

Material Microbes:
A Designer's Colony of Colour

Sarah Hickey



Material Microbes

A Designer's Colony of Colour

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Title:

Material Microbes: A Designers Colony
of Colour

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AUT Statement

This exegesis is submitted to Auckland
University of Technology for the Degree,
Masters in Design

Acknowledgments

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I owe my deepest gratitude to my primary supervisor Associate Professor, Dr. Amanda Smith. Without your knowledge, guidance and support this research would not have been possible. It was a great honor to work under your supervision.

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Question

What is the potential of localised microbes as colourants for the textile industry and can they provide an alternative to traditional methods of textile dyeing?

Abstract

History has shown a progressive shift from natural dyes derived from organic compounds to the complex chemically focused dyes found in most textiles today. Dangerous dyeing processes have led to the deterioration of our environment in the 21st century. It is my understanding as a textile designer working across the disciplines of biology and design, that 'living' systems found in nature can revive sustainable dyeing practices. Extracted from the New Zealand landscape, pigment-producing microorganisms are applied to knitted textiles establishing a dialogue of colour, revealing the importance of protecting and preserving these biodiverse ecosystems for the future.



Material Microbes: A Designers Colony of Colour unearths 'living' material systems as colourants for textile outcomes. As an emotive designer, the issues addressed respond to the pressing environmental crisis, and call into question the resources, processes and pollutants of industrial textile dyeing. Synthesising across disciplines, this research utilises traditional knitting techniques as a canvas for biological networks. Hand 'painting' microbes, submerging swatches, and forming microbe dye baths establishes innovative methods of dyeing knitted structures. While the main approach to this research is to establish colour, as discussed in the final section *Colour Membrane* it is also significant to establish a deeper understanding of the manipulating properties of agar media, in the *Agency of Agar* and to delve deeper into the bacterial compounds connectivity to textile substrates through the *Material Membrane* section of this research.



Introduction

The emergence of researchers addressing issues of sustainability has established a multi-disciplinary dialogue, forming a paradigm shift that offers true potential in challenging the aesthetics of design practices (Ginsberg, 2010). Biodesign¹ is a hybrid of disciplines, merging diverse biological systems with design concepts (Myers, 2012). It encapsulates 'living' systems to inform design practice, intersecting technology, biology and design. This new species of biodesign looks beyond the past misconceptions of 'green' or 'biomimicry' models to engineer inherent qualities found within nature (Chieza & Ward, 2015; Collet, 2012,). For designers, inserting nature into design has the capability of taking on different identities; moulding new materials, structures, finishes; and producing innovative compounds (McDonough & Braungart, 2002).

“Virtually every problem that we currently face – whether it is producing energy, finding fresh water or manufacturing benign materials – there will be numerous examples in nature that we could benefit from studying” (Pawlyn, 2011, p. 1).

In an age of technology, restoring faith in designers must come under a new social contract. According to “The Synthetic Kingdom” (Ginsberg, 2010), designers have saturated and exhausted design outcomes, driving the need to connect to the natural world around us, especially with raised awareness of continuous issues being caused by the advancements of climate change. The depletion of fossil fuels and loss of habitual landscapes is at the peril of attention-seeking artificial technologies that shadow the organic approaches (Hill, 1997). “While environmental degradation continues there are also unprecedented signs that we are beginning to embrace a ‘Great Transition’ toward an ecologically sustainable future” (WWF Living Planet Report, 2016, p. 6).

A dialogue of colour has long been deep-rooted in our cultural landscape, grounded in the traditional Māori craft of pigments and dyes, but “with the profusion of artificial colourants so familiar to us today, we forget the ingenuity of our ancestors from many cultures who discovered how certain

coloured natural substances could be fixed or bound to objects” (Smith & Te Kanawa, 2008, p. 1). This research employs the underlying morals of the Kaitiaki², creating a connection with the world around by establishing bacteria patterns on fabric. This research explores the intersection of biology and design with the aim of answering the research question: What is the potential of localised microbes as colourants for the textile industry and can they provide an alternative to traditional methods of textile dyeing?

The toxicity levels of human-made dyes evokes the need for designers to better understand the ways in which sustainability interfaces with an indigenous cosmology and the idea of human connectivity to the land through the need to develop sustainable dyeing practices (Te Kanawa, 1994). Evolution has seen a shift from natural dyes derived from plants and minerals to the use of synthetic substitutes; the implications of this adaptation have grossly contributed to our environmental crisis (Smith & Te Kanawa, 2008). Dynamic cross-disciplinary researchers question this destructive model of dyeing and draw back to a pivotal concept of sustainability (Narsing Roa et al., 2017). Concerned by the narrowed approach to design thinking, this research paper demonstrates diverse applications of biopigments³ to hand-knitted textiles (Keune, 2018).

This research works in an interdisciplinary nature across both design and bioscience, disciplines which have underpinned the mixed methodological approaches to the research conducted in this study. In identifying the interdisciplinary nature of these disciplines, “one can say that scientific and artistic practices share epistemic potential in that they challenge common assumptions, question installed systems, and criticize fixed patterns of thinking” (Schindler, 2015, p.3). Consequently, this body of work discusses the potential of harnessing microbial biopigments (bioscience) for the application of textile knitwear (design). In addition to discovering and developing an innovative method to dye textile knits, this research also explores the relationship between *Fibre and Fabric* and the *Agency of Agar* on the final microbe⁴ pigmentations grown.



