8 Biotextiles: Evolving Textile Design Practices for the Bioeconomy and the Emerging Organism Industry

Carole Collet

The Sustainable Textile Design Imperative

Historically, textiles have evolved around our ability to generate materials from our local natural environment. Linen and wool are prime examples, and our human history can be traced back more than 2000 years via the lens of local, hand-made cloth production. With the first industrial revolution (18th century), the steam engine and mass-manufacturing methods began the first great acceleration of our exploitation of natural sources at a global scale. This model preempted what is now described as the "take, make and dispose extractive industrial mode" (Ellen MacArthur Foundation, 2017) which results in dramatic environmental consequences. The textile industry today is an acute example of our endeavor to disrupt and destroy the very natural resources we depend upon to thrive as a species. A report published by the European Union in 2013 states: "Textiles is fourth in the ranking of product category which cause the greatest environmental impact, just after food & drinks, transport and housing" (European Commission, 2013, p. 1). With rampant consumption patterns putting even more pressure onto mass production, there is a strategic imperative to shift our ways of making, and to update our current manufacturing models. We know today that we are "rapidly eroding the resilience of Earth, having already undermined 60 percent of key ecosystem services in support of human wellbeing" (Rockström & Klum, 2015, p. 43).

In 2015, the United Nations launched its Sustainable Development Goals (SDG) to help target and address critical environmental challenges and to stimulate rapid and lasting actions. Centered upon people, planet, peace, prosperity, and partnership, 17 specific goals are defined to provide a framework for sustainable progress (United Nations [UN], 2015, p. 5). SDG 12 in particular endorses new targets for sustainable consumption and production and aims to achieve "the sustainable management and efficient use of natural resources" by 2030 (p. 26). In July 2017, a report assessing progress from nations against the SDG goals claims that "[g]lobally, the material footprint rose from 48.5 billion metric tons in 2000 to 69.3 billion metric tons in 2010" (UN, 2017, p. 9). This relates to the amount of global raw material extracted from the planet to meet global production and consumption demand. We are consuming our natural resources faster than they can regenerate. In terms of textiles and fashion, "clothing production has doubled from

2000 to 2014. The number of garments exceeded 100 billion by 2014" (Cobbing & Vicaire, 2016, p. 1). This pace of production and consumption is unprecedented and unsustainable. We need to start aligning our production models with new approaches that can sustain equilibrium with the natural world that we depend upon to survive.

But "while environmental degradation continues there are also unprecedented signs that we are beginning to embrace a "Great Transition" toward an ecologically sustainable future" (World Wide Fund for Nature, 2016, p. 6). Many textiles and fashion companies are actively working on improving the sustainability of their supply chains, or reviewing their energy and water efficiency to decrease their carbon footprint. However, as it stands today, this industry still largely relies on a linear model of production that does not integrate the cost to nature and the long-term consequences of extracting non-renewable materials, or generating lasting water, soil, and air pollution. Founded on a heavy use of fossil fuel, this industry is inherently unsustainable as it depends upon a finite, non-renewable resource. Oil is used not only for energy and raw material production, but also for the generation of chemical dyes, finishings, and coatings, and for the fabrication of synthetic fibers such as polyester. "Demand for polyester has grown strongly and steadily. In 1980, only 5.2 million tons of polyester were produced globally. By 2014, this reached 46.1 million tons" (The Ethical Fashion Source, 2016, p. 3). So how can the textile industry reinvent itself? How can it benefit from the emergence of a sustainable bioeconomy, and how can designers help reconnect textile fabrication processes with biological alternatives?

The next section will introduce the bioeconomy as an emerging textile design context, and will discuss how we can transition from a 20th century model of manufacturing that relies on chemical and energy intense processes towards a 21st century model that emulates biological and circular principles.

The Rise of the Bioeconomy and the Organism Industry as a Context for Textile Research

By default, designers are inscribed within economic models and are an integral part of production systems. Their design specifications pervade entire supply chains. Many professionally-active designers today are educated to design for a linear economic model based on non-renewable natural resources. For too many, sustainability is an option, a plug-in when and where possible. This is changing slowly, and in the UK creative design education is fast adopting learning strategies that embrace sustainable values. New economic models such as circular and bio-based industries are emerging, and with them a whole new range of design toolkits. The next generation of designers has begun to embrace a shifting context where the bioeconomy seems to be a fast evolving model for a post-petroleum society, and today, "more than forty countries have integrated bioeconomy in their policy strategies" (Global Bioeconomy Summit, 2015, p. 4).

