge, MA, USA

Muqing Bai
muqingb@mit.edu
Harvard University
Cambridge, MA, USA

Pattie Maes
pattie@media.mit.edu
MIT Media Lab
Cambridge, MA, USA

Hiroshi Ishii
ishii@media.mit.edu
MIT Media Lab
Cambridge, MA, USA

Misha Sra
sra@cs.ucsb.edu
University of California, Santa Barbara
Santa Barbara, CA, USA

ABSTRACT

As knowledge around bio-digital interaction continues to unfold, there are new opportunities for HCI researchers to integrate biology as a design and computational material. Our motivation for the workshop is to bring together interdisciplinary researchers with interest in exploring the next generation of biological HCI and exploring novel bio-digital interfaces implicating diverse contexts, scales, and stakeholders. The workshop aims to provide a space for interactive discussions, presentations, and brainstorming regarding opportunities and approaches for HCI around bio-digital interfaces. We invite researchers from both academia and industry to submit a short position paper in the following areas: Synthetic Biology, Biological Circuits, Do-It-Yourself Biology (DIYBio), Biomimetic Interfaces, Living Interfaces, Living Artefacts, and Bio-ethics. We will evaluate submissions on fit, ability to stimulate discussion, and contribution to HCI. On our website we have included examples of past work in this area to help inspire and inform position papers. Our website will host a recording of the entire workshop session with accepted papers to support asynchronous viewing for participants who are unable to attend in-person or synchronously.

CCS CONCEPTS

• **Human-centered computing** → **HCI theory, concepts and models**; **Interaction techniques**; **Interaction design theory, concepts and paradigms**.

KEYWORDS

Biotechnology, Biological Interfaces, Synthetic Biology, Microorganism, Bio-HCI, Microbial-HCI, Living Artefacts, Biomaterials

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*Both authors contributed equally to this research.

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1 INTRODUCTION

1.1 Living Bits

As we continue to envision the future of human-computer interaction, we must challenge the conventional approach, medium, and means of computation to think beyond digital interfaces. In addition to wearable computers that might find themselves on our

