
A Biological Imperative for Interaction Design

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Abstract

This paper presents an emerging approach to the integration of biological systems- their matter, mechanisms, and metabolisms- into models of interaction design. By bringing together conceptual visions and initial experiments of alternative bio based approaches to sensing, display, fabrication, materiality, and energy, we seek to construct an inspirational discussion platform approaching non-living and living matter as a continuum for computational interaction. We also discuss the emergence of the DIY bio and open source biology movements, which allow non-biologists to gain access to the processes, tools, and infrastructure of this domain, and introduce Synbiota, an integrated, web-based platform for synthetic biology research.

Keywords

Interaction Design, Biological Design, DIY Bio, Open Source, Physical Computing, Tangible Media

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation:
Interaction Styles D.2.2 Design Tools and
Techniques: User Interfaces

Introduction

In 2007, noted theoretical physicist, Freeman Dyson began an essay in the New York Review entitled 'Our

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Biotech Future,' [1] with, "The twentieth century was the century of physics and the twenty-first century will be the century of biology," citing biology as bigger in impact for its economic consequences, its ethical implications, and its effects on human welfare for the coming century. As a community of researchers dedicated to exploring and advancing the human side of Human-Computer Interaction, the impact of a global shift in thinking toward the importance of biological systems is bound to impact the experiences we create, the systems we develop, and our modes of working within an integrated infrastructure of science and technology, design, and culture.

But how does this paradigm shift begin to infiltrate research currently created using algorithms written in human generated computer languages and experiences primarily designed for output on consumer electronic devices, all artificially produced human constructs of contemporary culture?

Scientists, artists, and designers have long been inspired by biological systems, both in form and behavior, and have used them to inform on the development of structure and pattern [2] [fig.1]. Forms of biomimicry have served as the basis for physical structures as well as in the derivation of mathematical formulas, creating abstractions for natural models in the digital realm. The strategic difference, however, as we seek the future of biological integration lies not in an attempt to emulate nature, but to use the natural systems themselves, their matter, mechanisms and metabolisms, in conjunction with superimposed control structures, to render the possibility of entirely new models of interaction and experience. In this way, we do not simply learn from biology and apply it to an alternate artificial system, but biological material

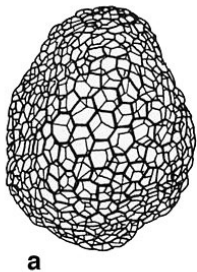


Fig. 1. Reticulum
Plasmatique from Darcy
Wentworth Thompson,
On Growth and Form

becomes the matter through which we simultaneously manipulate and experience our world.

In recent years, the established discipline of Tangible Media [3] has given rise to the vision of Radical Atoms [4] marking a leap toward physical programmability by assuming a hypothetical generation of materials that can change form and appearance dynamically, so they are as reconfigurable as pixels on a screen. Radical Atoms is a vision for the future of human-material interactions, and demonstrates a commitment to the fundamental importance physicality still plays in the human experience with technology. A biological imperative for interaction design creates a possible path toward radical atoms, investigating an alternate material reality which complements existing models of manipulation while opening the door to the unknowns of programmable materials can converge directly with biological code.

The development of new paradigms in biological synthesis also provide potential solutions to address broader issues affecting contemporary culture - such as practical concerns of diminishing resources and climate change. As a community of researchers, we should aim to embrace and explore what this may offer in terms of new forms of expression and experience, as we search for a sustainable future for ourselves and our discipline.

A Holistic Approach to Device Design

As interaction designers and HCI professionals, our discipline relies heavily on the industry of consumer electronics. These devices are manufactured in complex global supply chains, utilizing precious materials, including rare earth metals, which are dangerous to mine and with diminishing supplies that we are using faster than we can produce. They consume power,

many in the form of disposable batteries. And with a general standard of planned obsolescence, the devices amount quickly into massive amounts of technology waste which generally cannot be disassembled, reused, or recycled.

The fundamental power of good design lies in taking what may appear as a constraint and turning it into the solution. As contributors to this industry we have a responsibility to think more holistically about the experiences we are creating, and seek to challenge and mediate what creates desire. Biological solutions may afford the opportunity to design nature-based sensing and display mechanisms, create devices that are independent of traditional power structures (self-sustaining) and that are fabricated in materials and through processes which integrate cohesively into the planet's cycles of waste and renewal. These ideas should not be considered at the expense of an experience, but rather an opportunity for defining new models of interaction.