The bioeconomy, in contrast with the petroleum-based economy, relies on the management and production of biological resources and combines agriculture and forestry together with innovative biotechnologies and genomic research. There are many variants and definitions of the bioeconomy; in this chapter, it will be referred to as "the knowledge-based production and utilization of biological resources, biological processes and principles to sustainably provide goods and services across all economic sectors" (Global Bioeconomy Summit, 2015, p. 1). In short, it is an economy founded on biomass and biofabrication principles rather than on fossil fuels. As such, the bioeconomy is not a truly new concept, but resonates with the origins of farming, brewing, and bio-processing, such as making wine or cheese. Yet recent advances in biosciences, in particular within the field of synthetic biology, have emulated a renewed perspective on the potential of the bioeconomy to address major sustainable challenges: "examples include using specialised microbes to transform wastes into bioenergy, or using plants as pharmaceutical 'factories' for reliable and rapid vaccine production" (Biotechnology and Biological Sciences Research Council, 2015).

From a material perspective, there is an increasing range of new textile biomaterials coming out of science labs and start-up companies that are based on bio-circular models. Waste has become a valuable resource to be upcycled into new materials thanks to the dynamic properties of biological agents. Examples include grape leather, a process that uses leftovers from winemaking to create vegetal leather ("Grape leather," 2017), orange fiber made with citrus and orange rinds left over from juice production ("Orange fiber, n.d.), or S.Café®, a yarn made from recycled coffee grounds ("S.Café", n.d.). Even "poo" has become a valuable commodity as demonstrated with Manure Couture, where Dutch designer Jalila Essaïdi proposes to extract the cellulose present in cow manure to create textiles (Tucker, 2016). In Finland, where the sustainable exploitation of forests is critical, there is a strong focus on developing innovative cellulose materials:

> The renewability, climate-friendliness and biodegradability of cellulose-based materials are not the only properties that make these materials attractive when compared to the finite materials that they are substituting for. The organic nature of biomaterials also involves unique properties and allows for previously unimaginable applications… Nanocellulose, carbon fibres from lignin and bio chemicals from hemicelluloses have a multitude of future applications ranging anywhere from bionic materials to superconductors, to growth substrate for synthetic biology. (Kääriäinen & Tervinen, 2017, pp. 31)

These new bio-based materials and textiles offer sustainable alternatives to oil-based fibers such as polyester, and help shape a more circular textile industry.

From a more hi-tech and biotech perspective, the bioeconomy has entered a truly new era with synthetic biology tools. We can now genetically create and engineer living "machines," from the bottom up, by creating designer microbes and yeast to produce bespoke materials. Synthetic biology has opened the door to a fast developing organism industry where the "market is expected to grow to $11.8 billion in 2018 with a compound annual growth rate of 34.4% over the five-year period from 2013 to 2018" (Bergin, 2014).

In terms of textiles, leading biotechnology companies are now partnering with designers and design brands to bring to market new materials produced by genetically engineered yeast. In July 2017 for instance, Bolt Threads, a US based biotech pioneer launched a partnership with Stella McCartney to create the first dress made from bio-fabricated silk. Their technology enables them to "engineer fibres from scratch based on proteins found in nature, and then develop cleaner, closed-loop processes for manufacturing, using green chemistry practices" (Stella McCartney & Bolt Threads, 2017). Meanwhile, Adidas unveiled the first shoe made from biosteel fiber (Adidas, 2016), and Modern Meadow (2017) launched Zoa in September 2017, "the first ever bio-fabricated leather material brand" under the direction of Suzanne Lee, Modern Meadow's fashion designer and creative director. These radical developments validate the need to recalibrate what and how we design when our manufacturing tools have become living cells. How do we design with a synthetic nature? And how can we ensure this hi-tech end of the bioeconomy can lead to better sustainable production systems? Most biotechnology companies refer to a sustainable narrative when commercializing their genetically programmable new materials. This in itself is a paradox, as historically speaking bioengineering has not been associated with concepts of sustainability. Bolt Threads (2017), for instance, states that "the main input in [their] fiber-making process is sugar from plants that are grown, harvested and replanted. Compare this to polyesters which are made from petroleum. [sic] Currently, more than 60% of textiles are made of polyester and other petroleum-derived fibers." Of course, finding new biosolutions that can replace polyester and help shift from our current dependence on non-renewable oil and toxic chemical processes can only be a positive step forward. However, a full life cycle analysis of these bio-manufacturing plants is not available yet. It is a very young, fast evolving industry. Even if it offers a promising sustainable future, we also need to remain mindful of the bigger picture. If the entire industry was to turn to bio-synthetic fiber production made from genetically-modified organisms feeding on sugar, what would that mean in terms of the global environmental impact of sugar production? As usual with sustainable challenges, we need to think about the overall equilibrium.