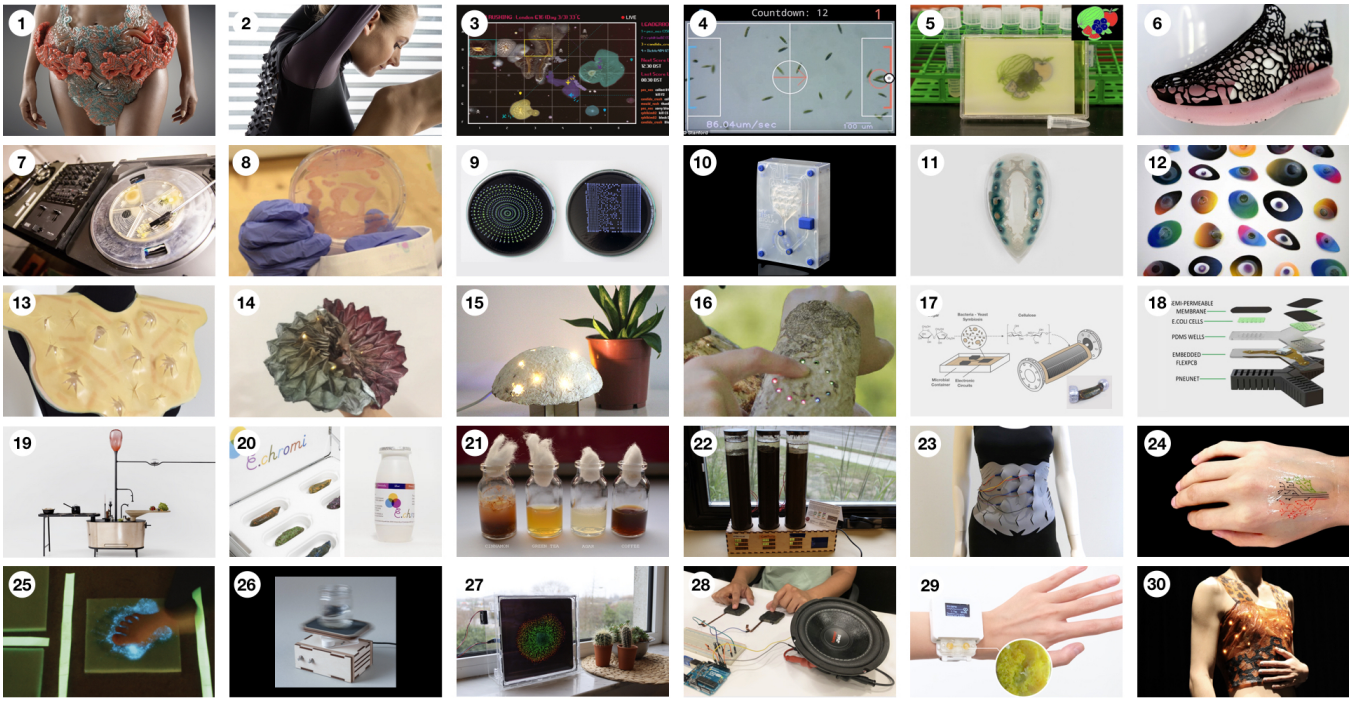

Figure 1: Selected works that demonstrate or in close relation to the vision of Living Bits [46] and Radical Aminos: 1. Mushtari [4], 2. bioLogic [58], 3. Mould Rush [30], 4. Euglena Soccer Game [27], 5. RGB E.Coli [14], 6. Breathing Shoes [34], 7. Biota Beat [31], 8. Antibiotic-Responsive Bioart [32], 9. OpenLH [17], 10. My First Biolab [16], 11. Vespers [3], 12. Carbon Eaters [34], 13. Social Microbial Prosthesis [13], 14. Grown Microbial 3D Fiber Art [42], 15. Mycelium Artifacts [56], 16. Myco-accessories [51] 17. Growable Robot [44], 18. Biosensing Soft Robot [25], 19. Microbial Home [41], 20. E. chromi [12], 21. Microbial Perfume [54], 22. Bio-electronic soil sensing device [33], 23. Gut-Brain Computer Interfaces [53], 24. 3D Printed Living Responsive Materials and Devices [37], 25. Designing Direct Interactions with Bioluminescent Algae [43], 26. Living Light Interfaces [5], 27. Flavorium (Living Monitor) [20], 28. ReClaym Our Compost [8], 29. Slime Mold Integrated Smartwatch [38], 30. SCOBY Breastplate [7].

bodies, there are already trillions of living biological "computers" on, inside, and around our bodies. Half of them are our own human cells, but the rest are other living organisms that co-inhabit our body [48]. This network of living cells in our body is arguably the most sophisticated form of a complex system. They are constantly communicating, sensing the environment, and producing several kinds of molecules (proteins, enzymes, etc.) to keep the body alive. As Mark Weiser, a pioneer in ubiquitous computing said, *"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it"* [57]. Such notions may also apply to the agents of biotechnology and synthetic biology. As we begin to explore next generations of interfaces, there is an opportunity for augmenting digital interfaces with living systems, which could bring new and/or alternative capabilities and outcomes that cannot be realized through non-biological means alone. In our workshop, we expand on the concept of *Living Bits* [46]. Inspired by how *Tangible Bits* [24] sought to bridge the gap between the digital and physical environment, *Living Bits* concept frames the living cell as a programmable computational unit; signifying the emergence of digital *bit* properties and the abstraction of computational parts in the living system. As such, *Living Bits* serves as an endpoint for programmable bio-digital interfaces, allowing the digital system counterpart to intimately tap into the biological information and its functionality. Similar to digital circuits, synthetic biological circuits offer the potential to "wield computational control over biology", allowing researchers to reprogram living cells to sense, compute, and actuate with molecular granularity and precision. Researchers have also developed methods for the cell to have digital logic gates for computation, performing Boolean functions, as well as designing programming languages and software to create them (e.g., [40, 47, 52]).

1.2 Radical Aminos

We also introduce the term *Radical Aminos*–inspired by *Radical Atoms* [23]–to belabor the reprogrammable material nature of biological computers. All living creatures use a set of twenty amino acids that by themselves are simple but varied (e.g., some are big, some are small, some like water, some do not). However, when combined, they create an infinite library of materials with vastly different properties. *Radical Aminos* is the combination of the best

of digital computers - the ability to be easily programmed to perform fast, complex computation - with the best of living cells - the ability to synthesize and manipulate matter with wide ranging properties. Over the past decade, researchers have explored the ability of living organisms to produce and to surface specific outputs (e.g., growth, movement, compounds, etc.) that can be detected by the human and digital sensors, as part of interactive interfaces. Outcomes of such explorations have included wearable devices [3, 4, 13, 34, 42, 51, 53, 53, 58] to musical instruments [31], built environments [41], food [12], games [11, 21, 30], digital data storage and translation systems [1, 10, 22, 28], and robots [25, 44] etc., demonstrating a rich spectrum of research in HCI that engages with microbes. They come together to form a theme (and a special interest group) that we identify as *microbial-HCI*, or *microbe-HCI* [29]. Though digital technology dominates modern industrialized societies, these projects demonstrate that there is a possibility to rethink computation using organic and living systems.