This also leads to a questioning of the nature of consumer electronics in general - how do we define 'progress' within the current state of our world. Is the fulfillment of Moore's Law really what we need for a sustainable future? Are there situations in which bigger, slower, and highly valued serve as a more appropriate experiential construct? Many examples have emerged from the developing world in which this proves to be true.

Beyond Biomimicry: Integration and Control of Biological Processes

Materiality and Control Structures

All materials and matter can be considered from the perspective of their internal control structure, defined

by how they behave when subjected to outside forces. Every material is also dynamic, potentially just not at a temporal or spatial scale by which humans experience it immediately. For example, we think of stone as static, but over long periods of time exposed to the elements, it breaks down and changes shape. Water has a natural control structure easily effected by temperature and pressure to change states from solid (ice) to liquid (water) to gas (vapor). Microorganisms have slightly more complex control structures, determined by the mechanisms of their DNA, but can also be defined by their observable patterns of behavior in response to their environment.

From the perspective of interaction design, the point is to consider any matter (living or non-living) in the way a hardware system would be considered- deriving input from sensing the world, interpreting that input, and generating a response as output which, in turn, creates feedback. This forms the basis of a methodology for integration of biological processes into an interaction scenario. Consider what the biological organisms or processes will contribute to an scenario, and what the knowns and unknowns of those processes entail. By utilizing our existing tools and technologies of interaction design to mediate or augment a resultant experience, we begin to explore novel forms of interaction which may manifest new materialities. Or when applied appropriately, can be more seamlessly integrated into varying natural environments and take advantage of a shift in temporal or physical scales.

Information displays

The idea of 'biological pixels' set forth in Dewy [5] [Fig.2] provides a straight forward example of biological process integration. Dewy is a display surface of 'pixelized' condensation, creating images, patterns, and

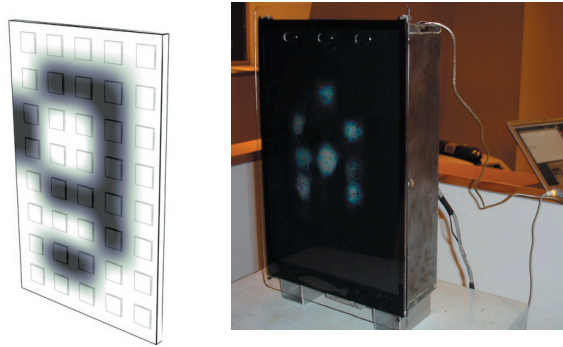


Fig.2. Dewy: A Condensation Display developed by Parkes and Offenhuber.

text out of the process of the physical state change of water. With an Arduino controlled array of peltier junctions, Dewy works like a spatially controlled fogged window, conveying information through a slow and subtle means.

Within living organisms, the production of color often provides easily understood behavior patterns which can be exploited. The presence of the pigment chlorophyll in plants is directly related to the absorption of light, and can be manipulated in tone through controlled inputs of light. UK artists Heather Ackroyd and Dan Harvey produce 'grass paintings,' [6][Fig.3] where a photographic digital image is projected onto a surface of grass seed. As the grass grows, areas receiving more light become a deeper green and a gradient of yellow-green shades creates a recording and 'display' of complex photographic images. The imagery produced is a one-way process and will be temporary and transient, as the impact of extraneous light inevitably corrupts the picture.



Fig. 3. Testament, a large scale grass portrait by UK artists Heather Ackroyd and Dan Harvey

The potential to create a continuously changing display

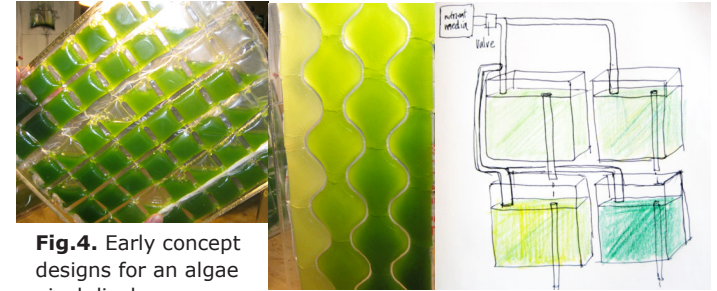


Fig.4. Early concept designs for an algae pixel display

with chlorophyll is examined in an early concept idea for a microalgae pixel display [Fig.4]. The typical 12 day growth cycle of a culture of microalgae can be mapped to a distinct Pantone™ scale of yellow to greenish shades, based on the density of algae present. The color of an array of 'pixel boxes' can be controlled through monitoring optical density, and based on the programming of a desired display color, can be adjusted through the automated removal of material or added nutrients, CO₂, and light to promote the acceleration of growth. The display offers a subtle means of visual display in alternate materiality. The change of pattern, however, embodies a divergence in display temporality, requiring a day to move between shades in a continual fashion, and the programming and potential applications must reflect and embody this.