This new range of biotextiles is shaping a new manufacturing horizon for designers. As seen above, the bioeconomy entails working with natural bioprocesses, upcycling bio-waste into new materials as well as developing synthetic biological biofabrication models. Designers will need to understand these new fabrication processes to be able to design for a new kind of biological production line. According to the European Union, "recent and continuing progress in the life sciences now makes the Bioeconomy one of the most dynamic sectors of the European economy and it is also one of the largest employers" (European Plant Science Organisation, n.d., p. 5). Designers can contribute ideas and creative thinking to this new bio-based regenerative economy to help transition towards a more sustainable future. They have begun to adapt their design briefs and to develop new design protocols to operate within the context of the bioeconomy and the emerging organism industry. Today, designers engage directly with material creation. Not content to script and shape existing materials, they become alchemists, gardeners, or even cooks to transform their tacit understanding of the creative process into new materials.

The next section will showcase a range of examples that embrace this new breed of designers, and review how they operate in the context of the bioeconomy and the organism industry.

Designing for the Bioeconomy and the Organism Industry

How can we shift from designing for manufacture to designing for biofacture? How can design contribute towards and shape the sustainable potential of the bioeconomy and the organism industry?

> Before 2100, the bioeconomy will have to double its output of raw material while halving its environmental impact. This will require not just smart science and technology but due attention will have to be given to shaping societal behavior and adapting to changing economic realities. (European Plant Science Organisation, n.d., p. 8)

Figure 8.1. Lacebark produced by the Lagetta lagetto tree. Photograph: Carole Collet.

The design profession will need to transition to this new context, and the recent rise of biodesign, a discipline that intersects biology and design principles, highlights the beginning of an emerging and profound paradigm shift for design.

The integration of biology into material systems combines traditional and ancestral techniques together with cutting-edge radical new biotechnologies such as synthetic biology. This wide landscape of techniques allows biodesigners to interconnect tradition with innovation. In 2013, after curating *Alive: New Design Frontiers* (2013), the first international exhibition that examined biodesign via the lens of sustainability, I set up the Design & Living Systems Lab at Central Saint Martins, University of the Arts London to frame this very new landscape. By exploring the intersection of biological sciences and design, the D&LS Lab develops new biomaterial agencies and propositions for future sustainability that harvest techniques issued from botanical craft practices as much as from cutting-edge synthetic biology research. First and foremost, I am inspired by how nature works and behaves. So I ask: how does nature make a textile? How does nature make a pattern at ambient temperature, without impacting on its local ecosystems, but instead by nurturing life? What can I learn from observing nature? Figures 8.1 and 8.2 show a lacebark produced by the Lagetta lagetto tree in Jamaica and a textile-like bark produced by a coconut tree.

Figure 8.2. Textile-like bark produced by a coconut tree. Photograph: Carole Collet.

Figure 8.3. *Strawberry Noir*, part of the speculative *Biolace* series, Carole Collet, 2012.

Figure 8.4. *Basil ̊ 5*, part of the speculative *Biolace* series, Carole Collet, 2012.

Figure 8.5. *Lace Doily* hand-made lace with fresh strawberry roots, Carole Collet, 2012.

Both of these examples reveal that, in the natural world, there are sets of DNA code that can control the fabrication of materials to look and behave as a man-made woven cloth. These examples inspired the development of the *Biolace* project in 2012, where I used speculative design tools as well as traditional craft techniques to imagine the future potential of synthetic biology to grow ready-made constructed fabrics. The idea here is to imagine growing woven fabrics locally, as opposed to following the current conventional model, which involves many different stages of production from fiber to final product and relies upon different manufacturing stages spread across the globe. *Biolace* proposes to design multi-functional plants that can cater for the local food industry and the fashion supply chain at the same time (Figures 8.3 & 8.4).

Set in a future vertical urban farming context, these plants can generate locally both a food and a textile harvest. *Strawberry Noir* and *Basil ̊ 5* illustrate a future post-natural world, whilst *Lace Doily* is real, hand-laced with fresh strawberry roots (Figures 8.5 & 8.6). The *Biolace* project explores plant roots as a material system for textiles using both speculative and traditional craft tools.

If *Biolace* explores the imaginary of the organism industry and the future of synthetic biology with bio-craft techniques, artist Diana Scherer casts plant root networks at the seeding stage to create new textiles. Her work is located at the intersection of horticulture, design, and photography. By carefully selecting plants for their root characteristics and in collaboration with plant scientists, Scherer creates living woven root systems that can be harvested and then dried. In her project, *Interwoven—Exercises in Rootsystem Domestication,* Scherer grows root systems to form a final product such as a rug (Figure 8.7).

Figure 8.6. *Lace Doily* (details), Carole Collet, 2012.

