MA THESIS ARTS AND CULTURE: DESIGN AND DECORATIVE ART STUDIES

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Date: January 2016

Type of Paper: Master Thesis

Word Count: 16,851 (excluding footnotes)

Programme: MA Arts and Culture, 2015-2016

Course: MA Arts and Culture, 2015 -2016

Course Code: 5794VMATH

Specialisation: Design and Decorative Art Studies

EC: 20 EC

Tutor and First Reader: Dr. Marjan H. Groot

Second Reader: Prof. dr. ing. Robert Zwijnenberg

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The Sustainable Fashion Paradox Solved? How Bio-design can answer the environmental and sustainability issues of the 21st century fashion industry

'Man has lost the capacity to foresee and forestall.
He will end by destroying the Earth.'[1] *Albert Schweitzer*

'We overlook only too often the fact that a living being may be regarded as raw material…something that may be shaped or altered.' *H.G. Wells*, '*The Limits of Individual Plasticity' (1895)*

1 Carson (1962) p.vi; Carson dedicated her revolutionary book on environmental damage to Albert Schweitzer and uses this quotation as her opening.

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Abstract:

Studies have shown that the emergence of environmental activism and awareness came largely with Rachel Carson's Silent Spring, *first published in 1962. However, fashion has been late to follow this trend with some estimates unbelievably placing the emergence of sustainably aware fashion as recently as 2010. As such, the fashion industry is still responsible for a large proportion of global pollution at almost every stage of garment existence, from production through to disposal. Petrochemicals, toxic chemical dyes and energy intensive recycling are just the start.*

Current efforts of the fashion industry to become sustainable aim only to make the system 'less bad' with initiatives focusing often on one aspect of the process, for example with fair trade, rather than looking at the whole. What may be obtained fairly will most likely meet the same end as that which was obtained 'unfairly' be that in landfill or perhaps sent abroad for alternative use. I will argue that this is the reason for a total overhaul of the current fashion industry processes.

This thesis aims to illustrate that bio-design is the only viable option to replace this unsustainable fashion system. The use of living materials in bio-design allows for a cyclical design process in which nothing is taken from nature that cannot be given back. The Tissue Culture & Art Project and Suzanne Lee use bio-design in the production of new materials, whilst Natsai Audrey Chieza and Blond & Bieber create bio-designed garment dyes. Bio-design includes a wide array of processes including biomimicry and synthetic biology and so these cases have been chosen to show as many facets of this as possible in order to demonstrate the huge potential of the field for creating sustainable fashion.

Key Words: bio-design, fashion, sustainability, life sciences

Introduction

Studies associated with the fashion industry are not a recent phenomenon, nor are those associated with environmentalism and the call for global sustainability.[2] However, 'sustainable fashion' as a seeming paradox, is a very recent occurrence in comparison, with one author suggesting its emergence was as recent as 2010.[3] Sustainability is about an intergenerational selflessness justified by a need to help future generations to live long and happy lives. Fashion, by definition, is not something that encourages selflessness, rather it is an industry founded upon the need for consumers to appear more 'fashionable' than others in competing social groups and to consume indiscriminately in order to achieve this. However, the in-built need for fashion to innovate and renew may lend the industry well to a much-needed change in processes and materials.

The fashion garment life span is, at present, somewhat linear and encompasses far more than the average consumer probably comprehends. Fabrics are grown or created, dyed, transported globally, purchased by consumers, and then disposed of. Each of these stages of the fashion garment life span causes much pollution and so has become no longer economically, socially, or most importantly, environmentally sustainable. The problems are so deep rooted that even if synthetic fabrics are replaced with natural fibres, for example, there are still problems associated with dyeing, transportation, and disposal to contend with. Environmental design proponents William McDonough and Michael Braungart have argued that design needs to change from its linear mind-set of creation to disposal, to something more cyclical, meaning every stage of the product's life has been considered in relation to the previous and subsequent stages so that no resources are wasted and the life *span* becomes a life *cycle*.[4]

Many fashion brands joined the sustainable fashion 'brigade' in recent years, most notably in the 21st century, in order to show their support for the planet and appease outraged consumers, including *Nike*, *Gap* and *H&M*, who have caused sweat shop scandals in the very recent past. Even established, older generation designers such as *Yves Saint Laurent* have joined the trend. These gestures include using fair trade materials, non-sweated garments, water-reduced productions, and recycled materials. However, it must be noted that at present, sustainability comes in varying degrees and applies only to certain sections of the garment life span with existing brands. While it is obviously a good thing that existing brands are aiming to clean up their garments, by only changing certain aspects of the garment's life, the life as a whole is still inherently bad. Additionally, it will be

2 Fashion industry interest can arguably be dated back to the mid-18th Century and the emergence of fashion pamphlets; environmentalism is more recent, dating back to the 1960s; see Carson (1962).

3 Seymour (2010) p.7; Black (2012) p.8 on the paradoxes of fashion.

4 McDonough and Braungart (2002) on cradle-to-cradle design.

seen in more detail that some sustainable solutions are not as sustainable as they may first seem. The only way in which the fashion industry may become fully sustainable is if there is a total system overhaul.

Bio-design embodies an emerging design movement which incorporates the use of living materials, or 'moist media,' such as fungi, algae, yeast, bacteria and tissue engineering, in order to enhance the function of the finished product and create a sustainable product.[5] In order to demonstrate that bio-design is the most viable option to clean up the fashion industry, I will present four case studies that address various aspects of bio-design, such as biomimicry and synthetic biology, as well as two different phases of the current industry that could set up a whole different garment life cycle, namely biological materials production, and biological dyeing. The first bio-design project I will present is actually considered to be 'bio-art' but uses properties of bio-design, that is, the use of living materials in its production whilst also demonstrating a biological materials design solution. The first case study is the Tissue Culture and Art Project's *Victimless Leather* grown from live tissue cultures that are shaped into a miniature leather jacket, and chosen as it employs use of synthetic biology in the form of tissue engineering in order to highlight problems associated with our perceptions of the clothes we wear. The bio-art/design hybrid demonstrates the ethical problems associated with some biotechnologies as well as shows how copying natural processes can result in a harmless, sustainable product. Whilst one way of conceiving of this project is to see an entirely new way of creating eco-fabrics, it is also a great example from which to start asking questions about the ethics associated with garment production. For example, is it acceptable to 'kill' micro-organisms to create bio-textiles?

The first 'bio-designer' I will consider comes with the second case study of Suzanne Lee and her *BioCouture* project. Lee is probably the most stand-out pioneer for bio-design in fashion textiles, being the first to write about it in her 2005 book *Fashioning the Future* and later creating the *Bio-Couture* initiative to help other designers and existing brands to improve their sustainability credentials. I have included Lee as one of my case studies because her work is almost entirely unavoidable when researching bio-design in fashion. Lee's leather-like eco-material made from bacterial cellulose created by fermenting tea in water seems to bring a real start to the academic discourse on bio-fashion. Lee's bio-textile is created using natural processes of fermentation, rather than synthetic biology and so has been placed in the materials revolution next to *Victimless Leather* in order to show the variety of materials production methods that bio-design can offer, even at these early stages of its development. By changing the traditional materials used in fashion, a whole new life-cycle can be set in motion, with issues of disposal and chemical waste completely eliminated.

5 Myers (2012) p.8.

Aside from fabric production, I have chosen two bio-design projects that address another area of the fashion industry that creates a huge amount of chemical and material waste: fabric dyeing. Alongside bio-material creation, it is fitting to create bio-dyeing in order to fully close off the bio-designed cycle from current fashions for toxic chemicals. Excess dye used to colour fashion garments currently seeps into local water systems, killing entire eco-systems in the process, and in addition to this, many tonnes of fabric are discarded every year because it is dyed the wrong colour. Therefore, the third case study comes with Natsai Audrey Chieza who has created the synthetic biology project *Faber Futures* to explore growing pigment-producing bacteria onto fabrics to 'dye' them. Alongside Chieza I have placed the fourth case study, Blond and Bieber's *Algaemy*, which also explores the use of living materials for dye. However, rather than using synthetic biology, Blond and Bieber use naturally occurring algae colour pigments which are photosensitive and so create 'living colours.' The design duo combines traditional methods of printing, demonstrating how some aspects of the old fashion system can be compatible with the new, with the futurist notion of bio-design in their aptly named *Algaemy* project.

These four case studies will demonstrate how bio- design can make a huge difference to thinking about sustainable garment creation when biology and fashion come together. Harmless bacteria and tissue cultures which already naturally exist in great abundance can be used to replace the chemical and, most importantly, the superficial.

This thesis therefore intends to outline that the fashion industry's current efforts to become 'environmentally friendly' and sustainable are meagre at best and that there is a global need to be awakened to the true meaning of sustainable, cyclical design. This will be shown by an exploration first into the origins and meanings of what it is to be truly sustainable and environmentally aware, followed by an analysis of how the fashion industry has tried and largely failed to become integrated with these ideas. Following on from this, I will introduce bio-design and how its design principles are highly desirable and could effectively solve the sustainability problems of the fashion industry. Four case studies have been carefully chosen from the bio-design field in order to demonstrate how it is that the principles of bio-design can bring about an environmentally aware garment with a life cycle that brings no harm to either the wearer or nature. Simply switching from standard cotton to organic cotton or employing more women in factories in post-war torn countries, is no longer a big enough gesture for the fashion industry towards more sustainable standards. Bio-design creates options for long term solutions in line with the notion of an intergenerational selflessness that is characteristic of truly sustainable behaviour and I will conclude having demonstrated this.

CHAPTER 1: FASHION AND ENVIRONMENTALISM

Environmentalism

If the history of the Earth was reduced down to one year, humans would only have existed for 23 minutes, but would have consumed a third of the global natural resources in the last 0.2 seconds.[6] The alarming pace at which natural resources are used up will only quicken, unless true environmentalist tactics are globally propounded and acted upon. It was only 50 years ago that our planet consisted of three billion people, but this number has sharply risen to a figure today of just over seven billion.[7] It could quite logically be predicted that in another 50 years the global population could have reached an astounding figure of 15 billion. As the global population increases, so does demand for natural resources. At the current rate of resource consumption, there will almost certainly not be enough resources for everyone. In fact, the current system of waste pollution is so unsustainable that if current rates of resource consumption and waste generation continue, the human race will need another planet by the year 2030.[8]

Sustainability, therefore, is about an intergenerational selflessness that allows us to live in harmony with our environment, rather than destroying it for current needs so that there will still be resources (as well as a planet) for the humans of the future. A truly sustainable system is one in which more is not taken from the environment than is given back in a cycle of resource consumption and expulsion. The pressing need for environmental awareness and sustainable practices is a fairly recent phenomenon, with the advent of such ideas coming with the publication of Rachel Carson's *Silent Spring* in 1962. Carson's book is widely credited with beginning the modern era of environmental concern as it warned about the dangers of poisoning the earth with pesticides and finishing chemicals.[9] With Chapter headings such as 'Rivers of Death,' the bleak truth behind human polluting activities was uncovered.[10] Much of the blame for the depletion of natural resources comes from the mid-18th Century Industrial Revolution activities, in which mass production was born, with Karl Marx then aptly declaring that capitalism had sown 'the seeds of its own destruction.'[11] In the desire to make a fast profit, industrial activities made a long-lasting impact on the environment.

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6 Scarcity/Waste Exhibition (2015).

7 World Population Counter.

8 Scarcity/Waste (2015) Exhibition Pamphlet.

9 De Steigner (1997) p.xi.

10 Carson (1962) Chapter 9.

11 Marx (1850), quoted in De Steigner (1997) p.6; see also Rocamora and Smelik (2016) Chapter 2.

Carson, therefore, successfully elevated the environment from relative obscurity to a major public concern and within a decade, the first ever 'Earth Week' was celebrated (April 1970), which included activities of environmental clean-up and mass demonstrations.[12] However, as will be seen environmentalism does not have an entirely global reach just yet.

The Fashion Industry

The global fashion industry is truly far-reaching in its enterprises, and there are few people who are not touched by it in some way. First and foremost, the fashion industry is the world's fifth largest business sector, with at least half a billion people alone employed by it, while many more participate in fashion's consumption and almost everyone feels its global effects, be they environmental or otherwise.[13] Fashion is, therefore, a unique concept as it touches all people in all aspects of life, even across history. Everyone wears some kind of garment and as such, fashion reflects cultural values and sometimes even marks of current affairs.