Fabrication

Perhaps the most developed area of integration of biological processes is fabrication. In the search for sustainable materials, designers have begun to look at the metabolic processes of micro-organisms as a way to synthesize natural composites. For example, fueled only by a mixture of oak pellet fuel, wheat bran, and gypsum, the fungi mycelium, creates a strong lightweight, alternate to bricks or concrete when cast



Fig 4. Bioculture, bacterial cellulose garment by Suzanne Lee



Fig 5. Mycoform, cast mycelium bricks by Terreform1

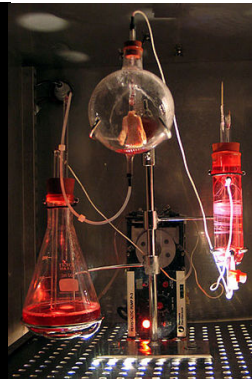


Fig. 6. Victimless leather from the Tissue Culture and Art Project

in a 3D structure, as in the project Mycoform [7] [Fig.5] from Terreform1. Fashion designer Suzanne Lee grows cellulosic textiles from a bath of the bacteria in kombucha [8] [Fig.4]. And living tissue from mouse cells is grown into the structure of a miniature jacket in the project Victimless Leather [9][Fig.6] from the Tissue Culture and Art Project.

Biological systems utilize fabrication methods typically light on material and energy consumption, and through integration of an imposed and interactive control structure, the processes that guide the formation of resilient structures in nature, can be rendered into desired forms, composites, or products. Designed Morphologies [10] [Fig.7] from Corrie van Sice offers a controlled and interactive fabrication approach to provide a varying density, directional strength, and gradation for optimal structural design. In aggregation through electrolysis (the process of making coral),programmable current emulates a biological ion pump, allowing accumulation of crystal onto a conductive surface, resulting in multilayered composite

of varying properties.

A related project, Bio Computation [11] also seeks to apply the logic of structural design in nature. A collaboration between architect David Benjamin and biologist Fernan Federici, Bio Computation explores methods of extracting complex behaviors of cells at the scale of microns and applying them to architecture at the scale of meters. Working with both software and wetware, designers can program the growth patterns of multiple materials (for eg. 3D lignocellulosic patterns in xylem cells) to solve architectural structure design problems, while optimizing around the physics of scale translation limitations.

Energy

We need to look no further than the recent fall out of Hurricane Sandy on the East Coast of the US to recognize the issues around our current centralized and seemingly invisible system of energy production and management. These ideas were initially addressed within the HCI space in the 2010 paper, 'Materializing

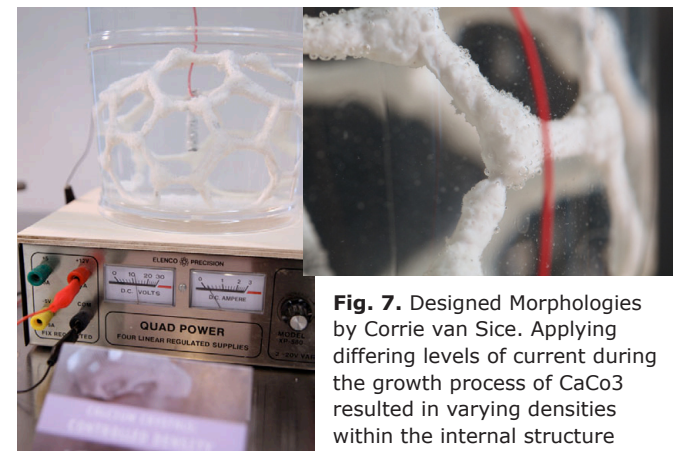


Fig. 7. Designed Morphologies by Corrie van Sice. Applying differing levels of current during the growth process of CaCo3 resulted in varying densities within the internal structure

Energy' [12] by Pierce and Paolos, articulating a design approach positioning energy as a tangible thing, to be considered along with choices made about an object's overall design. A series of self sustaining novel devices called 'energy momentos,' provide critical investigation around the themes of the *intangibility of energy*, the *undifferentiatedness of energy*, and the *availability of energy*.