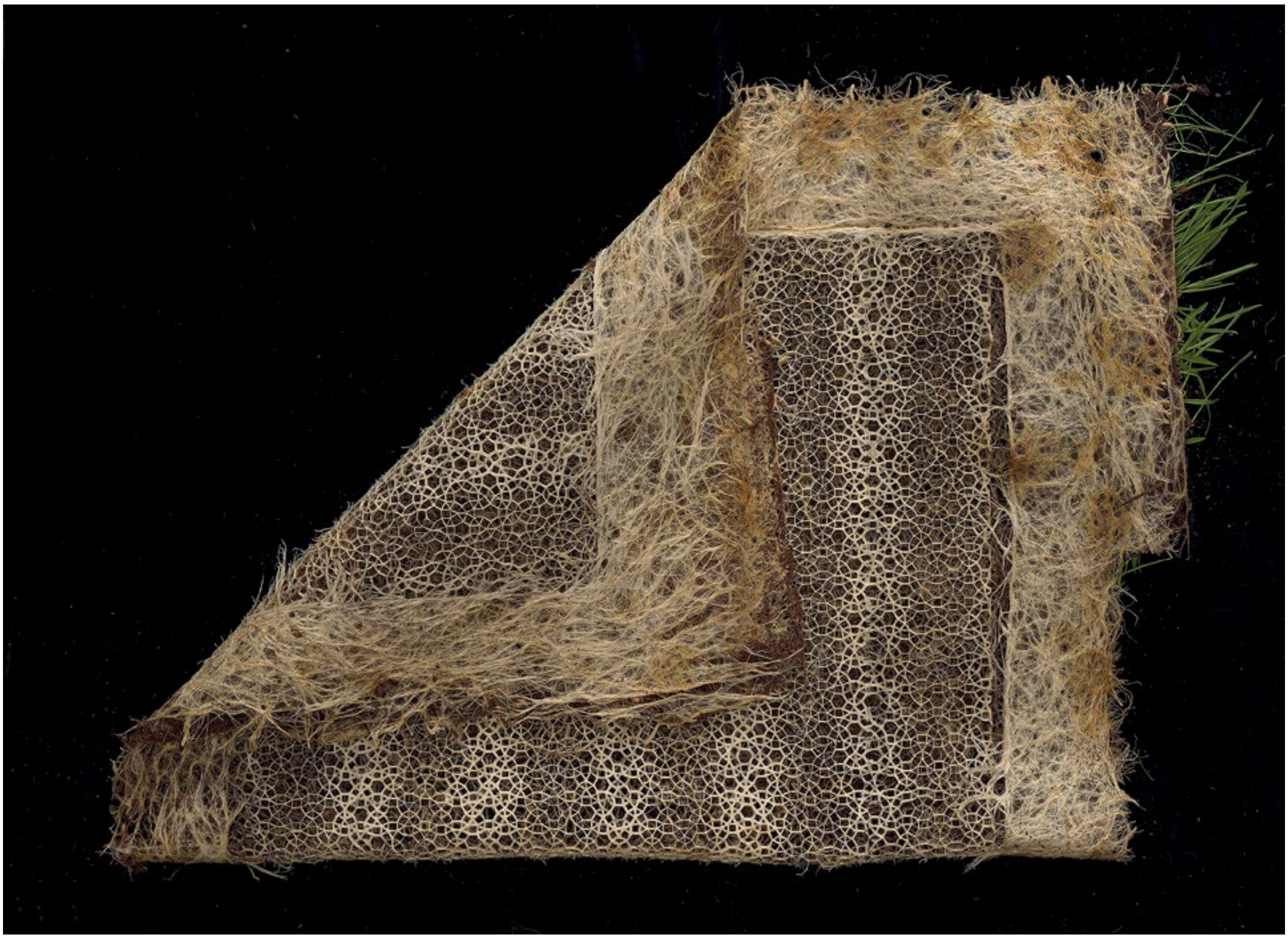

Figure 8.7. *Interwoven—Exercises in Rootsystem Domestication*, Diana Sherer, 2016.

Figure 8.8. *Harvest*, Diana Sherer, 2016.

Figure 8.9. *MarsBoot*, a collaboration between Liz Ciokajlo, Rhian Solomon, and Maurizio Montalti, 2017. Photograph: George Ellsworth.

Here, the artist has to nurture the plant growth, simultaneously guiding the shape of the final root network to control the final outcome. *Harvest* shows the challenge of fully controlling the directional growth of the roots to obtain a carefully composed root mat (Figure 8.8).

Both the *Biolace* and the *Interwoven* projects endorse a fundamental and explorative research approach to evolve new ways of making. But before all, these projects develop new design protocols that include working with living organisms to create new materials and products. The difference with conventional design involving inert or dead matter is striking. When collaborating with a living organism to create a product, a designer needs to understand the parameters of growth, such as heat, humidity, and light levels, to be able to master the fabrication process. Optimizing and altering these parameters will affect the inherent dynamic biological properties of a living system and influence the resulting materiality, as seen with Diana Scherer's work.