It must be noted that there is a difference between the term 'fashion' and clothing, which is intended as nothing more than protection from the elements and to cover the body for modesty. Fashion is more of a distinguishing attribute, in which a person can be specifically seen to be following a 'trend,' and can therefore be designated to a particular social status or grouping.[14] Fashion thus paradoxically confirms individuality but also membership of a particular group of people. It is because of this desire to create an image or identity that is continually unique from its competitors and imitators that fashion is actually a series of inventions and innovations that play out in a series of constant updates with twice yearly shows of the new 'must-haves' from respected designers and seasonal collections in high street stores. In this vein, Immanuel Kant amusingly declared that 'Fashion belongs under the title of vanity, because in its intention there is no inner value.'[15] Though, it must be remembered that fashion embodies experimentation and readily embraces new materials and technologies in order to be at the forefront of design, and so in theory, it also has far more to offer.

Fashion is also a unique concept in that it is additionally paradoxically based on both newness and obsolescence. The recent phenomenon of 'fast fashion,' whereby clothing is rapidly mass-produced very cheaply in order to make a fast turnover of both products and profits, has brought this idea to a head. Fashion garments are currently bought in vast quantities because of their

12 De Steigner (1997) p.104.

13 Brown (2010) p.7; Black (2012) p.9.

14 Barnard (2002) p.13.

15 Smith and Kubler (2013) p.8.

enticing low prices, and because these items are so cheap, they are worn very few times before they are disposed of or replaced. This is illustrated by the fact that in the UK, between 2005 and 2008, the price of clothing dropped by about 25 percent, whilst the quantity bought rose by around 40 percent. Perhaps even more alarming is that it is estimated that 21 percent of these garments were never even worn.[16] Shoppers are thus now bound by an endless consumption cycle because they feel no financial investment or valued attachment to the garment. 'Fast fashion' has no doubt been exacerbated by the inherent social media and celebrity culture that seems to have exploded in the 21st Century with increased use of the internet. People from all areas of society are continually on display and under scrutiny to appear in a certain way. The fashion industry has exploited these insecurities along with cheap labour and raw materials in order to both fuel and fulfil these desires. However, it will be seen that this behaviour comes at a very high price for the environment.

Sustainable Fashion

Carson's 1962 *Silent Spring* warns about how dyes and pesticides connected with the fashion industry cause environmental damage, ironically declaring it 'the current vogue for poisons.'[17] However, the fashion industry has been slow to pick up on the vogue for responsibility for the environment, being one of the last industries to join the action. Although the first 'Green Designer' exhibition was held in London in 1986, and *Esprit* led the way for the high-street in 1991 with their 'Ecollection' of sustainable clothing, recent estimates put the wider emergence of sustainably aware fashion at around 2006.[18] Meanwhile, Sass Brown's 2010 book *Eco Fashion* claimed to be the first to fully consider sustainable fashion.

Currently, the unsustainability of fashion is multifaceted, with each stage of the product life cycle, including material production, dyeing, cutting and assembling, transporting, sales, laundering and disposal, all contributing to environmental damage in some way. Most companies seem to focus on just one aspect of this process, such as ethical trading, while others focus on using less harmful dyes, forgoing the need for sustainable practices elsewhere. In this way, consumers, unable to comprehend the complexity of the situation, buy garments that address only one facet of the entire problem within sustainably made clothing, and likely perceive that they have no further responsibility beyond that initial purchase.[19] With these varying degrees of seemingly ecological

16 All statistics here: Claudio (2007) p.A450; Mendes and De la Haye (2010) p.290.

17 Carson (1962) p.297.

18 English (2013) p.183.

19 Palomo-Lovinski and Hahn (2014) p.96.

behaviour it becomes increasingly understandable why there is no real standardised definition of sustainability within the fashion industry.

With the new-found trend of 'throw-away' fashion, budget retailers have facilitated the ability to buy clothes so cheaply that there is no apparent guilt in disposing of it after only one wear. Previously, families would have kept clothing for a number of generations, especially for use between children, in order to save money. This is a process now largely rendered unnecessary. Approximately 500,000 tonnes, or one billion items of clothing go to landfill in Britain alone every year, with this translating into roughly 114,000 items of clothing thrown away every hour, highlighting the extent of this unsustainable consumerist behaviour.[20] In the UK, in 2011, 34 percent of unwanted clothing was sent overseas, 31 percent was sent to landfill, 28 percent was equally re-used or recycled, and the rest was incinerated.[21] While most of these solutions seem as though they solve the problem of unwanted clothes, they all, in fact, pose problems of varying degrees to the environment.

The average piece of polyester clothing contains a toxic chemical, antimony, which is used as a catalyst in the polymerisation process that creates polyester but is not actually necessary for polyester production.[22] Antimony causes cancer when heated and released into the air supply, as with the incineration process. Additionally, PVC (Polyvinyl Chloride), commonly found as a cheap alternative to leather in many fashion outlets, when heated, gives off hydrochloric acid, which contributes to creation of acid rain when released into the air.[23] In addition to this, solid wastes from fabric cuttings equates to 15-20 percent of pre-consumer garment wastage, being sent straight to landfill or incinerators.[24] This means that there is essentially a hidden statistic for incineration and landfill as these fashion offcuts are not included in figures for garments disposed of in the same way.

At 34 percent, sending unwanted clothing overseas was the most common response in the UK in dealing with the fallout of 'fast fashion.' The *Marks and Spencer* 'Shwapping' initiative, begun in 2007, for example, collects items of clothing from customers to send to developing countries, with four million items of clothing collected in 2014 alone.[25] Consumers in more developed countries donate their unwanted clothes to countries in 'need' in order to generate a 'feel-good factor.' However, a common practice in developing countries is to burn rubbish, clothing included, as fuel for

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20 M&S 'Shwapping' Webpage.

21 DEFRA Report (2015).

22 McDonough and Braungart (2002) p.37; for information on polyester and antimony.

23 McDonough and Braungart (2002) p.40.

24 Brown (2010) p.154;English (2013) p.186.

25 *M&S* 'Shwapping' Webpage; some of the clothing is also resold by Oxfam or recycled.

cooking. Burning fabrics like polyester and PVC is therefore contributing to debilitating illnesses in these countries.[26] In addition to this, the huge influx of clothing from the West has damaging consequences for local clothing production, and therefore employment, which has almost disappeared in some areas. Furthermore, vast quantities of synthetic 'throwaway' fashion garments are ending up in make-shift landfills in these developing countries, where greater problems arise because water systems are disrupted around the waste that does not break down, creating deadly malaria in the pools of stagnant water.[27]

Re-using old garments helps to reduce the quantities of clothing being sent to landfill, but essentially, there are only so many times that garments can be refashioned before they must meet their inevitable end in the landfill site. No matter how many times you re-use polyester, it will still take 200 years to break down in landfill. Jessica Ogden uses second hand fabrics, Miguel Androver collects recycled items, and Rebecca Earley re-fashions second hand blouses, all in the name of 'sustainable fashion.'[28] These projects illustrate the notion of using 'less bad' solutions, whereby the greater problem of design is largely ignored in favour of using a temporary fix that can be dealt with later, preferably by someone else.

Recycling seems to be the current 'environmental saviour,' with the majority of Western society having easy access to household recycling facilities. However, recycling is not as environmentally friendly as is often assumed. There are two kinds of fabric recycling methods used at present: 'mechanical fibre recycling' and 'chemical fibre recycling.'[29] The former creates new fibres of a lower quality, meaning synthetic or virgin fibres need to be mixed in to make the fabric usable, but ultimately these blended fibres will go to landfill, as they cannot be recycled again in their hybrid state. This method is most commonly used for cotton. The latter method is preferable as it creates a fibre that is of equal quality to the original. This is mostly used for nylon and polyester. However, this method requires use of toxic and polluting chemicals and high amounts of energy, so does not entirely solve the problems of environmental damage. Consumers are often duped into making eco-friendly choices by buying and wearing clothing made of fibres from recycled materials. For example, fashion designer Issey Miyake (*Elttob Tep*, PET Bottle spelt backwards), design duo *Matt and Nat*, and high street brand *Patagonia* create garments and accessories made from recycled plastic bottles as a solution to the problem of plastic bottles going to landfill, otherwise taking hundreds of years to biodegrade. However, fibres from plastic bottles contain toxins such as

26 McDonough and Braungart (2002) p.37.

27 Brown (2010) p.7.

28 English (2013) p.190-2.

29 Gould (2015) webpage; for information on these two processes.

antimony, catalytic residues, ultraviolet stabilisers, plasticisers and antioxidants that were never designed to lie next to human skin, let alone be re-fabricated into a garment.[30] These recycling processes are thus energy intensive and, in all probability, create more toxic waste than they save.

In addition to this, there are approximately 80,000 defined chemical substances used by industries today, of which only about 3000 have been studied to date for their effects on life.[31] This huge number of chemicals used by industry is only likely to rise as scientific innovations and discoveries continue. Another issue is that textile dye factories take in clean water and expel it back into nature, contaminated with fabric dyes, which usually contain toxins like cobalt and zirconium.[32] In addition to destroying ecosystems directly from the factory, the presence of these chemicals in the fabrics means that end products cannot be left to biodegrade as they will leak into the soil, nor be incinerated as the heat would release the chemicals into the air. Moreover, 30-50 percent of European and American fashion goods are produced offshore, meaning huge amounts of travelling for both raw materials and finished products, which contributes to greater carbon dioxide levels in the atmosphere and global warming, as a result.[33]

Current efforts of the fashion industry to appear sustainable and environmentally friendly are still, at best, unsubstantial. From the 1980s, there have been incremental steps towards a more eco-friendly future for fashion with Katharine Hamnett creating environmentalist slogan t-shirts to raise awareness, though this was clearly a first step and contributed more to changing attitudes than anything else. In the 1990s, *Benetton* advertised their products as secondary to their social consciousness, and in this way, it could be said that consumers were purchasing a 'social placebo' in which their purchase made them guilt free and socially aware.[34] The 'sweat shop free' *American Apparel* was founded in 1989, lauding the use of local, American labour in good working conditions with fair pay, although still using synthetic materials, dyed with toxic chemicals. *EDUN* was founded in 2005 by Ali Hewson and Bono to be a sustainable fashion brand. It is now owned by LVMH (the huge luxury goods conglomerate that also owns *Dior*, *Céline*, *Dom Perignon*, and *Moet et Chandon*), demonstrating that *EDUN* is really a front for a huge conglomerate multi-national corporation appearing as though they are sustainably aware. The 2011 *H&M* 'Conscious Collection' tried to address the problem of unsustainable fashion at the heart of the high street, though in the process,

30 McDonough and Braungart (2002) p.58.

31 McDonough and Braungart (2002) p.41-42.

32 McDonough and Braungart (2002) p.81.

33 English (2013) p.194.

34 English (2013) p.118.

they inadvertently labelled the rest of their collections for sale 'unconscious.' Stella McCartney is a fashion designer widely known for her vegetarian status and refusal to use leather or fur in her production of garments, but nevertheless claims 'I am a fashion designer, not an environmentalist.'[35] Even 'sustainable fashion' is, therefore, not as sustainable as it might first seem.

CHAPTER 2: FASHION AND BIO-DESIGN

Bio-design

Bio-design is a relatively new field that has emerged within the realm of design, coming into prominence recently with the publishing of William Myers' comprehensive collection of bio-design projects in 2012. Although, it should be noted, Janine Benyus published her work *Biomimicry* in 1997, and McDonough and Braungart's highly influential *Cradle-to-Cradle* work was published in 2002. So it can safely be said that concepts of bio-design and the use of nature's life cycles in a new form of design for environmentalism have existed since at least the end of the 20th Century.

The definition of bio-design that this thesis adheres to follows the line that what is designed (actual or conceptual) must utilise living materials, for example, cultured tissues, plants, fungi or bacteria. Bio-design therefore exemplifies the biological and natural, having grown and allowed the ultimate engineer, nature, to create something more in tune with the natural environment.[36] Bio-design embodies what it means to let natural processes show the way to greater coherence with the environment and according to Benyus, biomimicry is the ultimate form of design because everything in nature that has reached us today has survived for billions of years to get here, fossils being those systems doomed to failure.[37] Essentially, the idea is for bio-design to cross traditional design boundaries and conceptions in order to change accepted values of life at all levels so that the planet might be saved.