A societal rethinking around decentralized and distributed models of energy production and distribution brings to light the fact that energy is all around us, and can be harnessed in small quantities in clever and seamless ways if properly designed as an integral part of a product, interface, or local infrastructure. Bio energy has been an underutilized form of readily available energy, harnessed from natural biological processes. The body, an inherit part of any interactive experiences, offers one such source, through its heat or mechanics, while microorganisms offer another. For example, microbial fuel cells [Fig 8] are simple devices which generate electrical power by tapping into the metabolic processes of microbes. The conceptual project, Carnivorous Domestic Entertainment Robots



Fig. 8. Student made microbial fuel cells inoculated with 'sludge' from Gowanus Canal in Brooklyn, NY. When connected in series, they produced enough voltage to power an Arduino board

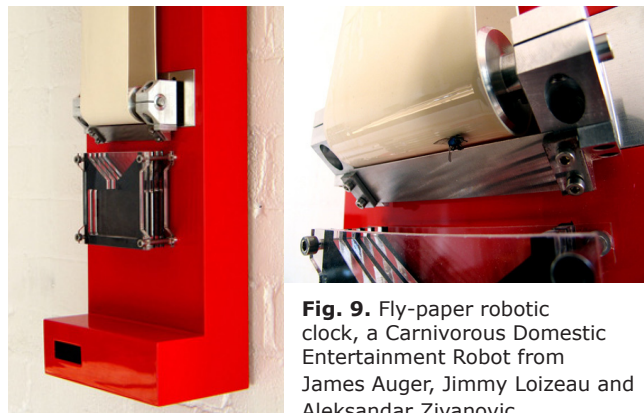


Fig. 9. Fly-paper robotic clock, a Carnivorous Domestic Entertainment Robot from James Auger, Jimmy Loizeau and Aleksandar Zivanovic

[13] [Fig.9] from Auger, Loizeau, and Zivanovic, postulates a future where devices within the home can power themselves through the breakdown of biological organisms in microbial fuel cells, and in turn, their functionality serves to capture the necessary organisms, thus creating a self-sustaining device. One example features a mechanism of flypaper on a roller used to entrap insects. As the flypaper passes over a blade, captured insects are scraped into a microbial fuel cell and electricity is generated to turn the rollers and power a small LCD clock.

Living materials and components

The creation of interactive experiences within more natural contexts requires a shift in the material constructs which we normally associate with electronics, circuitry, and computation. However, in order to leverage and utilize our existing knowledge around analog and digital systems in the creation of interactive experiences, a cohesive language of technical design must be maintained, incorporating new materials, potentially living materials, into this vocabulary.

Material properties such as magnetism, conductivity, capacitance, or resistance are essential in the creation of circuits, and may be sought out in the creation of biological organisms infused with a particular material property or functional behavior, by simultaneously augmenting an organism while taking advantage of its existing unique capabilities. One possible example lies in the production of a conductive slime mold. The organism *Physarum Polycephalum* (yellow slime mold). [Fig. 11] is a model organism for many studies involving cell motility. Despite being a single cellular organism, *Physarum* exhibit intelligent characteristics of maze solving, often creating efficient networks that mimic real-world transportation systems, such as a famous experiment of instinctively mapping the major



Fig 10. Experiments in magnetic organisms by Alex Dodge and Johnny Lu. Pumpkin seeds injected with a homemade aqueous ferrofluid solution

highways of the US when food is positioned at the sites of major cities [Fig.11]. This network finding capability has an analog in circuit production - that of laying out traces. When infused with a conductive material, the slime mold has the potential to naturally grow circuit traces, creating a conductive path. To test this potential, experiments are currently underway using an aqueous solution of organic Bare Conductive ink [Fig 11]. In a similar vein, Figure 10 shows experiments in creating a living magnetic plant, through the infusion of homemade aqueous ferrofluid into pumpkin seeds.



Fig.11. Above: slime mold traced major highways of the U.S. Right: experiments in conductive slime mold



Doug Fulop has developed a series of conceptual electronic components called the bioLogic series [Fig. 12]. Utilizing the familiar visual language and technical vocabulary of the datasheet, he presents (currently) fictional electronic components which incorporate a living element into the electronic functionality - for example, a time delay relay triggered by the growing of grass, with the intended purpose "to replace electromechanical switches in situations when a natural, biological time scale is more appropriate than a fixed electromechanical one." Another example is a small vial of algae serving as an optical sensor, graduated by the density of growth within the culture. We can imagine an entire library of electronic components each which a functionality infused with a biological element or process.