But when it comes to root systems, some of the most recent innovative projects are arising from working with mycelium, the root network of fungi. Mycelium absorbs nutrients from its surroundings and can rapidly change its growth patterns and other behaviors in response to its environment: it is agile, dynamic, and adaptive. It is known as a recycler organism and has the ability to disassemble large organic molecules into simpler forms. Inspired by visionaires such as Maurizio Montalti and Phil Ross, who pioneered this idea very early on, an increasing number of artists and designers are exploring mycelium to create new "grown" materials. The latest example is a collaboration between Maurizio Montalti (Officina Corpuscoli) and Liz Ciokajlo/Rhian Solomon (OurOwnsKIN) which resulted in the production of *Caskia / Growing a MarsBoot*, commissioned for the MOMA exhibition *Items: Is Fashion Modern?* in October 2017 (Figure 8.9).

The project addresses the restrictions characterising space travel and the need to optimize logistic needs, by minimising the quantity of required matter (fungal mycelium spores) loaded in the craft at launch and by later growing materials and tools during the journey towards Mars. In this scenario, astronaut's sweat is filtered and combined with fungal mycelium, partly feeding the fungal culture for the generation of grown materials, raising debate about how much of our own bodies can be utilized as a material source for producing fashion items in space and on Mars (OurOwnsKIN, 2017).

In this example, the brown leather-like material is a natural composite grown with mycelium and the *MarsBoot* becomes a symbolic icon to explore future conceptual possibilities for grown materials in the context of space travel.

Mycelium Textiles is another example of a research project that explores the potential of mycelium, but with a focus on creative biodegradable and sustainable coatings and materials for the textile industry. In this project, traditional finishing textile techniques are revisited to grow a range of mycelium textiles, using waste coffee as the main food source to feed mycelium as it grows. The careful nurturing of mycelium and the control of the dynamic properties of life allow for the development of composite materials, partly as a result of the design intent and partly as the manifestation of the mycelium life form. *Mycelium Lace* (Figure 8.10) shows how mycelium can be grown to mend and strengthen a cellulose-base lace cloth.

Mycelium rubber (Figures 8.11 & 8.12) is the first self-patterning mycelium material ever produced. The floral patterns on the surface of the mycelium rubber have grown without a mold; they are simply the result of a self-assembly and cellular self-organization behavior inherent to living systems.

Figure 8.10. *Mycelium Lace*, Design & Living Systems Lab, Carole Collet, 2015.

Figure 8.11. *Self-Patterning Mycelium Rubber*, Design & Living Systems Lab, Carole Collet, 2016.

Figure 8.12. Details of *Self-Patterning Mycelium Rubber*, Design & Living Systems Lab, Carole Collet, 2016.

The creation of this collection (work in progress) converges the growing stage of the material with the control of the final form. The final outcome will be a collection of fashion collars. They will be grown, as opposed to sewn together. In a conventional design and manufacturing context, a designer would specify the transformation process required to shape a product after a material has been grown (i.e., wood from a tree), extracted (i.e., a metal sheet), or produced via a petrochemical process (i.e., plastic). Here, the developmental morphogenesis of the mycelium material becomes the site for design intervention and the final form evolves out of the growing process. Figures 8.13 and 8.14 compare key conventional textile manufacturing steps with emergent "horticulturing" practices.

Mycelium Textiles offer new propositions to grow textile products as opposed to textile materials and proposes to bypass conventional steps by converging the shaping stage with the growing stage. This is currently very much an exploratory project, but the aim is to develop new protocols to grow bespoke textile products locally at ambient temperature.

As seen above, biodesign can rely on a range of design methodologies, from using the growth process of an organism to control the morphogenesis of the final output, to using speculative design tools or working in a biology lab to co-produce with living organisms.