It should be noted that there is a difference, however, between bio-design and bio-art. Something that is bio-designed includes the use of living materials in order to benefit or enhance the

35 Quoted in Black (2012) p.32.

36 Myers (2012) p.7; Myers' book *Bio Design* as *the* authority on bio-design has been heavily influential here.

37 Banyus *Biomimicry* Webpage Ch.1.

product in terms of its environmental and sustainability credentials. Myers writes rather emphatically that bio-design is unlike biomimicry, cradle-to-cradle, and 'green' design, in that the use of living organisms specifically enhances the finished product, and are therefore the key features of the design, something that is not necessarily true for these other concepts.[38] This is a slightly narrow view to take, and so I include the notions of cradle-to-cradle as well as biomimicry within my definition of bio-design, although I agree that there must be some use of living materials in order to differentiate between bio-design and simply design. Bio-art, on the other hand, does not create solutions but rather poses questions about uses of biotechnology in design and commodification of the life sciences, for example, in order to encourage awareness of the human impact on science and nature going into the future.[39] This can be related more to the field of bio-ethics. Bio-art, therefore, sometimes includes the use of living materials, as will be seen with the Tissue Culture and Art Project's *Victimless Leather*, but can also include artworks that help challenge or understand these bio-designs, without the use of living materials. For example, Elio Caccavale created *MyBio Dolls* (stuffed fabric dolls, 2005) which help children to understand possible future genetic modifications of animals, but do not actually use any living material.[40] Of course, there will be some cross-over between bio-design and bio-art as the artist-designer-scientist boundary becomes increasingly blurred, and perhaps the definitions will adapt to this growing hybridity accordingly.

Another aspect of bio-art and bio-design that needs further explanation is synthetic biology. Alexandra Daisy Ginsberg, author of *Synthetic Aesthetics*, refers to synthetic biology as the 21st Century equivalent to the Industrial Revolution for design.[41] Synthetic biology is the design of new biological systems that do not already exist, the artificial; or the redesign of already existing biological systems, the unnatural.[42] Essentially, synthetic biology is the manipulation of life and so as an aspect of bio-design, it has the potential to bring mankind more in line with nature.[43] As a work of bio-art, synthetic biology can have the power to question these new technologies and their use or abuse of biological processes. It is the design of biology rather than design with biology that makes this branch of bio-design different from mere incorporation of living materials into design and as such synthetic biology has the potential to bring together the other facets of bio-design such as

38 Myers (2012) p.8.

39 Ginsberg et al. (2014) p.69; also pp.211-212.

40 Groot (2014) pp.5-8; on Elio Caccavale.

41 Ginsberg et al. (2014) p.x.

42 Synthetic Biology FAQ webpage.

43 Ginsberg et al. (2014) p.x and 25.

biomimicry, biological materials, and bio-technology in order to advance the future of using living materials as modern machines.[44] With regards to the below case studies, two use synthetic biology (*Victimless Leather* and *Faber Futures*), whilst the other two (*BioCouture* and *Algaemy*) do not. This will demonstrate the various applications the different branches of bio-design can have.

If nature, living entities and their associated, interconnected life-cycles can be incorporated into design, the much needed materials and process revolution can begin. This reflects the poignant idea of Myers that 'there are no such things as things, there are only systems.'[45] Acknowledging just how interconnected every life is with nature and other lives, including an intergenerational interconnectedness is to realise what it means to be truly biologically and sustainably designed, something that McDonough and Braungart (2002) expound with their ideas of cyclical, cradle-to-cradle designs. With this in mind, bio-design means that there is only ever life.

Bio-design and Fashion

Considering the current wide coverage of sustainability and environmental impact in the academic field of fashion, it is surprising that bio-design does not feature in the majority of such publications.[46] It appears to still be a very niche field of research, at least in terms of fashion. In the field of bio-design, fashion is reciprocally excluded, with Myers including only five fashion-related topics in *Bio Design*, totalling only 23 of 467 images, while Benyus makes no explicit reference to the fashion industry at all in *Biomimicry*.[47] The fashion publications that do contain information on bio-design are very few and the field is never fully explored. For example, Kate Fletcher and Lynda Grose include a chapter on 'Biomimicry' in their book *Sustainable Fashion*, but it focuses only on the work of Benyus rather than branching out to consider the entire bio-design field. [48] Sandy Black's comprehensive *Sustainable Fashion Handbook* covers a vast majority of sustainable fashion topics, including the bio-design project of Suzanne Lee, *BioCouture*.[49] However bio-design is included here under the wider heading of 'technological' development, which while true, is slightly misleading. Presenting

44 Ginsberg et al. (2014) p.52.

45 Myers (2012) p.13.

46 For example, Brown (2010); Quinn (2012); Farley-Gordon and Hill (2015); and these are just books based on future fashion and sustainability. Other secondary literature, including English (2013), has chapters on sustainable fashion, and Bio-design is equally left out of the discussion.

47 Benyus (1997) webpage; Myers (2012); calculation of images my own.

48 Benyus (1997) webpage; Chapter 1; Fletcher and Grose (2012) pp.114-23.

49 Black (2012) pp.310-311.

ideas of bio-design next to electrical, digitised designs such as light up dresses, which are entirely unaligned with environmental agendas, does little to promote the emerging field in fashion. Bradley Quinn, author of *Fashion Futures*, makes a similar misjudgement, explaining that wearable technology will enable people to be more aligned with their environment.[50] However, Quinn is referring to a technologically advanced 'environment' in which everything is digitally enhanced, supplying global wireless internet access, rather than the natural environment, supplying the air we breathe.

Bio-design is evidently an emerging concept for the fashion industry, although considering fashion's fast pace and continual need for change, there is no reason why bio-design could not be taken up seriously with relative ease and acceptance. Bio-design is so important for fashion because it seems that the industry is almost out of options with regards to solving its sustainability problems. Chemical recycling, incineration, and creation of petrochemicals cannot reasonably continue; landfill is no longer a viable option; re-using old clothes will only work to avoid problems of recycling or landfill for a limited time; and sending clothes abroad only hides the growing problems associated with Western fast fashion cultures. Synthetic fibres are unable to biodegrade as the naturally occurring enzymes for this process simply do not exist. Fletcher and Grose explain that it is only possible to make changes to these kinds of problems if the solutions are thought of in advance.[51] Bio-design offers a total overhaul of the design system with a material as well as process revolution, with all aspects of the cycle considered beforehand. For example, Aniela Hoitink started *NEFFA*, and Bernhard Schipper created *SCOBY Tec* in order to investigate future textiles technology using microbiology, researching both new materials and processes for their sustainable construction, consumption and disposal.[52] Bio-design has the potential to solve the fashion industry sustainability problems because it does not attempt to remedy the current system but actually seeks to start a new one.

50 Quinn (2012) p.6.

51 Fletcher and Grose (2012) p.17.

52 See *List of Related Projects*.

CHAPTER 3: CASE STUDIES

Case 1 - Victimless Leather

Creators and Creation

Oron Catts and Ionat Zurr are the artist duo behind the Tissue Culture and Art (TC&A) Project, launched in 1996. Hosted by *SymbioticA*, the Centre of Excellence in Biological Arts at the School of Anatomy and Human Biology at the University of Western Australia, the idea was for the artists to take the tissue engineering research and apply it to non-medical endeavours in order to raise questions about the ethics and moral dilemmas that surround the use of this medium in commercialised products as well as in art.[53] The TC&A Project *Victimless Leather* was designed with creating cultural awareness in mind and to be a catalyst for societal discourse on where humanity and fashion is headed and how. As stated previously the planet is fast running out of natural resources and the fashion industry is a large contributor to this. When considering *Victimless Leather* it is with the notion in mind that the artists desired to create a new 'design paradigm' with the focus

53 TC & A website and also *SymbioticA* website.

not on conventional manufacturing but on biological growing in order to (at least) change the way we think about fashion manufacture for the future.[54]

Victimless Leather was first exhibited in 2004, in the Perth *John Curtin Gallery* as a commission for the exhibition on the future of fashion and textile production, 'The Space Between.' The *Victimless Leather* is grown from a mix of both mouse and human immortalised cell lines, created using the tissue culture technologies of the medical field. This living tissue is then grown over and supported by a biodegradable polymer matrix scaffold in the form of a small leather jacket. The jacket is then placed inside, what has been termed by the artists, a 'bioreactor,' a clear, sterile environment, where the essential nutrients needed for growth can be drip fed into the scaffold polymer matrix to feed the cells (Image 1). This will result in eventual biodegradation of the scaffold polymer matrix, leaving a tissue cultured, *Victimless Leather* jacket (Image 2).[55]

***Victimless Leather* and Fashion**

The nature of dress, essentially and originally, is to cover and protect the body from external temperatures or even threats. This essentialist viewpoint of dress has long since been lost in the developed world and is now the subject of the far broader notion of 'fashion.' What is worn today often become a status symbol and, at times, a political one. It is in this vein that *Victimless Leather* begins its discourse with the world of fashion. Catts and Zurr have explained that fashion and one's choice of clothing are a human invention and so tangibly reflect on what it is that humans make of their effect on the 'Other.'[56] Those who engage in fast fashion, theoretically, are showing that they have little care or even knowledge about the effect of their garments on other humans, or the environment. *Victimless Leather* is therefore a starting point for discussion regarding our relationships with our clothes and the systems and beings implicated in this.

The application that the artwork *Victimless Leather* has on the fashion industry is multi-faceted. An emotion is evoked towards the 'fabric,' something that is untouched by conventional fashions. If we are faced with a coat that we know was grown for us with our own cells, then perhaps we will think twice about throwing it away to landfill and we will think more about what it means to really create a garment. In addition to this, as a biological entity, the leather that is produced, from our own cells or otherwise, would be entirely biodegradable and so could give its nutrients back to the environment instead of laying to rest in landfill.

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54 Catts and Zurr (2014) p.20.

55 All information on this process in this paragraph from TC&A *Victimless Leather* webpage (2004).

56 Catts and Zurr (2004) TC&A webpage *Victimless Leather*.

It is important not to look at the material as simply another consumer product, a key concern of the artists, but to examine it in the realm of bio-art where it might have real potential to change the face of the fashion industry in at least a conceptual way and how it is that clothes are both made and perceived. Catts and Zurr explain that the aim of their tissue engineering projects, in general, are to highlight to humans their position in the world with regards to both the environment and other living things.[57] The very nature of fashion is to be self-centred as there is a desire to be seen as better-dressed and 'newer' than the next person, and it is because of this that we have lost all sense of our responsibility towards others. It is this trend of the self that does not seem to be diminishing that *Victimless Leather* can begin to address. In a broader sense, when Catts and Zurr explain that they want to raise questions about 'exploitation of living beings' this is a reference not only to their artwork but also to the wider realm of fashion's victims, including the workers and the environment.[58]

Because Catts and Zurr do not intend their art work to be seen as a piece for real-world design and application, stating that it is for 'cultural and not commercial' ends, there has been very little coverage by them in their essays on tissue culture engineering about fashion and what they make of the effects that *Victimless Leather* could have on the fashion industry.[59] As a result of this information gap, there is still a wide disparity between art and design, and the fashion industry is largely none the wiser of this new technology.[60] It has been noted that scaling up the production of *Victimless Leather* would create problems for the technologies available at present but there is no mention of the idea that this creation could be used in a commercial sense, because the artists claim that this is not what it is for. An important debate has, thus, been missed. *Modern Meadow* is a company which has taken on the commercialisation of *in-vitro* ('in glass') meat and leather production, with Catts and Zurr adding simply that 'as this product will not be consumed but rather used externally' it might be more widely accepted than the *in-vitro* meat.[61] This tissue culture technology offers a real alternative, at least for commentary on sustainable changes to the fashion industry, but there is no further elaboration on these possibilities made by Catts and Zurr, much to the detriment of the sustainable fashion debate.

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57 Catts and Zurr (2008) p.33.

58 Catts Zurr (2008) p.34.

59 Catts Zurr (2008) p.33; see also *Bibliography* for Catts and Zurr (2004, 2008, 2013a, 2013, 2014).

60 Cogdell (2011) p.28. Cogdell reasons that there is an art/design split as bio-artists are a different entity to the bio-designers, and they focus more on ethics than commodities.

61 Catts and Zurr (2014) p.24.

Current Debates

Aside from the lack of debate regarding the application of tissue engineering to the fashion industry by Catts and Zurr, there are other areas for debate that have developed, to the credit of the artwork, which can also be applied to the fashion industry. Christina Fei of *The Genteel*, a Toronto-based online fashion and design magazine, explains that a main drawback of the use of the tissue cultured leather is that it would not be cheap and it would be a technical luxury.[62] This is a very typical free market, consumer-centric question. Most new technologies are expensive when first released as they are a novelty, introduced by one company and then sooner or later, someone else finds cheaper, more efficient ways to make it and the product becomes accessible further. This is a model that applies even outside of the fashion industry. However, the edge that the *Victimless Leather* has on this issue is that it has the power to make humans stop and think about the implications on others of trying to make the product cheaper, because this will always come with a cost to the living 'Other.' The headline of the *New York Times (NYT)* in 2008 of 'Museum Kills Live Exhibit' pulled the public's attention to this 'Other' and provided some debate as well as evoked public reactions which demonstrate the place that bio-design has in society at present.