Expanding beyond hybrid electronic-biological components, biological organisms can be used directly

National

bioLogic Switches

May 3, 2011

BIO3680 Biological Time Delay Relay - Food & Energy Harvesting

BIO3680G
Biological Time Delay Relay - Food & Energy Harvesting
General Description

The DS3680 is a time delay relay designed to operate over a wide range of supply voltages, ambient temperature, and all lighting and H₂O sources. These switches are intended to replace electromechanical switches in situations when a natural, biological time scale is more appropriate than a fixed electromechanical one.

Since there may be considerable variability and environmental influences, biological switches should be used when the rest of the circuit is also dependant on related environmental or biological functions. A sample use case for this relay includes a circuit which would turn on after 1-2 weeks except when exposed to significant amounts of radiation or deprived of light.

Key advantages over electromechanical time delay relays include guaranteed inter-cycle variability, support for fuzzy

logic triggers, sustainable components and infinite repeatability.

The relay requires nutrients, H₂O and exposure to light. Shaved grass is created for consumption.

Features

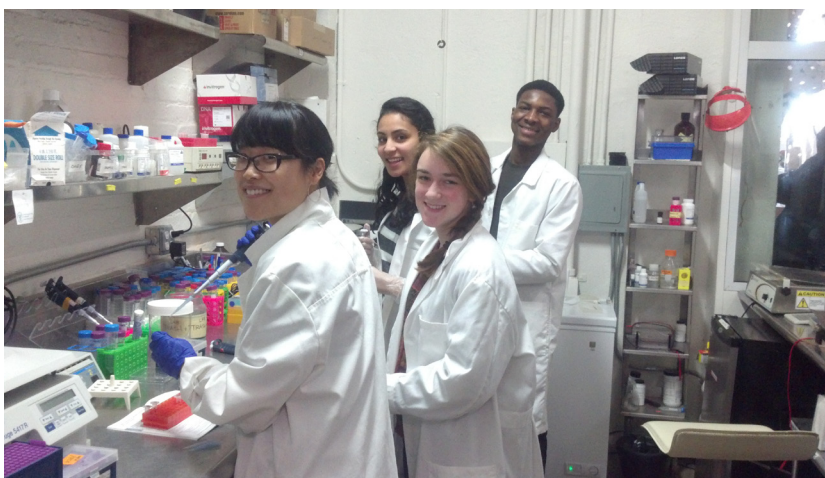
- Cross H₂O and light source compatibility
- Min time setting: variable depending on seed ~ 3 days
- Max time setting: variable depending on seed ~ 21 days
- High input voltage range. Very low input current
- Guaranteed variability
- Exposure to biological and environmental variables
- Sustainable design - infinite repeatability
- SPDT Contact Form
- Fail-safe disconnect feature

Connection Diagram

Standard Package



Fig. 14. & 15 The DIY Bio Movement in action: Above: projects from the Spring 2011 NYU ITP Wet Lab course, *Design Frontier in Biology and Materiality*. Below: participants in a Genspace course do hands-on learning of cutting edge new techniques and technologies of synthetic biology and personal genomics, in an environment of open IP and in FBI bio safety level 1 certificated facility.



one very important way - the DNA of the E.coli bacteria has been modified through the process of synthetic biology, a direct manipulation of its 'code' on a biological level.

From Biological Processes to Biological Code

Major changes in the tech sphere impacting how innovation, product development and consumerism work in the biotechnology industry. Two major changes are already afoot, namely, the introduction of DNA synthesis and the availability of in silico tools such as integrated development environments and Cloud-computing. We think that these technologies are going to accelerate and transform biotechnology, and open up channels for non-biologists to have access to systems in which manipulating DNA is as straight forward as editing computer code.

Manipulating DNA is the fundamental action required to make biotechnology. The high growth Synthetic Biology market is centered on a relatively new technology called DNA synthesis (DNA printing). While it is still currently more expensive than the classical DNA engineering techniques, it takes days rather than months to get DNA. Following the economics closely shows that it is only a matter of time before the cost becomes similar to that of classical DNA engineering methods.

Similar to Moore's Law, which describes the exponential price-performance of computer processors, the Carlson Curves describe the exponential increase in DNA synthesis productivity over the years, with concurrent exponential decline in cost [16]. Based on current predictions, the price of building DNA is getting cheaper, faster, and this is enabling people to build longer and longer DNA molecules.