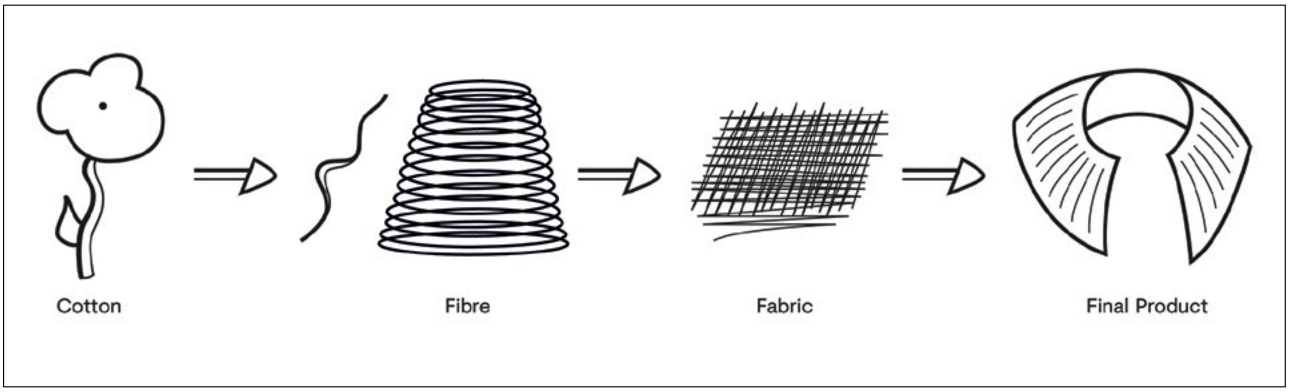

Figure 8.13. From cotton plant to final products; example of key manufacturing stages. Diagram: Carole Collet.

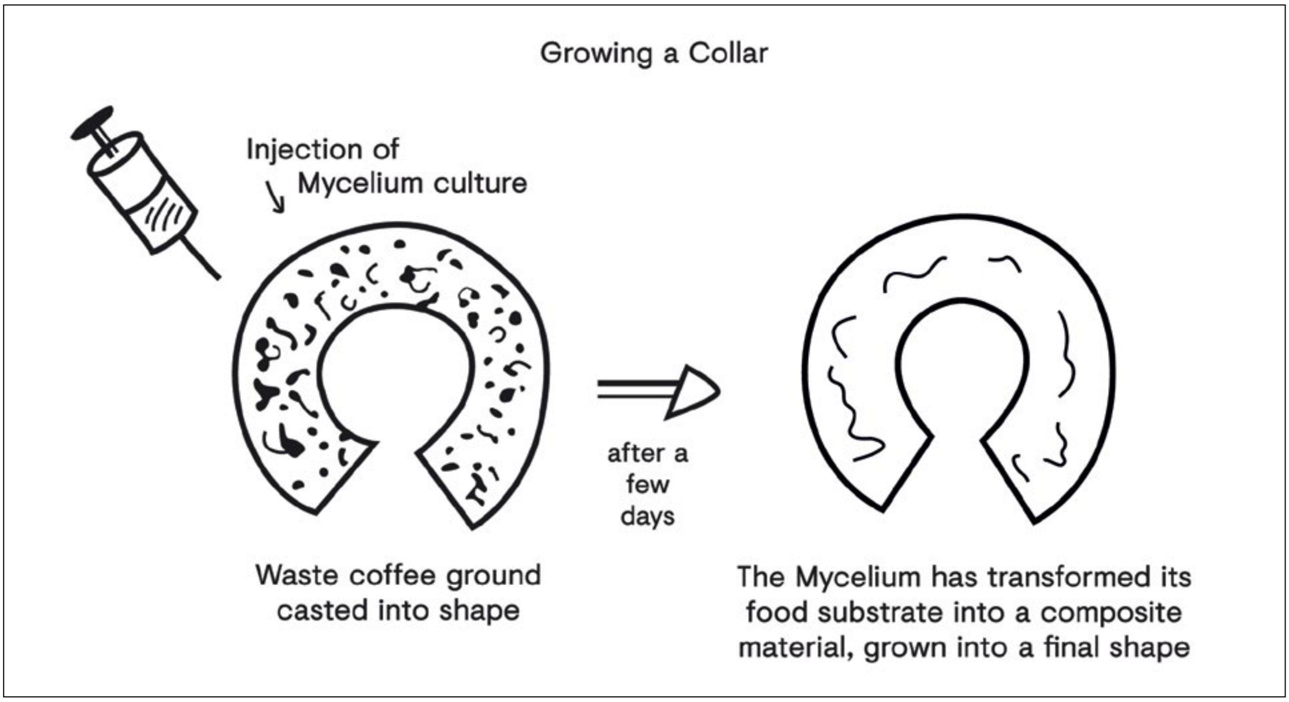

Figure 8.14. Using mycelium to grow local products such as a fashion collar, using waste substrate for food.

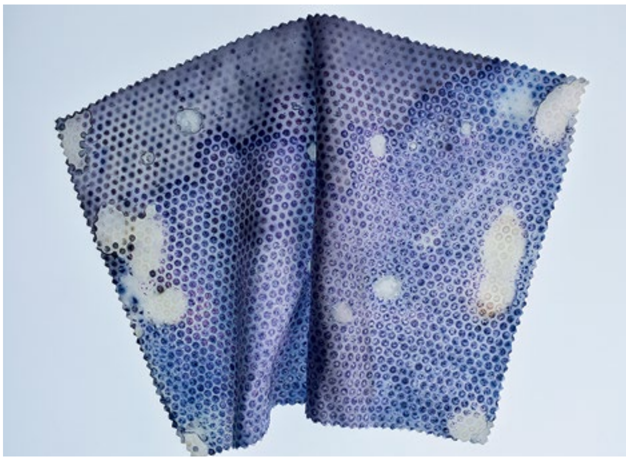

Figure 8.15. *Faber Futures* | *Void* (experimental sample), Natsai Audrey Chieza, 2017.