The *NYT* article, covering the 2008 'Design and the Elastic Mind' exhibition, opens by introducing *Victimless Leather* as 'one of the strangest exhibits at the…very strange show at the *Museum of Modern Art (MoMA)*.'[63] That the author reiterates that the small jacket is 'strange' twice in one sentence demonstrates the general response to the item as being something rather disquieting. Perhaps people do not feel an affinity with the grown, semi-living clothing as they do with a piece of leather, or perhaps it is exactly because there is more of an affinity with something that is 'alive' that causes the uneasiness. This is demonstrated in the *NYT* article as the author claims that the leather was 'kept alive in an incubator with nutrients, unsettlingly alive.' When the public is faced with the reality of their leather being once alive, it raises all kinds of disturbing questions to consumers of the implications of their consumption and the processes required to make their clothes. There seems to be real alarm when the curator of the exhibition 'had to kill the coat' but not when killing cows or even (indirectly) humans.[64]

In the same vein, the project raises the issue of the 'Semi-Living,' a term coined by the artists to describe what it is that they have created and also to give an ethical and moral resonance to their aim of not providing 'yet another consumer product' but rather raising awareness in a cultural sense

62 Fei (2015).

63 This and the previous sentence refer to Schwartz (2008).

64 On curator Paola Antonelli 'killing' the jacket; Schwartz (2008).

of the human treatment of the environment and other life forms.[65] With this in mind and with regards to the event at the *MoMA*, Catts explained that he was actually pleased with the exhibit having to be 'killed' as it reminds people 'that these works are/were alive and that we have a responsibility towards the living systems that we engage in manipulating.'[66] Christina Cogdell, Professor of Design at the University of California, Davis (US), writes in the same manner of uneasiness of the exhibition but in the sense that the artwork has a very obvious over-arching sense of placing the current 'machine-age, modernist mould' onto the future.[67] These bio-designs and bio-artworks are a way of approaching the future in an entirely different manner from the design that has gone before and it is important not to lose this notion in exhibitions where it is easy to become enveloped in the shiny machines of the future. The future of fashion is a real problem with real-life consequences that will have their impacts in our lifetimes. Cogdell therefore concludes that Paola Antonelli, the senior curator of the exhibition 'Design and the Elastic Mind' misinterpreted the piece.[68] A bio-designed future for fashion can have little hope if this is the ongoing case.

There have also been a wide variety of other misunderstandings of *Victimless Leather* that can also help to hinder the developments of *in-vitro* leather production in the future. In *Wired Magazine*, Lakshmi Sandhara writes about being able to wear leather 'without killing an animal' which is actually not true of the tissue culture.[69] The culture needs nutrients to grow and these nutrients come from bovine foetal serum, which entails killing both the foetus and the mother in order to obtain it (there is research into finding alternatives at present but nothing is coming close as yet).[70] It seems that a lot of publications meant to reach a wider audience, that is, the would-be consumer audience, mask certain aspects of the creation of *Victimless Leather*. There appears to be a heavy emphasis on the fact that the leather is produced from immortal cell lines, 'essentially forming a renewable resource.'[71] Even the *MoMA* website skirts around this potentially problematic area of the artwork and claims that the *Victimless Leather* offers 'the possibility of wearing leather without *directly* killing an animal' [emphasis mine], demonstrating that there is still an animal 'victim' in the

65 TC&A Project *Victimless Leather* webpage (2004).

66 In an interview with *NYT* (2008).

67 Cogdell (2009) p.92.

68 Cogdell (2009) p.95.

69 Sandhara (2004).

70 Catts and Zurr (2014) p.28.

71 For example, see Sandhara (2004).

production process.[72] If Catts and Zurr have taught us anything it is to ask questions and consider all aspects of a situation and so the covering of certain facts by various information outlets highlights the artists' fear of commodifying their creation before the world is ready for it.

Contributing to the lack of fashion industry debate on *Victimless Leather* is that the artwork is always combined with the fact that the artists want to highlight the ethical and moral implications of using animals and living organisms for our own ends, leaving fashion unengaged. No one (that I have found) really and truly engages with this concept of the moral and ethical implications of using the 'Semi-Living' as an alternative for the use of leather, or other materials, in the fashion industry as a viable alternative product. Even Suzanne Lee unfortunately respects the wishes of the artists not to be seen as makers of consumer products and so merely introduces the work and then leaves it firmly in the realm of art and not a fashion design of the future.[73]

The artwork is clearly vital in its raising awareness of what design can do, but it is nonsensical to eliminate something from commodification simply because the commodified is what is seen to be bad about the fashion industry. The future of the planet depends on changes to these attitudes. Frances Stracey, an 'Art and the Sciences' researcher, follows in this pattern in her article entitled 'Bio-art: The Ethics Behind the Aesthetics.'[74] Because the vast majority of the scholarship on *Victimless Leather* and tissue engineering outside of the medical profession adheres to the wishes of Catts and Zurr to not see it as a consumer product but as an ethical discourse on how humans treat other beings, the focus on fashion seems to drop to the wayside. The piece was commissioned first for an exhibition on textiles in 2004, something that has been forgotten in some cases, with Linda Weintraub even wrongly referencing the piece as from 2008 (the year of the *MoMA* exhibition).[75] The main focus appears to be on *MoMA* and the fact that the piece had to be 'killed' there and the debates surrounding the use and abuse of the 'Semi-Living.' Catts and Zurr do not even write a full essay on the implications of their work on the fashion industry. In Myers' *Bio Design* publication, an overview of works to 2010, *Victimless Leather* is treated as an 'Experimental Function' and as an artwork in a much broader field than fashion to question the use of living, biological materials for our own (non-specific) ends.[76] The main concept behind *Victimless Leather* was an irony that shows that

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72 *MoMA Victimless Leather* webpage (2008).

73 Lee (2005) p.68.

74 Stracey (2009).

75 Weintraub (2012) p.301.

76 Myers (2012) p.132-133.

actually a 'victimless utopia' is much further away than initially thought, something that has been proven unequivocally true for the fashion industry.

Case 2 - BioCouture

Creator and Creation

Suzanne Lee founded the *BioCouture* research project after having interviewed Dr. David Hepworth, a biologist and materials scientist working with bacterial cellulose at the British firm *Cellucomp*, for her 2005 book *Fashioning the Future: Tomorrow's Wardrobe*.[77] *BioCouture* is the first 'biocreative' design consultancy, established to help the fashion industry to create a more sustainable future for its products by using renewable and biodegradable resources that nature has provided us, such as bacteria, fungi and algae.[78] It is a design-directed attempt to really show how the fashion industry can change its methods of manufacture in order to preserve and save the environment.

The main focus of *BioCouture* is fusing the fashionable with the biological in order to create a new spectrum of 'bio-materials' that are environmentally sustainable in production, use and disposal. Cellulose is the basis for wood, cotton and paper and is the most plentiful renewable resource in the world, according to Dr. Hepworth.[79] The first and most frequently quoted 'bioethical' fabric that Lee created is bacterial cellulose; something Lee terms a kind of 'vegetable leather.'[80] This relatively inexpensive kombucha tea- based mix of yeast and bacteria forms a material composed of millions of tiny bacteria. Once the tea is brewed, the sugar is added and then when this has cooled to below 30 degrees Celsius, it is transferred to a bathtub (or similar) and the yeast is added. As the yeast and bacteria ferment the glucose, organisms produce a flat sheet mat of cellulose over about two to three weeks on the water surface that can simply be lifted off when ready and dried (Image 3). The fabric can be dyed with non-toxic vegetable dyes, cut and sewn, or dampened and moulded to make clothing or accessories.[81] Bacterial cellulose is entirely biodegradable and compostable and could be combined with other household waste such as vegetable peels, instead of sending it to

77 Lee, TED Profile webpage and Lee (2005) p.64.

78 Lee, *BioCouture* webpage.

79 Interview in Lee (2005) p.64-65.

80 Lee, TED Talk (2011).

81 For the whole process of Suzanne Lee's bacterial cellulose creation see Lee, TED Talk (2011) or her DIY recipe.

landfill.[82] In addition to this, the biodegradability factor of the material can be engineered to degrade after three weeks or three years depending on the designer's requirements.[83]

***BioCouture* and Fashion**

Lee has a clear, fashion-orientated goal to her design research on biological fabrics and so the notion of fashion and the associated industry is already embedded in the discourse surrounding her project. Rather than taking a strictly theoretical or ethical ideal, Lee takes on the practical side of the fashion-industry. The notions of sustainability and waste reduction are at the centre of Lee's designs and the cyclical production nature of the materials stand a real chance of changing the future face of fashion. For example, the World Wide Fund for Nature (WWF) estimates that it takes 20,000 litres of water to produce a kilogram of cotton, which would make the equivalent of just one t-shirt and a pair of jeans (this is the same for both organic and fair trade cotton).[84] When this is compared with the production of bacterial cellulose, Lee explains that making a garment such as a t-shirt would require around 50 litres of water, and the majority of that water could then be used again to make more bacterial cellulose, unlike in cotton production, where the contaminated water is simply disposed of after use.[85] Lee has voiced hopes for the future industrial production of bacterial cellulose, advising that the water needed for the production could potentially come from an industrial waste stream containing sugar which would reduce inefficient water and sugar usage.[86] These factors, when combined with the fact that the material is also biodegradable and compostable, thereby creating no waste after use, demonstrate that the potential is there for the fashion industry to adjust and become at one with nature and potentially eliminate destructive waste from its processes.

However, the revolution may be some time off yet as Lee acknowledges that bacterial cellulose is unlikely to produce a soft texture like wool or cotton, the current fashion industry standards in the majority of garment production. This means that the fabric is also unlikely, at least for now, to be a real contender for the total replacement of current fashions for textiles.[87] 'Michael LeRod' illustrates this resistance to change as he comments on Lee's TED talk that the bacterial

82 Lee, TED Talk (2011).

83 Bonanos (2013).

84 WWF webpage.

85 Lee wrote this to 'Angeliki Zafeiropoulou' in the comments section of the Lee, TED Talk (2011).

86 Lee, TED Talk (2011).

87 Lee, TED Talk (2011); see also on lack of production of 'fluffy' fibres as mentioned in previous sentence.

cellulose is 'far from fashionable and chic.'[88] Furthermore, on the *Design Boom* website, 'Ryan' highlights this discomfort felt about the new eco-textile writing, though with a touch more optimism, claiming 'This creeps me out a little, but it's cool.'[89] Ironically, the embedded need in fashion for continual change does not really seem to apply here. The material could be a real contender for the replacement of leather, which corroborates more with what Lee claims the aim of creating the material was: the bacterial cellulose fabric was not designed to replace conventional fabric production, but rather to be a fabric that can coexist with existing materials such as cotton, wool or leather, in order to take some of the increasing pressure off diminishing global resources. [90] Lee made common items of clothing, for example a bomber jacket, a 'denim' jacket, as well as a biker jacket, to show how versatile the fabric can be and that it can be used in ways that are familiar, even though the fabric is not (Image 4). If a more revolutionary stance is taken with reference to overhauling the fashion system as it stands, then there may be more chance of success. It seems as though there is both fear and ambiguity within the fashion industry with regards to actual change. Perhaps this is the real fashion paradox: an industry that thrives on change yet persists in its traditional methods of manufacture.

Another problem that mass-consumption of bacterial cellulose encounters is that it is at present fairly difficult to scale up. Lee currently makes the material in experiment-sized bathtubs and only creates small quantities at a time, so there is no certainty whether or not this material could ever become a viable competitor with other materials in the fashion industry, let alone something that could replace part if not all of fashion's present-day fabrics. Time is also a crucial factor in the development of bacterial cellulose as a consumer product as the 'throw-away,' fast fashion industry is currently able to produce thousands of units of garments per day, while it takes two to three weeks to form sheets of the fabric using Lee's current process, which can only produce a few garments at a time. Perhaps it is the cyclical innovation of this design, taking resources from cradle-to-cradle, which is vital in demonstrating to the fashion industry how it might become more sustainable in the future.[91] Realising that the whole process from end to end of a fashion garment needs to be considered and intertwined means that fewer resources will be wasted and the environment will not have to suffer as a result of a garment afterlife afterthought.

However, according to Dr. Hepworth, it could become possible to make clothes within hours and allow the bacteria to remain alive in order to customise garments for an exact fit, with no waste.

88 Comments section of Lee, TED Talk webpage (2011).

89 *Design Boom* webpage, September 19 2010, 'Comments Section.'

90 Lee, TED Talk (2011).

91 For more on cradle-to-cradle, see McDonough and Braungart (2008).

He explains that by spraying a glucose solution along the hemline, for example, the garment could lengthen overnight.[92] Lee provides a recipe online to make her microbial cellulose and while this is probably something meant, at present, for experimental curiosity, it nevertheless opens up a possible future for do-it-yourself clothing.[93] Theoretically, if consumers could make or repair their garments at home with a bacterial cellulose solution then packaging waste as well as shipping pollution of products could be eliminated. There is also the future development of 3D biological printing to contend with on this idea.[94] While Lee's research is still very much in its experimental phases, the ideas behind the design and the cyclical processes of the fabric's life, nevertheless, is what is so ground-breaking and influential in the field of sustainable fashion design.