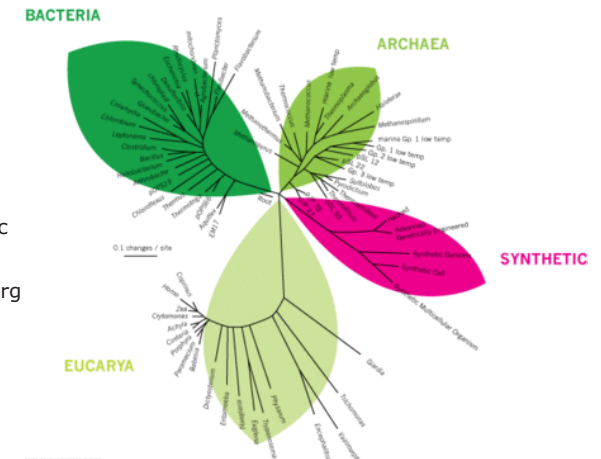
The DIY Bio Movement and Open Source Biology

Until recently, the vast majority of work, products and services offered in the biotechnology industry originated from walled gardens such as traditional academia (universities and technical institutes) or corporations. Only recently have we been witness to a grassroots movement called “DIY Bio” (do-it-yourself biology) where individuals have the ability to pursue biotechnology development using alternative means [Fig. 14 & 15]. Bio hacker spaces are opening across the world offering an environment for development free from the IP constraints of university or corporate labs. While the analogy to the open source hardware movements rings true, DIY bio spaces also need much stricter regulations for the safety and ethical considerations inherent in working with DNA. For example, Genspace, an early DIY bio space in Brooklyn NY, worked closely with the FBI while under development to receive Bio Safety Level 1 certification.

This is the very beginning of the democratization of biotechnology, and what has been seen before in computing (recall the original Apple computer and development of Linux), will likely occur again in biotech as we transition from a market powered by scarce and expensive tools to one of ubiquitous tools and open documentation. This market evolution will allow large numbers of people to get involved with very little barrier-to-entry.

With the experiences gained from the computer revolution of the early 80’s we should be prepared to see similar disruptions in biotech that create new markets and ecosystems that match or exceed the impact of the desktop publishing revolution. There are two factors driving the democratization of biotech; the first is the rapid decrease in the cost to synthesize DNA (DNA Printing), and the second is the increasing accessibility to tools and documentation (DNA programming).

Fig. 16.
The Synthetic
Kingdom by
Daisy Ginsberg



Synbiota

Synbiota [17] is a newly emerging web-based collaborative platform that enables biological developers and designers to create, share, and manage their biological projects. By bringing the tools, knowledge, networks and know-how to the masses, it enables crowd-sourcing, distributed-innovation, and collaboration in biotechnology R&D, Synbiota believes that solutions to many of the world’s greatest challenges in food, fuel, medicine and beyond will be solved, and that many new valuable markets and ecosystems will emerge as a result.

Ethical Issues and Implications

In her project the Synthetic Kingdom [15] [Fig.16] Daisy Ginsberg speculates a future where an extra branch has been added to the Tree of Life, creating a synthetic kingdom of organisms, full of synthetic biology curiosities- from a new strain of light-emitting bacteria that evolved from a hairball found in a patient’s stomach, to bioluminescent kidney stones in bioelectronics-factory workers. It is simultaneously utopic and dystopic, and subtly points out many of the deep contradictions within synthetic biology. For all the promise synthetic biology holds, it must be recognized that it holds an equally disturbing future potential. Within the biology community, and now as it emerges in other disciplines, practitioners and the public at large must remain in a wide-ranging debate about how best

to guide synthetic biology in a safe and socially useful direction [18].

As a technology, biology is a far more intimate part of everyone's everyday life than the mobile phone or even electricity. However, this ubiquity is also a source of concern for those who fear that as a species, it is a technology that we are not yet responsible enough to wield. There are many important questions that must be asked and answered before Synthetic Biology technology is fully accepted, and it is the work of the designer to responsibly explore and define what this technology is and how we will allow it to change us as a society and species.

Conclusion

Society is currently in the midst of a paradigm shift in our relationship to and understanding of biology. For interaction design, it is an area still in its nascency and we hope this paper opens up a discussion within the CHI community among emerging practices of integration of biological processes and technologies for our domain.

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