Figure 8.16. *Faber Futures* | *Void*, Natsai Audrey Chieza in collaboration with Ginkgo Bioworks, exhibited at Hubweek, Boston, 2017.

For designers, this also means that we can integrate traditional hand-made and man-made production modes together with what I call the "grow-made" fabrication process.

But when it comes to textiles, one of the most damaging environmental impacts relates to the use of large quantities of water and chemical dyes. Independent designer Natsai Chieza proposes an alternative dye technique that relies on a bacterial production line. She cultivates bacteria that can dye fabric as part of their growth process at ambient temperature, without requiring large quantities of water. This innovation can radically transform our conventional water-intensive toxic dyeing industry. Figures 8.15 and 8.16 show her latest fashion textile range, up-scaling petri dish sample tests to lengths of fabric that display the patterns resulting from the bacterial life forms.

Chieza selects bacteria that can naturally express color. She then orchestrates variations in color expression by simply altering the environment of growth via the growth media and temperature levels. By controlling how the fabric is folded when in contact with the bacteria, she can also generate patterning techniques that resonate with traditional resist-dye techniques. This is the most innovative use of natural bacteria for a chemical-free dye technique that could revolutionize the textile industry. Traditional natural dyes that rely on toxic heavy mordants to fix color into fibers are therefore not a viable solution for sustainable textiles. Synthetic dyes are born out of petrochemistry and generate persistent water pollutants. This new bacterial-based technique offers a transformative, innovative approach to sustainable textile dyeing and patterning.

All the projects cited in this section have relied on "design-science" collaboration. The intersection of scientific and creative expertise is increasingly proving to be a model for sustainable innovation. Chieza began by working at a small scale in collaboration with Professor John Ward at University College London (UCL). Her recent collaboration with Ginkgo Bioworks in Boston has allowed her to challenge the scientific process further and to create hybrid biodesign protocols that incorporate biological research together with creative thinking and an understanding of the needs of the textile industry.

Another pertinent example is a current Ph.D. project at Chelsea College of Arts, University of the Arts London by designer Miriam Ribul that has developed experiments in dissolution and regeneration of cellulose. During a series of design research residencies at the RISE Research Institutes of Sweden with Dr. Hanna de la Motte, she has developed design-led models to shape regenerated cellulose. Her work shows how material development in the science laboratory can become inherent to the design process. An innovative technique that enables regenerated cellulose to be directly shaped into a 3D form, with variations in both the tactile and visual aspect of the base material, has resulted in the first samples shown in Figure 8.17.

The potential for regenerated cellulose to be used in the form of pigment to produce a print effect has also been tested (Figure 8.18). In this test sample, both the base fabric and the print paste are made of regenerated cellulose, thus creating a patterned mono-material that can be upcycled easily. Here we see the very early stage of the design development in the context of the bioeconomy. Working with these emergent bio-materials directly in the science laboratory offer new possibilities for designers, and crucially allows them to get involved into the material development stage to influence and develop new textile applications.

Figure 8.17. Regenerated cellulose 3D tests, Miriam Ribul, 2016.

Figure 8.18. Regenerated cellulose print test, Miriam Ribul, 2016.

This section has shown a range of approaches to design in the context of the bioeconomy. From speculative work that explores the emergent and future potential of synthetic biology, to creating biomaterials in collaboration with living organisms such as plants and mycelium or co-opting bacteria to create colored patterns without chemicals, these textile proposals offer new possibilities to design for a fossil-free manufacturing system. Balsamo (2011) writes that "designers work the scene of technological emergence: they hack the present to create the conditions of the future" (p. 6). A fast growing generation of designers is embracing old biological principles as much as new bioengineering protocols to reimagine materials and products of the future and to explore technological emergence to develop alternative sustainable design scenarios. They set the boundaries for a transition from global manufacturing to local horticulturing and open the door to a new kind of design practice.

Conclusion

As a growing number of initiatives take a stance to protect the environment, the bioeconomy is fast emerging as a transitional model away from the current linear petrochemical economy. Converging traditional exploitation of biological resources together with cutting-edge synthetic biology research and the design of living factories, the bioeconomy invites designers to recalibrate their practice. Biotextiles can offer alternative material choices and designers have begun to get involved directly in the material development phase to influence future sustainable textile propositions. However, we need to remain critical of the promises of the bioeconomy. It will deliver its environmental benefits only if it respects the circularity of our ecosystems, and it must incorporate inherent sustainable practices. But even if we succeed in shifting from conventional linear manufacturing systems to more sustainable circular bio-based production models, we are still at risk of endorsing further our current overconsumption mindset. The bioeconomy can only succeed if we alter our consumption behaviors, and fundamentally rethink the notion of progress to create a new bio-modernity that is inclusive, interconnected, and mindful.