Current Debates

Suzanne Lee and her *BioCouture* project appear to be the authority on fashion and bio-design at present with Lee's work being totally unavoidable in the research of this field. As such, it becomes difficult to find real debate surrounding her work and the implications it has on the fashion industry, with the majority of publications that include Lee and *BioCouture* either including it in an almost dictionary-style entry of what it is and how it is made, with no elaboration, or praising it as the saviour of sustainable fashion, with no critical engagement. There is very little, to nothing in-between. Myers includes *BioCouture* in his *Bio Design* publication under the function of 'Ecological Object Engineering,' a chapter that is dedicated to biological designers who have focused on reversing the effects of the Industrial Revolution and saving the environment.[95] Lee's work is recognised as contributing to this field of design and sustainable fashion, but it often appears as if it stands alone in the publications of bio-design, rather than as part of a wider discourse on sustainable fashion. As previously stated, in the whole of *Bio Design*, there are only 5 fashion-related projects presented.[96] In addition to this lack of representation on the main stage of bio-design, Myers does not engage with the projects critically. The projects are presented simply as they are, like dictionary entries, under a wider chapter heading relating to ideas such as experimental functions or beauty. This lack of a critical eye means that *BioCouture* is seen as something more conceptual rather than a critical, practical design and as such, is not challenged and confronted with a 'real life' analysis. This is

92 Dr. Hepworth quoted in Lee (2005) p65.

93 See Lee's 'BioCouture: Grow Your Own Material Recipe' webpage.

94 See *Modern Meadow* website for their research on this.

95 Myers (2012) p.76 and p108-111.

96 Myers (2012); calculation my own.

unfortunate because bacterial cellulose could be improved (for example, it is still not waterproof) and eventually be commodified as a viable alternative for the fashion industry.

There is not a shortage of scholarship on ecological and sustainable fashion.[97] Designers and scholars alike are aware of the impact of fashion on the environment but solutions like Lee's bio-designed couture are somewhat scarce in the majority of these 'fashion' publications. For example, Quinn does not include Lee in his 2012 book *Fashion Futures*, instead focusing more on advances in wearable technologies and how technology can create new fabrics to look the same as current ones, only more 'sustainable.'[98] These replacements for materials that already exist include *Biophyl* which is a plant-based polyester, and *Cocona* which is denim made from coconut shells.[99] However, these materials are more of a gesture to consumers who have increased their environmental 'awareness' in recent years and want to think that they are no longer harming nature with their purchases, but in reality, they do not solve the underlying problem of the entire cycle of design and the pollution caused by dyeing and also landfill where these mixed fibres will eventually end up. Brown is another authority on fashion, writing the 2010 book *Eco Fashion*, which also makes no mention of Lee.[100] Brown explains that fashion no longer expresses current issues and is firmly set against nature with its fast-fashion culture contributing to both landfill and third world disease.[101] Brown's introduction packs a great punch of environmental awareness but her collection of 'sustainable' designers does not match her intentions. Brown presents designers such as *Les Fees de Bengale*, a design group who use fabric made only by women, for women.[102] Obviously this initiative is helping some disadvantaged women with employment, but in the wider scheme of things, it does nothing to counter landfill and resource destruction. It is not until you reach for Myers' book on bio-design that Lee is encountered, alongside creations such as bio-bricks and moss tables. There is clearly still a wide information gap existing between the 'fashionable sustainable' and truly bio-designed fashion.

Lee founded *BioFabricate* alongside *BioCouture*, which aims to facilitate talks between artists, designers, and scientists about materials development that contribute towards solving global

97 See, for example, Lee (2005); Claudio (2007); Brown (2010).

98 Quinn (2012) p.6.

99 Quinn (2012) p.104-5.

100 Brown (2010).

101 Brown (2010) p.7.

102 Brown (2010) p.31.

issues of sustainability and environmental responsibility.[103] This, like the majority of bio-design publications, has a broader focus on generically 'bio-designed' materials, including works on biological cement and mycelium chairs, rather than specifically fabrics for fashion design. [104] Arguably, these other industries could influence the fashion industry with their material innovations, though a cement dress is probably unlikely to ever catch on. The bio-design in fashion debate is therefore lacking and has a challenging future ahead if it always takes a side-lined position.

The vast majority of webpages devoted to Suzanne Lee and *BioCouture* have an overwhelmingly optimistic feel to them about the future of fashion. For example, the *Dezeen* website talks about the exciting futures of fashion (although it is in a technological context, rather than sustainability), and *Vice Magazine* simply introduces Lee's work as 'Suzanne Lee Grows her own *BioCouture* Bomber Jacket,' a somewhat basic title, and poses the question 'Would you wear these?' at the end of the article, inviting the reader to think only in commodified terms.[105] One is left with the overwhelming feeling that this is entirely ground-breaking and is the answer to the problem of unsustainable fashion. Whilst this is not untrue, it masks the multi-faceted problems and debates that should surround it. It seems that because Lee was the first to create a 'fashionable' bio-textile like no other eco-fashion offering that has come before, *BioCouture* has been put on a pedestal and most webpages and publications simply want to introduce it to the world, feeling that it is perhaps inappropriate to criticise or debate it for fear of losing it. This is the commodification of bio-design that *Victimless Leather* was aiming to avoid: Lee received praise for her practical design while Catts and Zurr encouraged debate and interaction about the conceptual ethics aside from the fashion industry. The art/design divide is all too clear in this instance and it poses a real problem to the development of sustainable fashion.

For all the optimism that the public and websites have shown, Lee has put the bacterial cellulose project aside for now, choosing to focus on researching new biological materials, rather than continuing with the commodification of just one.[106] Lee felt that the bacterial cellulose 'vegetable leather' was not economically scalable without genetic modification of the bacteria involved.[107] She is now Chief Creative Director of *Modern Meadow*, a company dedicated to making *in-vitro* meat and leather, where she directs material creation in labs. *Modern Meadow* mainly

103 *BioFabricate* website – most recent conference was October 2015, New York.

104 Eric Klarenbeek (Mycelium Chair) and BioMASON (Biological construction materials) are included within the *BioFabricate* website Directory.

105 *Dezeen*, Fairs (2014); *Vice*, Levitt (2011).

106 Venkataramanan (2014).

107 Andreotti (2015).

focuses on the creation of meat food products for consumption on a large scale, and Lee uses the same tissue engineering technology in the creation of an 'eco' leather.[108] It is arguably advancement on the vegetable leather, although it must be noted that the stated aim of creating leather without killing an animal sounds great emblazoned on the *Modern Meadow* website homepage, but as in Catts and Zurr's *Victimless Leather*, above, this is not yet possible, because of the need for foetal bovine serum which comes from a slaughtered bovine mother and foetus.[109] This is something not mentioned anywhere on the website for *Modern Meadow* and highlights this lack of questioning and debate surrounding the break-through 'sustainable fashion' work of Suzanne Lee. Hope is not all lost, however, as bacterial cellulose lives on in *SCOBY Tec*, a German start-up that makes material compounds based on bacterial cellulose, in order to create sustainable wearable technology.[110]

Case 3 - Faber Futures

Creator and Creation

Natsai Audrey Chieza is founder and creative director of the ongoing research project *Faber Futures*, exploring the use of programmable, pigment-producing bacteria as an alternative textiles dying method, in connection with creating a sustainable future for fashion.[111] The design project essentially brings together a new era of biotechnology with traditional crafting techniques in order to demonstrate that the current situation of colouring clothes in the industrial age is no longer sustainable and that there are ways that nature can combat it. *Faber Futures* offers a challenge to the way we conventionally view our clothes in order to realise that change is needed. The *Faber Futures* project is a collaboration with Professor John Ward (Professor of Synthetic Biology for Bioprocessing, The Advanced Centre for Biochemical Engineering, Department of Biochemical Engineering) at *The Ward Laboratory*, University College London. Chieza works as a Designer in Residence alongside scientists in order to find alternative applications for their research and findings on synthetic biology in the field of sustainable fashion. Chieza is the leading designer in the field of pigment-producing

108 Grushkin (2015).

109 *Modern Meadow* website; this demonstrates the need for works like Catts and Zurr's 'Victimless Leather' to create ethical discussions and raise awareness of the hidden victims; see also Dilawar (2015).

110 See *SCOBY Tec* website 'About.'

111 Chieza 'The Print Room' webpage.

bacteria used to both directly 'dye' and screen-print fabrics. As such, *Faber Futures* presents the first collection of textiles coloured in this way.

Within the *Faber Futures* research project, Chieza first presented 'The Print Room' at the 2013 'En Vie/Alive' exhibition at the *Espace Fondation EDF* in Paris. This project presented the first ever traditionally screen-printed textiles using dye made from synthetic pigment-producing bacteria. Chieza explains on her website that the Streptomyces bacteria, commonly found in soil, are 'trained' to produce pigment as a by-product of their metabolic activity, which comes about as a result of interfering with the bacteria's nutrition and growing conditions.[112] The programmed bacteria are thus able to generate specific colour ranges and once extracted from the bacteria, the pigments can then be screen-printed. Chieza next presented the 'Rhizosphere Pigment Lab,' which was commissioned by the *Science Gallery* 'Grow Your Own' 2013 Exhibition in Dublin. The *Science Gallery* wanted to demonstrate that science can also have craft and design applications in addition to the fact that the rhizosphere, the section of soil surrounding a plant root, is unique to each plant species.[113] The exhibition piece showed three stages of the scientific endeavour: which plant the soil bacteria came from, the pigments produced by each soil bacterium, and samples of pigments used to dye silk scarves *in-vitro* (Image 5). This was a live experiment, using living bacteria. The final project, 'The Fold,' builds on the previous two projects, using the pigment-producing bacteria and method of colouring fabrics *in-vitro* to create silk scarves printed with unique designs. Chieza writes that the confines of a 150mm petri dish produced very limited results so she instead used origami-like folds which allowed larger quantities of fabric to fit into the petri-dish to be coloured.[114] The silk is inoculated and the bacteria are allowed to grow and seep through the different layers of fabric, creating colourful, mirrored prints as they go and essentially depicting the seven day life span of the bacteria (Image 6).

***Faber Futures* and Fashion**

The main driving force behind the bio-design of Chieza is that conventional industry standards for the fashion industry and their dying processes do not consider environmental impact and the finite resources that are affected. Chieza's *Faber Futures* thus takes a direct discourse with fashion and its unsustainability, as an ultimate epicentre of fabric wastage and pollution, presenting her research as a possible answer to these problems. The World Bank estimates that around 20 percent of global industrial water pollution comes from the textiles industry dyes and within this, it is estimated that

112 Chieza 'The Print Room' webpage.

113 'Grow Your Own' Exhibition 'Rhizosphere Pigment Lab' webpage (2013).

114 Chieza 'The Fold' webpage.

there are 72 different toxic chemicals.[115] These chemicals can cause diseases in both humans and animals and because many chemicals cannot be filtered out of the water, this problem will only escalate. With just one dye mill using 200 tonnes of water for one tonne of fabric dyed, it is clear why so much water is fast becoming contaminated and that finding an alternative to chemical dyes is imperative.[116] Chieza's method of dye requires only 25 millilitres of water in order to colour one t-shirt, as opposed to the 2700 litres of water and 150 grams of chemical currently consumed.[117] This project thus illustrates the potential that lies in using living organisms as the raw materials of the future fashion industry.

The unique colours and patterns created by pigment-producing bacteria offer a sustainable alternative to the conventional, polluting, chemical dyes that are currently in vogue. One reason for this is that every microbe is different and, as such, produces different colours and patterns. In addition to this, conventional dye techniques of mixing colours to create other colours can also be employed. Another reason is that we might view our clothes in a different and perhaps even more personal way if we know that the dye and pattern is unique to the garment and that it originates from a whole process of life and death of bacteria. This kind of view may make us value garments more and not want to throw them away so quickly. Moreover, like the bacterial cellulose of Lee, Chieza explains that actually 'we know that pretty much anyone can do this' which opens up the do-it-yourself potential for creating clothes at home and reinforcing the value and personal attachment to garments, as well as eliminating a whole host of other polluting activities, such as transportation.[118] The same bacteria can produce different colours and patterns depending on the fabric, adding to the variations and personalised effect. In line with these possibilities, one of Chieza's goals is to create a predetermined colour chart, which would help eliminate some of the unpredictability for possible future commercial use.[119]

Millions of tonnes of unused fabric go to waste each year when dyed the wrong colour. It could be argued that the constant strive for perfection in current fashions is what drives this unsustainable dye culture. A change in attitude to fabric colours and trends, however, may not be necessary with the use of pigment-producing bacteria. Perhaps bacteria can be trained to grow again over 'dyed' fabrics to create new patterns or trends in fashion. In the last event, if the fabric needs to

115 As referenced by *Eco 360* webpage.

116 Chieza at 'Bio-Design in Textiles' (2015); Blackburn (2009) p.140.

117 Chieza at 'Bio-Design in Textiles' (2015) for her measurement; *Eco 360* webpage for standard measurement.

118 *Protein* webpage.