2 MOTIVATION

As the knowledge around human-microbe interaction continues to unfold, there are opportunities for HCI researchers to integrate microbes into interactive systems. Our motivation for the workshop is to bring together interdisciplinary researchers and practitioners with interest in exploring the next generation of biological HCI [29, 39, 45], exploring novel bio-digital interactions in different contexts, scales, and stakeholders (Fig. 1). The workshop aims to provide a space for stimulating discussions, presentations, and brainstorming sessions around future research directions for HCI around microbial interface design. Whilst biodesign is gaining much attention, so too are applications and research implicating living organisms specifically. We compiled the following list of research areas and corresponding questions related to *Living Bits* and *Radical Aminos* that would benefit the HCI community, to be used as departure points in our workshop:

- Microbes as Computational Agents [46]: Should we begin to consider microbes as computers and binary bits and atoms? If so, how does this concept translate to research across the various domains in HCI? How might thinking about microbes as computational agents shape various fields in HCI?
- Bioaffordances [19]: How might the "affordances of biological material[s]" [19] differ from traditional materials in HCI (e.g., plastic, silicon, metal)? Does the meaning of affordance change when working with biological materials? How do the affordances of biological materials guide specific interaction mechanics [20, 43]?
- Designing Living Artefacts [5, 20, 26]: How could livingness shape the ways in which artefacts are designed and displayed? How could we design towards addressing the three fundamental design pillars associated with living artefacts: living aesthetics (e.g., [5]), habitabilities (e.g., [59]), and mutualistic care (e.g., [38])?
- De-centering the Human in Design [36, 43, 55]: How might living bits be used for de-centering the human in the design process and outcomes? How might designing and interacting with living matter reach beyond the notion of the organism being a programmable material, perhaps considering it as an active counterpart? What can posthuman, more-than-human, and organism-centered [43] approaches teach us when working with *Living Bits* and *Radical Aminos*?
- Developing Sustainable Materials [6, 8, 9, 15, 35, 42, 49, 50]: How might computational microbes play a role in creating sustainable materials? What new methods might such sustainable materials require? How can we best pair sustainable materials with traditional electronic components to create interactive artefacts and interactions? Is the general effort of sustainability a goal for *Living Bits* and *Radical Aminos*, and bio-digital interfaces?
- Bioethics [2, 39, 43]: What new ethical guidelines arise when working with living organisms and how do they translate to practice? How can we disseminate best ethical practices to other Bio-HCI practitioners? How can we foster a future of bio-digital interfaces that are accessible to diverse communities and that are conscientious of safety concerns?

2.1 Workshop Goals

To inform and inspire participants in thinking about the opportunities for *Living Bits* and *Radical Aminos*, our workshop aims to address four grand challenges in this space:

(1) Define research methods, questions, and potential applications for *Living Bits* and *Radical Aminos*.
(2) Connect researchers and practitioners with shared interests to foster collaborations.
(3) Establish design space for bio-digital interfaces through consideration of the current state-of-the-art, future possibilities, and firm limitations.
(4) Understand existing bioengineering technologies that could be readily leveraged for bio-digital interfaces.

3 PRE-WORKSHOP PLANS

Our website is hosted at: https://www.media.mit.edu/. We will distribute the workshop call through email, social media, and our website. Examples include ACM SIGCHI mailing lists, MIT Media Lab mailing lists, and social media outlets (i.e., Facebook pages and Twitter). We will also contact practitioners in fields like biology who may not have a background in HCI but are exploring living bits through technology. The website will include examples of past work in this area to help inspire and inform position papers. We will encourage authors who may not have a background in the life sciences to present their wildest ideas (e.g. papers that form a vision about an interaction currently not implemented). We will also encourage presentations of prior work in this area.

We will invite researchers from both academia and industry to submit a paper in the CHI Extended Abstracts format up to a maximum of 4 pages. The papers will be classified in one or more of the categories: observation, integration, and modification and will range from descriptions of basic methods and toolkits to specific applications and prototypes. An accepted paper will address one or many of the defined grand challenges listed in our workshop goals. The submission portal will be accessed through our website. We are planning the paper review timeline as follows: call for papers on December 12th, 2022; submission deadline on January 12th,

2023; notification of acceptance by February 2nd, 2023; and final submissions due on February 10th, 2023. We will host accepted papers on the workshop website for participants and others to review.