References

Adidas. (2016, November 17). Adidas unveils futurecraft biofabric – World's first performance shoe made from Biosteel® fiber. Retrieved from http://news.adidas.com/us/latest-news/adidas-unveils-world-s-first-performance-shoe--made-from-biosteel--fiber/s/88ed218c-68a0-43ba-9ce2-4e87bce30652

Alive: New design frontiers. (2013). Retrieved from http://thisisalive.com/

Balsamo, A. (2011). *Designing culture: The technological imagination at work*. Durham & London: Duke University Press.

Bergin, J. (2014). *Synthetic biology: Global markets*. Wellesley, MA: BCC Research. Retrieved from https://www.bccresearch.com/market-research/biotechnology/synthetic-biology-markets-report-bio066d.html

Biotechnology and Biological Sciences Research Council. (2015, July 21). The bioeconomy – Transforming challenges into opportunity. Retrieved from http://www.bbsrc.ac.uk/news/industrial-biotechnology/2015/150721-n-what-is-the-bioeconomy/

Bolt Threads. (2017). [Technology to replicate spiders produce silk fibers process] Retrieved from https://boltthreads.com/technology/

Cobbing, M., & Vicaire, Y. (2016). *Timeout for fast fashion*. Hamburg, Germany: Greenpeace. Retrieved from http://www.greenpeace.org/international/Global/international/briefings/toxics/2016/Fact-Sheet-Timeout-for-fast-fashion.pdf

Ellen MacArthur Foundation. (2017). What is the circular economy? Retrieved from https://www.ellenmacarthurfoundation.org/circular-economy

European Commission. (2013, August). Sustainability of textiles. *Retail Forum for Sustainability Issue Paper N° 11.* Retrieved from ec.europa.eu/environment/industry/retail/pdf/issue_paper_textiles.pdf

European Plant Science Organisation. (n.d.) *The European bioeconomy in 2030: Delivering sustainable growth by addressing the grand societal challenges*. Retrieved from http://www.epsoweb.org/file/560

Global Bioeconomy Summit. (2015, November 26). *Making bioeconomy work for sustainable development*. Retrieved from http://gbs2015.com/fileadmin/gbs2015/Downloads/Communique_final.pdf

Grape leather: Using leftovers from winemaking to create fully vegetal leather. (2017). Retrieved from https://globalchangeaward.com/winners/grape-leather/

Kääriäinen, P., & Tervinen, L. (Eds). (2017). *Lost in the wood(s)—The new biomateriality in Finland*. Helsinki: Aalto University.

Modern Meadow. (2017). Introducing Zoa™ bioleather materials. Retrieved from http://zoa.is/

Orange fiber. (n.d.). Retrieved from http://orangefiber.it/en/

OurOwnsKIN (2017). Mars Boot Museum of Modern Art, New York, commission. Retrieved from http://ourownskin.co.uk/portfolio/mars-boot-moma-commission/

Rockström, J., & Klum, M. (2015). *Big world, small planet: Advance within planetary boundaries*. Stockholm: Max Ström.

S.Café: Sustainable performance. (n.d.). Retrieved from http://www.scafefabrics.com/en-global/home/index

Stella McCartney & Bolt Threads. (2017, July 20). *Stella McCartney and Bolt Threads announce a new partnership focused on sustainable fashion and luxury materials development.* Retrieved from https://cdn3.yoox.biz/cloud/stellawp/uploads/2017/09/Stella-McCartney-and-Bolt-Press-Release-FINAL-071817.pdf

The Ethical Fashion Source. (2016). *Future fibres sourcing report: An exploration of more sustainable and innovative fibres and yarns.* Retrieved from http://source.ethicalfashionforum.com/assets-uploaded/documents/Fibre_Futures_Report_-_Nov_16.pdf

Tucker, E. (2016, July 24). Jalila Essaïdi makes textiles from cow dung "to solve manure problem." Retrieved from https://www.dezeen.com/2016/07/24/mestic-haute-couture-from-manure-jalila-essaidi-poo-fashion-garments-bio-fabric-movie/

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development.* Retrieved from https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

United Nations. (2017). *The sustainable development goals report 2017*. Retrieved from https://unstats.un.org/sdgs/files/report/2017/TheSustainableDevelopmentGoalsReport2017.pdf

World Wide Fund for Nature. (2016). *Living planet report 2016: Risk and resilience in a new era*. Retrieved from http://awsassets.panda.org/downloads/lpr_living_planet_report_2016.pdf