119 'En Vie/Alive' *Faber Futures* webpage.

be thrown away, the bacteria is not chemical and polluting, it is naturally occurring and could nourish the plant soil it came from, effectively closing the bacteria-dye production loop.

It would be interesting to see how effective the bacteria would be in dying fabrics such as bacterial cellulose or *Victimless Leather*, in order to truly come full circle with sustainable fashion. At the *BioFabricate* 2015 conference, Chieza presented her first line of 'bio-pigmented' garments in a preview of what a collection of clothes could look like in the future if dyed in this way.[120] Chieza explains that through her design projects, she means to change the fashion industry to a science-based design perspective and that synthetic biology could really become a commodified technique for the textile dyeing industry by 2075.[121] Her conviction is evidenced with her branding of the Rhizosphere Pigment Lab a 'Design Studio.'[122]

Current Debates

Current scholarship on the environmental sustainability of the fashion industry does not seem to have a large focus on the waste produced from dye. A lot of publications focus on ethical trading as well as encouraging the sustainable growth of developing countries, which are currently being exploited by fashion brands looking for a fast profit. Waste and pollution created by dyes comes under the notion of sustainable development but working conditions and wages seem to take more of the centre stage in these debates. For example, Brown explains that her 2010 book, *Eco Fashion*, is the first to examine sustainability in fashion, yet focuses mainly on issues of fair trade, such as Anya Hindmarch's "I'm not a plastic bag" (intended to raise awareness about the damage to the environment of plastic bags) which was scandalously made from non-organic and non-fair trade cotton.[123]

Recycling and reusing fabrics as well as using fair trade materials does not eliminate problems of waste or chemical dye pollution, however. The Ethical Fashion Forum explains that the majority of garment production and dyeing occurs in developing countries where health and safety standards are more lax and so chemicals are not properly handled or disposed of. Even when the pay and welfare of workers dyeing fabrics is fair, the pollution outside of the factories is still gradually permanently damaging entire ecosystems. The lack of scholarship on this kind of environmental damage and its relation to the fashion industry dye is therefore shocking.

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120 *BioFabricate* website (2015).

121 Chieza website; 'Design Fictions.'

122 'Grow Your Own' Exhibition 'Rhizosphere Pigment Lab' webpage (2013).

123 Brown (2010) p.7 on first book to examine sustainable fashion; p.171 on Anya Hindmarch.

Faber Futures made its debut only in 2013, but since then the field of bacterial fabric dye has made many developments and so publications understandably become outdated rather fast. For example, Beckett Mufson wrote for *Vice Magazine* in December 2014 that bacteria could be a solution to the unsustainable fashion industry and that the next step for Chieza would be to create a collection of garments.[124] Chieza realised this in less than a year, presenting bio-pigmented garments at the October 2015 *BioFabricate* Conference, demonstrating the fast pace of the field.[125] In addition to this, academic scholarship takes years to research and publish, for example Myers' *Bio Design* was researched up to 2010 but was not published until 2012, by which time more was discovered and so the immediately accessible internet may be more useful in this context of debate.[126]

However, there is not a lot written in a critical sense on many of these independent websites and there is no control over what is published online. Some of the debates therefore offer only a superficial gloss, rather than valuable discussion and questioning. Chieza does not elaborate much on her projects on her website and so, because the *Faber Futures* webpages are so optimistic about the ongoing research, there is little room left for debate or doubt that bio-design and new forms of biology will be the answer to the unsustainable fashion industry problems.[127] Each of the projects is given a brief overview with a lot of pictures to accompany it, and there is no space for comments or interaction with viewers. 'The Fold' webpage alone has over 7000 views and yet there is no hint of what these thousands of people thought of the project and the idea of wearing bacteria-dyed clothing. While the aim may not have been to interact with the public and to simply provide a valid information source, the lack of reader opinions is to the detriment of the debate surrounding the project and the accessing of 'real' ideas and reactions.

Liz Stinson, of *Wired Magazine*, explains her reaction to the bacteria-dyed scarves by announcing, 'A few words I never thought I'd say: why, yes I'd love to wear this bacteria-covered scarf.'[128] This kind of (external to academia) potential consumer reaction to the bacteria-dyed fabric is vital to acknowledge because when it comes to design, the consumer is one of the most important aspects. By calling the scarf 'bacteria-covered' suggests some unease about its origin, but again it demonstrates how the garments might really be received and perhaps where marketing can be improved, for example. Stinson also explains that the dye is 'excretion' of bacteria which further

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124 Mufson (2015).

125 *BioFabricate* website (2015).

126 Myers (2012).

127 Chieza 'The Print Room' webpage.

128 Stinson (2015).

highlights her discomfort with it.[129] In theory, the disgust generated regarding chemical pollution by dye factories should be far worse than wearing harmless bacteria-coloured fabrics. It is all in the perception. The eco-friendly website *Global Cool* opens their article on *Faber Futures* with the optimistic line, 'Because standing out from the crowd doesn't have to cost the Earth…,' an attitude that bodes well for a positive reaction to Chieza's work.[130] However, there are no reader comments available again, and so public response is still widely unknown. In addition to this, the article builds up a positive profile of *Faber Futures* and the use of bacteria as a way forward for the fashion industry, although the optimism is short-lived as the webpage uses all the images from 'The Fold' project, in which the fabric takes on colour with bacteria grown directly onto it but the webpage describes the process of extracting the pigment to be used as dye in screen-printing, the process of 'The Print Room' project.[131]

It becomes clear that greater understanding is needed when it comes to Chieza's work before its application is billed as the next big solution to fabric dye pollution. Bio-design is about innovative design that can co-exist or even improve the environment as well as raise issues of ethics and the limits of science and technology, so it is important Chieza's work equally faces this scrutiny.

Case 4 - Algaemy

Creators and Creation

Essi Johanna Glomb and Rasa Weber are the duo behind the Berlin-based design studio Blond and Bieber. Glomb as a textiles designer, and Weber as a product designer, present projects that offer both practical design solutions and also a design narrative that explores the process and problems they intend to solve. In this vein, Blond and Bieber use textiles as their chosen method of expression as it offers a great deal of diversity, with textiles appearing in all aspects of life, all over the world. The two thus meet on the design borders and frontiers of textiles and product design.

Algae is commonly known as a weed and a nuisance but the Natural Sciences have long been exploring the benefits and uses of microalgae as an alternative source for things like energy and food production. However, its use within the realms of art and design has been relatively unexplored until now. Blond and Bieber collaborated in 2013, along with the *Fraunhofer Institute for Interfacial Engineering and Biotechnology* in Munich in order to take an aesthetic approach to algae. This resulted in the development of a way to print fabrics using microalgae, which they named *Algaemy*.

129 Stinson (2015).

130 *Global Cool* webpage (2015).

131 *Global Cool* webpage (2015).

The design duo created an 'analogue textile-printer' made from a wooden frame with a large printing wheel at the bottom which takes the production of the microalgae dye full circle in five steps *(in italics)* (Image 7). The algae is first *bred* by planting seeds in water, and then *fed* with sunlight and carbon dioxide (exhaled breath). Once the algae has grown to the right quantity, it is then *filtered* using a technique copied from Kenya whereby the water is drained using sheets of woven fabric (although in Kenya the drained product is then sold as a 'cake' food product at market). What is left is then *cooked* to create a paste which can be applied to the large *printing* roller on the bottom of the machine. The large roller has rubber patterns attached to it which can be changed for different effects as the machine can be driven over about 20 metres of fabric at a time.[132]

***Algaemy* and Fashion**

Blond and Bieber named their project *Algaemy* as it embraced a known, traditional technique of colouring fabric (alchemy) but explored what nature (algae) could provide to make it something that would not harm the environment, as an element of the unknown.[133] The project's discourse on fashion stems then from the design narrative of eliminating waste from factories that dye garments and pollute rivers.

Algae, like bacterial cellulose, are an abundant natural resource, occurring all over the world in huge quantities so are readily available as well as already harmoniously existing with the rest of nature, unlike the vast amounts of dangerous chemicals currently polluting rivers around dye mills. In addition to this, algae has thousands of species which can produce varying colours, without the need for synthetic biology, from the obvious shades of green to vibrant oranges and reds, so is unlimited in its colour palette and thus a viable competitor of chemical dye in the future.[134] Using a natural resource means that, in combination with a natural textile, the dye will biodegrade and return its nutrients to the soil, completing the design lifecycle. The duo calls their *Algaemy* project a 'design laboratory' in which research is carried out for the use of algae pigment in textile production.

Weber gave a TEDx speech in Hamburg and explained that the algae were a 'seemingly unappealing and unwanted plant' and as a weed, no one had really considered its potential for anything else, at least in the realm of fashion. In recent years, algae have been used for bio fuels and also nutrition in developing countries. If algae are suitable for use as food and for architecture, then there should be no reason why it cannot be suitable for use in clothing. Textiles are just as close to the body as food, and even closer than architecture so it is arguably the next move. Algae is one of

132 Weber TEDx (2015).

133 Blond and Bieber website and 'Bio-Design in Textiles' (2015).

134 Blond and Bieber at 'Bio-Design in Textiles' (2015).

the few species that thrives under the conditions of global warming as they like the higher temperatures and also higher levels of Carbon Dioxide as it helps them to grow.[135] This feature of algae means that it is only going to become more present in the world as a natural resource. Weber explained in her Hamburg TEDx talk that there had been algae plagues in both Germany and China, with the differences being only in its perception: in Germany 'war' was waged against the invading weed, but in China, the residents were oblivious and went swimming with the plants.[136]

It is this notion of cultural perception that shows how fashion design can change if we simply change our ideas of what is desirable and what is not. Algae have, until now, missed their aesthetic application and this is what Glomb and Weber have tapped into. Dried microalgae, which is how the scientists at the *Fraunhofer Institute* store the plant looks a lot like the pigments that are used to colour textiles and so from here the experimentation began for use in textile dyeing. There are actually around 60,000 species of microalgae in the world, but only one percent is used commercially at present, and Blond and Bieber currently research the use of only 15.[137] The use of microalgae therefore has a huge potential to change perceptions of colours, beauty and fashion.

Blond and Bieber discovered after making their first prints that the colours of the algae change when they are exposed to sunlight. For example, blue turned to green and red turned to yellow and so the colour palette was completely ruined, at least in conventional terms. Blond and Bieber turned this potential negative into a positive, however, stating that if we really consider how long we wear our clothes for, perhaps maybe no longer than three years, then there is no reason why the dyes and colours of our clothes should last for even longer.[138] The duo argue that the clothing would tell its own personal story, which would be valued much like old pieces of furniture that have aged with the weather or coloured with the sun.[139] There is an emerging theme with the work of Blond and Bieber, that is, one of changing common perceptions and beliefs about what design, craft, and beauty means, which becomes vital to accepting the narrative on the algae-printed designs as a fashionable future.

The *Algaemy* methods of production have real fashion industry applications as the duo collaborated with Berlin-based fashion designer Ylenia Gortana to create two looks for the 'Milk and Sugar' fashion show in 2014 (Image 8). The clothes were created without access to sunlight so that

135 Weber TEDx (2015).

136 Weber TEDx (2015).

137 Sayej (2014).

138 Weber TEDx (2015).

139 Weber TEDx (2015).

the colours did not begin their biodynamic transformation until they hit the runway.[140] This is an interesting process that may need adapting for commercial uses. In addition to this, Blond and Bieber have worked with the environmentally friendly and socially responsible German shoe brand *Trippen* in order to create algae-dyed shoes for the market.[141] Josephine Moulds, writer for *The Guardian* online 'Sustainable Fashion' segment, explains that actually when it comes to notions of eco-fashion, the smaller, up and coming innovative brands are those who provide the real future solutions.[142] In addition, Lizzie Harrison of London-based 'Sustain: Royal College of Arts' claims that most of the fashion industry is currently driven 'by compliance rather than innovation' with sustainability remaining the concern of big firms from the corporate social responsibility department rather than that of design, something that is a huge hindrance to real change.[143] It is thus left to those companies who are able to overhaul the whole system and start again from the beginning in order to totally eliminate waste and pollution from their design cycle. There seems to be a greater focus on reduction of environmental impact with current industrial production methods in the fashion industry rather than on changing methods in order to totally eliminate it and so Blond and Bieber's collaboration with existing brands demonstrates how their work might fit into more 'average' companies.