4 WORKSHOP CONTENT AND STRUCTURE

Our one-day workshop will consist of two main parts: (1) presentations and (2) discussions. In the morning, participants will present their accepted papers (submitted in the workshop application), which will be categorized into three sessions: observation, integration, or modification. Accepted papers will also be hosted on our website prior to the workshop for participant and conference attendee access. In the afternoon, we will engage participants in lively discussion sessions regarding the paper presentations, the ethics of using living organisms in HCI, and the future of *Living Bits* and *Radical Aminos*. We anticipate 25-35 participants in total. We provide a detailed schedule of the workshop in table 1.

Table 1: Proposed workshop schedule.

Time	Schedule Item
09:00 - 09:10	Introduction
09:10 - 09:30	Icebreakers!
09:30 - 10:30	Presentation Session: Observation
10:30 - 10:45	Coffee Break
10:45 - 11:45	Presentation Session: Integration
11:45 - 12:15	Presentation Session: Modification
12:15 - 13:30	Lunch break with Group
13:30 - 14:00	Small Group Discussions about Presentations
14:00 - 15:30	Ethics Discussion
15:30 - 15:45	Coffee Break
15:45 - 16:45	*Living Bits* and *Radical Aminos*: Outlook Discussion
16:45 - 17:00	Workshop Closing

5 REMOTE/ONSITE PLANS

We will have plans for supporting virtual, hybrid, and in-person workshop events so that we can adapt to any unforeseen circumstances (COVID or otherwise). Additionally, in the case that we are able to have an in-person event, we will also plan to enable participants to join and participate virtually if they need to. Last, by sharing workshop materials before and after the conference, we will enable asynchronous participation.

6 POST-WORKSHOP PLANS

We plan to post photos and videos of the workshop on our website and social media during and after the workshop. Next, we plan to organize a special issue of the MIT *Journal of Design and Science (JoDS)*. JoDS aims to create new connections between science and design as the future of human-microbe interfaces will rely on expertise from both fields. Authors will be encouraged to submit their work in addition with commentary on ethical considerations and nuances of observing, integrating and modifying living organisms. The online publication platform that JoDS uses, PubPub, will allow for collaborative peer review. We will encourage participants who have met through the workshop to submit articles together and to discuss other participant's articles on the web interface. Our intention is that workshop participants will become co-authors to foster community and collaboration.

7 CALL FOR PARTICIPATION

Due to the successful CHI 2021 Workshop, "Speculating on Biodesign in the Future Home" [18], in this year's workshop we look forward to attracting participants from the emerging field of Biological-HCI.

As the knowledge around bio-digital interaction continues to unfold, there are emerging opportunities for HCI researchers to integrate biology as a design and computational material. Our motivation for this workshop is to bring together interdisciplinary researchers with interests in exploring the next generation of biological HCI exploring novel bio-digital interfaces in different contexts, scales, and species. The workshop aims to provide a space for stimulating discussion, presentations, and brainstorming regarding the opportunities for and methods for HCI around bio-digital interfaces.

We invite researchers from both academia and industry to submit a short position paper in the following areas: Synthetic Biology, Biological Circuits, DIYBio, Biomimetic Interfaces, Living Interfaces, Ethics of SynBio. We will evaluate submissions on fit, ability to stimulate discussion, and contribution to HCI. Our website includes examples of past work in this area to help inspire and inform position papers.

Papers should be maximum 4-pages and in the CHI Extended Abstracts format. Submission can be accessed through our website: https://media.mit.edu. The submission deadline is January 12th, 2021. At least one author of each accepted position paper must attend the workshop and all participants must register for at least one day of the conference. We will host accepted papers on the workshop website for participants and others to review. Please see our website for more information: https://media.mit.edu.

8 ORGANIZERS

8.0.1 Jack Forman. Jack Forman is a graduate student at the MIT Media Lab, in the Tangible Media Group. Jack's vision is to make tangible artifacts embedded seamlessly with responsive behavior, through the development of programmable materials and ways to fabricate them, to make engaging human-material interfaces that utilize the emotional power of touch. Jack sees a future where these adaptive interfaces are ubiquitous, where every material is able to accept and respond to the change that is constantly flowing through us. Previously, Jack received his B.S. from Carnegie Mellon University, where he double majored in Materials Science and Biomedical Engineering.

8.0.2 Pat Pataranutaporn. Pat Pataranutaporn is a technologist, designer, and a graduate student at the MIT Media Lab. Pat's interests are at the intersection of biotechnology and wearable technology, specifically at the integration of bio and digital system to create personalized interfaces for the users. In his thesis, Pat developed Biological HCI, a design framework that investigates the relationships between human, computer and biological systems by defining biological materials as design elements.