With the technology and processes behind *Algaemy* still in developmental stages, it will be some time yet before the products reach the mainstream market. The duo is keen, however, for their method of dye to reach the market as soon as possible, illustrating their drive for a more sustainable fashion industry.

Current Debates

The majority of articles, blog-posts and webpages devoted to the *Algaemy* project are written in 2015, with increasing numbers continuously appearing as more and more people discover it. Because the project is so new, of course it is not to be found in major, if any, bio-design publications like that of Myers.[144] Even the majority of online articles are so new and undiscovered, that they do not have comments yet. It is therefore quite difficult to estimate the reactions to the project and to comprehend how it can move forward in the real world. For now, a top priority is for the concept to

140 Domus (2014).

141 Morgan (2015); also *Trippen* website.

142 Moulds (2015) March.

143 Moulds (2015) March.

144 Myers (2012).

travel and the ideas surrounding untapped resources to change in order for the possibilities of renewable and sustainable resources to become, quite literally, endless.

With regards to the changing colours, there are some clear benefits and disadvantages. This unpredictability has been spun well by Glomb and Weber, but ultimately, at present at least, predictability in clothing as it is worn, is a desired feature. For example, if you step out of the house wearing brown and green and then finish the day wearing red and blue, it may cause a sartorial problem. Unpredictability is not something that we bargain for in our current fashion choices. At the *Textiel Commissie* 2015 'Bio-Design in Textiles' Symposium, the idea that the colours changed in the sunlight was met with much scepticism by older, established designers, scholars and museum curators alike, which demonstrates this idea of the 'dinosaurs of design' Weber refers to in her speech in Hamburg.[145] Change is required before extinction. The idea that clothes tell a story is a little too romantic perhaps at present but of course if we can be convinced that wearing microalgae is good then these ideas may also eventually change. On the TEDx Innovations page on *Algaemy*, one reader commented asking whether the colours of the algae would also change with regards to body temperature, for example.[146] This is something that could also have medical implications and so it is important that ideas like these are shared with the designers and the public in order for the project to advance. These key debates are really still missing from the project as a whole.

The dye is so natural that the waste product could actually be eaten. On the design duo's website, the *Algaemy* project's full title is '*Algaemy* – crafting our future food' which shows the many applications the product can have, with no waste of the product at all. Natural dyes that use vegetables are often criticised for wasting food resources, so the use of algae as both an abundant food resource and clothing dye goes some way to counter this.[147] This idea is echoed with the optimistic *Dezeen* title of 'Blond and Bieber's dyes made from Algae "don't harm nature at all."' Blond and Bieber have really closed the design loop and even when there is a potential for waste product it can be eaten or left to decompose naturally. Ben Hobson, of *Dezeen*, explains that the dyes are non-toxic and reiterates the notion that nature is not harmed at all in the process, a vital aspect of the design that could really impact on the fashion industry.

One large problem that is not highlighted within the research of Blond and Bieber is that whilst it is theoretically possible to harvest algae from the nearest pond, the duo explain that using this method, you never get pure species and so the colour is less predictable and 'clean.'[148] It is, in

145 Weber TEDx (2015).

146 Reissman (2015); comment of 'Jennie Bisese.'

147 Fletcher and Grose (2012) p.43.

148 Sayej (2014).

fact, only possible to get the vibrant, crisp colours that they have produced from laboratory conditions and so at present they are still using samples of microalgae from the *Fraunhofer Institute* rather than obtaining it straight from nature. This poses a problem when looking at how using algae can combat the problems of global warming and algae plagues. If the vibrant colour palette of microalgae can only be produced by creating even more algae in laboratories then the natural, non-polluting factor remains but the idea of using an abundant, existing resource is somewhat lost.

An interesting idea arose from the online articles from architect and materials researcher Blaine Brownell for *Architect Magazine*, in that the way that the photosensitive colours change on the fabrics can be deemed a bio-designed and natural response to the smart textiles currently flooding the market.[149] A lot of the current fashion futures scholarship covers these kinds of technological developments rather than issues of sustainability, with debates centred on notions of electronic sensors and mechanisms for independent movement, or even lights incorporated into garments.[150] These advances in fashion are still contributing much to waste and environmental destruction as they are still using polluting chemicals and plastics in their production. Humanity might be technologically advancing, but this won't matter if there is no planet.

Brownell calls Blond and Bieber's *Algaemy* design innovation a 'low-tech alternative,' raising the intriguing point that bio-design could offer smart textiles a different future in fashion. Incorporation of electronics into fashion has even been included in mainstream publications such as *Vogue UK* and with the arrival of the Apple watch in 2015, there has been even more talk about how technology can become part of fashion and keep up with our growing obsessions with social media and internet advances.[151] However, these highly polluting advances with built-in obsolescence generate even more toxic waste and so creating materials with in-built responsiveness from naturally occurring organisms could be the start of combatting this. Glomb explains that their textiles 'will become a part of communication' which seems to illustrate this idea going forward.[152] The future of fashion is evidently multidisciplinary and simple colour changes will seemingly have multiple applications.

CHAPTER 4: ANALYSIS

149 Brownell (2014).

150 Quinn (2012).

151 Armstrong (2015) p.252-255 and 286.

152 Epstein (2015).

As has become evident in the context of environmental sustainability and fashion, the entire fashion system needs to be overhauled and replaced. Changing and adapting just a few isolated parts of the system can no longer be maintained if the future of the planet is to be taken seriously.[153] It is clear from the above four case studies that there are potential ways of realising this. Bio-design throws aside the current system materials and processes and wholly takes up both inspirations from natural processes as well as incorporating living things into the end product to ensure optimum fashion usage and minimum environmental impact.

Environmentally friendly clothing is often associated at present with the somewhat uncolourful and unfashionable hemp and dull, unbleached cotton, but the case studies above have demonstrated that this need not be the case.[154] The vibrant colours created by Chieza and Blond and Bieber alone demonstrate the possibilities that bio-design and synthetic biology can bring. Lee's conventional jackets made from bacterial cellulose and dyed with vegetable colourings also show how the new materials do not necessarily mean a fashion system *style* overhaul, and so may encourage more favourable opinions. The *Victimless Leather* jacket crosses the bio-art/design boundary and so illustrates the possibilities available to the currently heavily destructive fashion industry, but also invites viewers to ask moral questions associated with exploitation of others at the expense of fashion. The scaled down production demonstrates its step back from the standard models of the fashion industry at present. Perhaps the incompatibility of bio-design and current industry standards is actually exactly the point.

In the same vein of industrial standardisation, all of the case studies encounter problems of scaling up production as a hindrance to further progress. Lee has currently abandoned her bacterial cellulose project, citing the scaling up of production and potential use of genetic modification as the main reason. At present the *Victimless Leather* jacket is made on a miniature scale and while there are still experiments going ahead with *Modern Meadow* to create large scale leather productions without the use of 'real' cows, there is still the problem of the use of foetal bovine serum as well as the fact that it will be a long time yet before tissue engineering can create enough 'artificial' leather to meet current leather demands in the global market. At the same time, Chieza is still experimenting with lab-sized petri dishes, and Blond and Bieber use a simple hand-made production trolley to create one-time prints.

The notion of do-it-yourself fashion may be what carries these designs forward, especially with regards to Lee's *BioCouture* and Blond and Bieber's *Algaemy*. Lee already has a recipe for her bacterial cellulose available online, while the abundance of algae in the world would allow for

153 Fletcher and Grose (2012) p.11.

154 Fletcher and Grose (2012) p.33.

anyone to follow the *Algaemy* production process of drying, cooking and printing using the wild algae colour pigments. Chieza's bacterial dye could also eventually be something available in the home in the future. Scaling up production is a current industry desire for these bio-designed products as it fits with the machine age, mass-production model of consumption. However, bio-design has the potential to change the perception of mass-consumption to be regarded as something on a 'mass-individual' level in the home. This method allows the product to also be the machine, in an ultimate triumph of nature.[155]

The four cases have shown that they can combat a number of issues of the fashion industry at present. For example, if the taste for throw away fashion shows no signs of waning, perhaps the use of materials that can completely biodegrade with vegetable peelings is one answer to this problem. Lee's *BioCouture* bacterial cellulose, as well as the *Victimless Leather* tissue culture, is made from entirely naturally occurring, harmless living materials, and so when they are no longer required, they can be thrown out to decompose and return their nutrients to the ground. If these materials can be dyed using *Algaemy* techniques or Chieza's bacterial dye then the fashions are colourful as well as biodegradable and the bio-design fashion production cycle is complete. Incineration, re-use and sending clothes abroad would also be rendered unnecessary. Recycling will take on a new definition as living materials will be able to be re-used infinitely as they are taken and given back in equal quantities. By using this bio-designed fashion system, waste can be eliminated as the cycle is entirely thought out from the start. 'Waste' from one stage of the process will feed the next until it comes full circle.

The continued blurred line between bio-art and bio-design is another facet of the case studies that encourages debate and requires further analysis. *Victimless Leather* as well as the *Faber Futures* project was commissioned for museum display and so the question is necessarily raised of whether they are truly meant to be seen as critical design solutions for the future of fashion or whether they are merely there as rhetorical devices to provoke reactions and questions. Chieza and Blond and Bieber write on their respective webpages that their designs are the work of the future and believe that they are crafting future design solutions for the fashion industry. Chieza projects her work to 2075, while *Algaemy* is billed by its creators as the future fusion of food and fashion. Lee includes bacterial cellulose in her book *Fashioning the Future*, so must also believe that there is a future practical application for the eco-material outside of museum view. The context for these design solutions is therefore vitally important with regards to reception.

Museum displays suggest that the project is rendered more as an artwork, there to evoke intrigue and debate, whereas fashion shows, for example, demonstrate that there is a strong pull

155 Ginsberg et al. (2014) p.x.

towards the real world of fashion, as with Blond and Bieber and their collaborations with established designers. It could also be argued that it is this blur of artist-designer-scientist that means context no longer matters. *Victimless Leather* was meant to make a statement about the exploitation of the 'Other' in the world of fashion rather than present a fashion materials technology for the future, but the technology was taken up seriously by artist-designer-scientist company *Modern Meadow*. Regardless of whether the work was created purely as rhetoric or not, is often beyond control. There are ethical considerations that come with the design and art works, and this is an area for further exploration. Ultimately, the notion of the 'design lab' may be an apt way of looking at the production processes and arena for display when considering the artist-designer-scientist hybrid of bio-design and future fashions.

Conclusion

The emergence of the environmentalism movement has evidently come a long way since Carsons' 1962 *Silent Spring* publication, and while fashion was late to join the trend, there is still time and potential for it to make its mark. The Fashion industry is still undoubtedly highly polluting at every stage of its existance from production through to disposal, with the time between these two ends becoming increasingly shorter with the growing desire for 'throw-away' fashion. Current efforts of using water-reduced productions and policies of dyeing right-first-time are no longer sufficient. If the current over-dependence on non-renewable resources does not end, as the population increases there will not be enough resources or planet to go around. There is clearly a fundamental requirement for change to the current processes of the fashion industry if the planet is to be saved. Large fashion brands such as *Gap*, *H&M* and *Marks and Spencer* have already attempted to clean up their acts, but it comes merely as a social placebo for the 'internet generation' who believe that by buying organic or fair trade cotton, their duty to sustainable practices is complete. Water pollution, and dye contamination are not perceived in this 'guilt-free' purchase. The ingrained selfishness of the fashion industry at present is not compatible with the intergenerational selflessness required of sustainable behaviour. This is where bio-design can intervene.

Bio-design uses the various aspects of nature, be it biomimicry, living materials, bio-technology, or synthetic biology. All of these facets have the same thing in common; they incorporate nature as the ultimate guide to survival. This thesis has shown that there is a great potential with the use of bio-design in the fashion industry to create a total fashion system overhaul. It is vital that it is understood that not only small aspects of the system can be changed. It is now much more important to change the whole system so that it can become cyclical and closed off from toxic waste production. Consideration of the whole cycle before it begins is imperative. Bio-design is still a relatively new field of design and the artists and designers that I have considered in this thesis are all aware of the long road ahead before bio-designed fashion can be fully incorporated into 'real' situations. However, this does not remove from the design field's potential to overhaul the industry. It can no longer be denied that nature and her processes are the key to creating long-lasting design that will also save the planet.

The four chosen case studies are just the start of things to come and at present only offer an insight of how the entire workings of the fashion industry might be adapted in the future. Of the four case studies, two incorporate synthetic biology and two simply use living materials and existing natural processes. Of each of these two subdivisions of bio-design, one of each was related to materials processes, and the other to fabric dye. This demonstrates the far-reaching applications that bio-design can have to the fashion industry. However, it is still largely to the detriment of sustainable

fashion that fashion design and bio-design seem to be so disparate at present. When the bio-dye techniques of *Algaemy* and *Faber Futures* are considered in combination with the materials production of *Victimless Leather* and *BioCouture*, the possibilities of bio-design to be a real fashion system contender are really seen. Colours are vibrant and materials are biodegradable, while everything is renewable and in harmony with nature. The key to environmental success with all four of the design solutions is that they do not take, what they cannot give back, at least in terms of vital nutrients.

The continuing discourse between bio-art and bio-design can only help to further debates and encourage exploration and education with regards to these new bio-technologies and uses of living materials as methods for creating sustainable futures. It is important that considered action is taken and that consumers do not simply sit back and remain unquestioning about the future of the planet and the impact that their behaviours have on generations to come. The blurring boundaries between science and the arts demonstrates how interdisciplinary bio-art/design is and perhaps also shows that solutions to the global problems can only be solved when everyone comes together.

This thesis does not include research into the perils of bio-design and the dangers associated with bio-destruction and abuses of the new design paradigm. This deliberate exclusion of this side of the debate was intended to first show bio-design in a positive light for the fashion industry.
Bio-design and fashion are currently so niche that the purpose of this thesis was to demonstrate the potential constructive change bio-design could have for the fashion industry rather than to shut its possibility down before being given a chance. The bio-ethics of using bio-designed fashion, would make for interesting further research, however.

Another area for further research is the more conceptual bio-design work, such as Amy Congdon's *Biological Atelier*. The case studies I chose are based on existing technologies, whereas Congdon's research is purely conceptual and is therefore based on ideas of what might be possible in the future. Speculation has the potential to drive innovations, which may also be highly beneficial for the fashion industry. One final topic of further discussion might be that bio-design and the design revolution in general may need to be culturally directed.[156] For example, in the western world where throw-away fashion has become ingrained in the culture, perhaps fashion garments that biodegrade after a few months are what is needed; and in the developing world where there is a lack of fuel for cooking and keeping warm, garments could be designed to be safe for burning after use.

There are a lot of uncertainties when it comes to the suggestion of such a revolutionary system overhaul, but when everything is considered, the use of bio-design in the fashion industry seems a clear choice in order to make the fashion industry truly sustainable. Nature has provided the

156 McDonough and Braungart (2002) p.140.

processes and materials for survival of the human race and it was working against nature that led to the gradual destruction of so much of the environment. Bio-design allows for the fashion industry to copy nature's processes and incorporate her materials in order to create a life-cycle, rather than a life-span, eliminating waste and inefficient practices such as incineration. *Victimless Leather*, *BioCouture*, *Faber Futures* and *Algaemy* have all been shown to demonstrate how the fashion industry can adhere to the policies of nature and create a zero-waste system. The current fashion system is fatally flawed and bio-designed fashion products aligned with nature are the only way that the planet might not also become a 'fashion victim.'

Appendix of Images

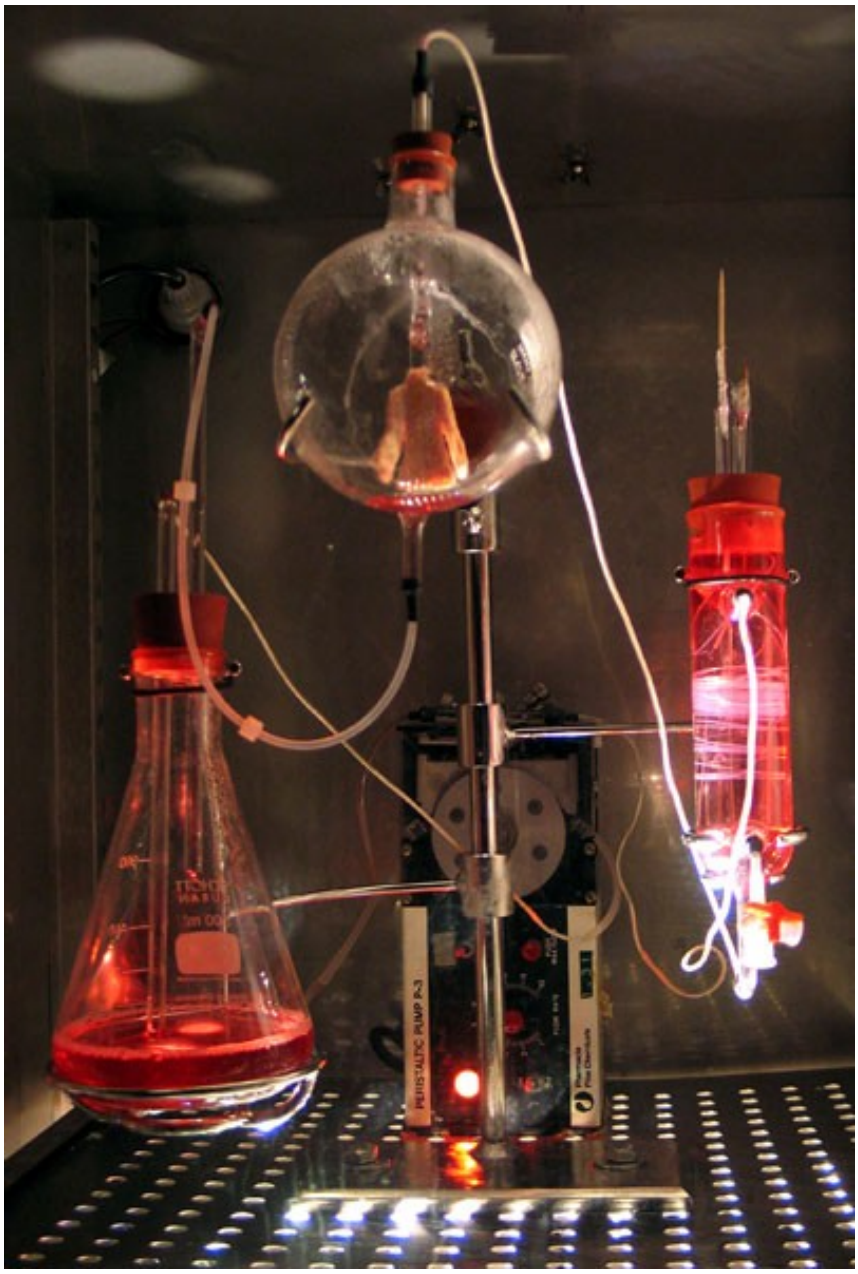

Image 1: Tissue Culture and Art Project, Oron Catts and Ionat Zurr, 'Victimless Leather' Installation, Photograph: Tissue Culture and Art Project

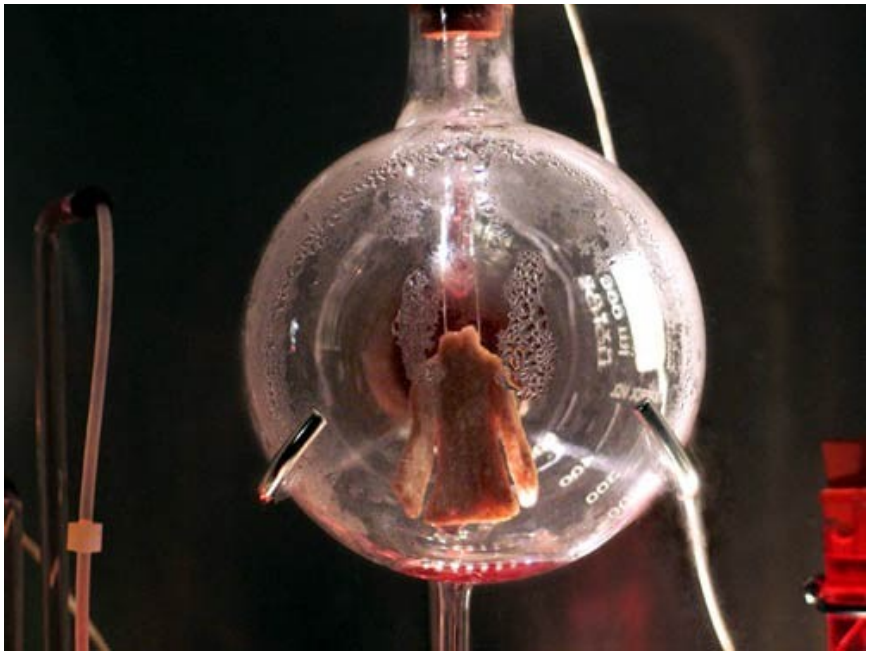

Image 2: Tissue Culture and Art Project, Oron Catts and Ionat Zurr, Close-up of ‘Victimless Leather’ jacket, Photograph: Tissue Culture and Art Project

Image 3: Suzanne Lee, bacterial cellulose production, Photograph: BioCouture

Image 4: Suzanne Lee, selection of bacterial cellulose jackets, Photograph: BioCouture

Image 5: Natsai Audrey Chieza, Faber Futures: Rhizosphere Pigment Lab silk in petri dishes, Photograph: Natsai Audrey Chieza

Image 6: Natsai Audrey Chieza, Faber Futures: Fold printed silk scarf, Photograph: Natsai Audrey Chieza

Image 7: Blond and Bieber, Rasa Weber operating the ‘Algaemy’ printing machine, Photograph: Lukas Olfe/Blond and Bieber

Image 8: Blond and Bieber, ‘Algaemy’ printed dresses, Collaboration with Berlin designer Ylenia Gortana for ‘Milk and Sugar’ Fashion Show 2014, Photograph: Lukas Olfe/Blond & Bieber

List of Related Projects

Whilst conducting my investigative research into sustainability and bio-design in combination with the fashion industry, I came across many related projects aside from those four selected case studies for my above-written thesis. As a useful departure for future research for both myself and others interested in the field of bio-designed, sustainable fashion projects, I have compiled a comprehensive, but not exhaustive, alphabetically ordered list of those projects and, where possible, their respective websites. All webpages last accessed 08/12/2015.

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- Laurel Katz (1994) 'The Spotted Marino/Hooked Beetle Sweater Production System' (beetles trained to walk on sheep, catching wool and weaving sweaters) http://bombmagazine.org/article/1827/the-spotted-marino-hooked-beetle-sweater-production-system-annually-yielding-three-sweaters-of-unparalleled-quality
- Tobie Kerridge and Nikki Stott (Royal College of Art) and Professor Larry Hench and Dr Ian Thompson (Imperial College Tissue Engineering and Regenerative Medicine Centre), 'Biojewelry' made from grown bone mass http://www.tobiekerridge.co.uk/# ; http://news.bbc.co.uk/2/hi/science/nature/4070522.stm
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- Martin Margiela '9/4/1615;' deconstructed fashion dyed with coloured bacteria, Boijmans Museum, Rotterdam (1997)
- *MediaMatic*, Biological art and design research and education, Amsterdam http://www.mediamatic.net/
- Oliver Medvedik, *Bioworks Institute*, 'Living Watch;' Myers (2012) pp.134-5.
- Koert van Mensvoort, *Rayfish Footwear*; fictional project using genetically modified rayfish that consumers could design for their own unique sneakers http://www.mensvoort.com/home/rayfish-footwear ; http://rayfish.com/ ; https://www.nextnature.net/projects/rayfish-footwear/
- *Modern Meadow*, tissue engineering for creation of meat and leather without killing animals http://www.modernmeadow.com/#home
- *Nano-Tex*, fabric finish that repels stains http://www.nanotex.com/

- Bernhard Schipper, Bacterial Cellulose for textiles *SCOBY Tec* (Symbiotic Colony Of Bacteria – Yeast) (University of Art and Design, Halle) http://scobytec.tumblr.com/
- *Schoeller*, 'NanoSphere' prevents dirt sticking to fabrics so they need less washing http://www.schoeller-textiles.com/en/technologies/nanosphere.html
- Ryan L. Smith and John Bissel, *Bio Plastic* (microorganisms that turn waste into plastic); Myers (2012) pp.102-103.
- Helen Story and Tony Ryan, *Catalytic Clothing*; garments containing photo-catalysts that create an anti-pollutant surface that purifies the surrounding air http://www.catalytic-clothing.org/
- Helen Story and Tony Ryan, *Wonderland* (2008); ten dresses that disappear http://www.helenstoreyfoundation.org/pro7.htm
- Manel Torres, *FabriCan*; spray-on fabric http://www.fabricanltd.com/
- Christofer Toumazou, *Geneu* skincare range based on individual DNA sequence, London http://geneu.com/
- Professor Fritz Vollrath and Dr David Knight, *Oxford Silk Group*, spider and natural silk biological research http://users.ox.ac.uk/~abrg/spider_site/index.html

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