8.0.3 Phillip Gough. Phillip Gough is a Senior Lecturer in Design, in the Affective Interactions Lab at The University of Sydney School of Architecture, Design and Planning. Phil's research into biodesign in the home of the future intersects with digital fabrication and connected devices. His research aims to understand how living materials can be used to create new interactions through bio-digital integration, and understanding the user experience of biomaterials in the home context.

8.0.4 Raphael Kim. Dr. Raphael Kim is a postdoctoral researcher at Materials Experience Lab, Delft University of Technology, The Netherlands. His research interest lies in designing living artefacts, creating playful human-microbe interactions, and fostering critical dialogues on the sociocultural implications of biotechnology in interaction design.

8.0.5 Fiona Bell. Fiona Bell is a PhD candidate in the Living Matter Lab at the ATLAS Institute, University of Colorado Boulder. Her research happens at the intersection of material science, biodesign, and human-computer interaction. Her primary research goal is to challenge current materials and making practices in light of the Anthropocene by designing for more-than-human futures. Thus, Fiona currently creates sustainable interfaces, focused on intimate interactions between human and nonhuman beings.

8.0.6 Netta Ofer. Netta Ofer is a PhD student in the Living Matter Lab at the ATLAS Institute, University of Colorado Boulder. In addition to using interaction design, her work makes use of dance and movement practices to investigate our relationships with living matter through a more-than-human lens and explore how we might de-centering the human in design research. She produces methods, interactions, artifacts, and art work probing the points of connection and /or tension between human and nonhuman bodies.

8.0.7 Jasmine Lu. Jasmine Lu is a PhD student at the University of Chicago's Computer Science Department. Through her work, she explores how we might build the future of interactive technologies to be more sustainable and engage users in ecological thinking. She focuses on engineering prototypes that encourage humans to be more than just users and consumers of electronic devices and, instead, enter roles of caretakers and maintainers. Her recent work explores how physical care for a living organism, embedded as a functional component of an interactive device, affects the user-device relationship.

8.0.8 Angela Vujic. Angela Vujic is a graduate researcher at the Fluid Interfaces Group in the MIT Media Lab. She is motivated by the connection between the microbiome and mental health to create technology that mediates the mind-gut connection. She aims to introduce gut-brain computer interfaces (GBCIs) to HCI, devices that enable individuals to modulate their gut activity or use their gut activity as inputs to other devices. She holds a degree in computer science from Georgia Tech where she developed brain-computer interface (BCI) glasses with a fiber optic display for assistive communication.

8.0.9 Muqing Bai. Muqing Bai is a graduate student at the Harvard Graduate School of Design. Before coming to the Harvard GSD, Muqing Bai received a master's at the Architectural Association. Muqing Bai's final research thesis was a recreated narrative of the Pacific Ring of Fire that aims to stimulate the reformations of the social-economical structures born out of neoliberal extractivism under sea-level rise. One of Muqing Bai's most recent works aims to purpose questions on the bio-material industries, particularly the anthropogenic manipulations of mycelium as bio-based alternatives.

8.0.10 Pattie Maes. Pattie Maes is a professor in MIT's Program in Media Arts and Sciences and runs the Media Lab's Fluid Interfaces research group, which aims to radically reinvent the human-machine experience. Coming from a background in artificial intelligence and human-computer interaction, she is particularly interested in the topic of cognitive augmentation, or how immersive and wearable systems can actively assist people with memory, learning, decision making, communication, and wellbeing.

8.0.11 Hiroshi Ishii. Hiroshi Ishii is the Jerome B. Wiesner Professor of Media Arts and Sciences at the MIT Media Laboratory. After joining the Media Lab in October 1995, he founded the Tangible Media Group to make digital tangible by giving physical form to digital information and computation. Here, he pursues his visions of Tangible Bits (1997) and Radical Atoms (2012) that will transcend the Painted Bits of GUIs (Graphical User Interfaces), the current dominant paradigm of HCI (Human-Computer Interaction). He is recognized as a founder of "Tangible User Interfaces (TUI)," a new research genre based on the CHI '97 "Tangible Bits" paper presented with Brygg Ullmer in Atlanta, Georgia, which led to the spinoff ACM International Conference on Tangible, Embedded and Embodied Interaction (TEI) from 2007.

8.0.12 Misha Sra. Misha Sra is the John and Eileen Gerngross Assistant Professor of Computer Science at UCSB. Her current work focuses on Human-Computer Interaction (HCI), eXtended Reality (XR), and Artificial Intelligence (AI). In particular, she is investigating the design, engineering and study of novel interfaces, interaction techniques, tools and systems for motor skill acquisition, realtime task assistance and creative collaboration. Her lab's goal is to bridge the massive gap between AI models and interactive Human-Centered AI design.

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