Methodology



Research Paradigm

This research merges a designers' inherent, tacit knowledge with biological processes, procedures and tools. This is recognised in an approach to biodesign. In this research, which generates discovery through action-based research, a hybrid of methodologies, which all draw from an action research methodological approach, has been employed to develop this research.

Critical in this research being able to move beyond the speculative and step outside the constraints of a designer's tool box, applying a hybrid of methodologies was necessary. Researching across both scientific and practice-based paradigms, the application of action-based inquiry was mandatory. This section of the exegesis discusses how this approach was applied to generate discovery and develop my work.

As Kuhn (1996) suggested, "to reject one paradigm without simultaneously substituting another is to reject science itself" (p. 79). However, by seeking to synthesise across

disciplines, as Myers' (2012) concept of biodesign looks to do, perhaps true innovation may be obtained. Research for this project recognises Myers' biodesign paradigm, enlisting both scientific and practice-based disciplines. Myers describes this paradigm as a "radical approach to design that draws on biological tenets and even incorporates the use of living materials into structures, objects, and tools" (Myers, 2012, p. 8). In *Material Microbes: A Designer's Colony of Colour*, 'living' systems inform practice. Inherent understanding of textile forms and acquired knowledge of biological systems reveals 'living' colour (Venil, Aruldass, Dufossè, Zakaria, & Ahmad, 2014). This thesis parallels the creative attributes of designers, producing an inquiry of qualitative potential through the use of pigment-producing microorganisms. It provokes a need to challenge systems of thinking and speaks to a wider community of biodesigners (Kretzer, 2017; Myers & Antonelli, 2014).

Action Research

Undertaking a hybrid of research across disciplines, I have employed a methodology that allows for growth, experimentation and development of ideas. Action research explores the integration of cross-disciplinary methods, challenges current assumptions of practice and builds a common vocabulary between the two disciplines (see also Tröndle et al., 2011). As discussed by Professor Reg Revans (1972), the formula of action research states that learning $L=P+Q$, where L is the outcome of learning.

“The fundamental difference in action learning is that there is small amount of ‘P’ – programmed knowledge – and a large amount of ‘Q’ – the ability to ask penetrating questions”
(Revans, R. (1984). Action Learning- Introduction by Reg Revans [Video file]).

The $(L=P+Q)$ approach to this research is appropriate to building on existing knowledge and seeking new frontiers of design systems

through insightful questioning. It is critical for this research to develop a balance between action and learning, reiterating Reg Revans’ (1998) remark that “there can be no learning without action and no (sober and deliberate) action without learning” (p. 83). Therefore the implementation of an action learning methodology allows for a collaborative inquiry across both science and design, posing new questions and promoting reflection (Raelin, 2001; Yeo & Nation, 2010).

Schön’s (2008) conceptual framework of reflective practice discusses that the need to reflect is as important as action itself. Schön’s framework creates a double-loop learning method through which reflection in and on action can take place to create a research movement and outcome. It is in this form of reflective practice that I can achieve “a dialogue of thinking and doing through which I become more skillful” (Schön, 1983, p. 31). This method of reflective practice can lead “to an understanding of experience that may have been overlooked in practice” (Raelin, 2001, p. 68). For me as a practitioner, the informed choice of adopting biological processes and procedures meant the ‘making’ emerged through scientific finding. Materials and ideas merged across disciplines in real experiments, allowing for a community of inquiry.

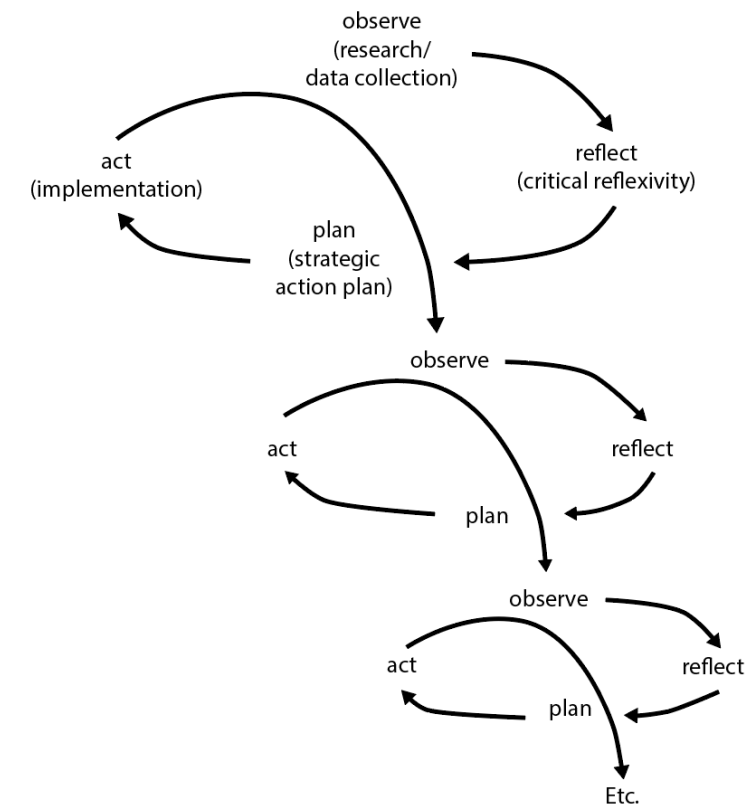


Figure 8:
 O’Leary, Z (2005) Researching
 Real-World Problems: A Guide
 to Methods of Inquiry. London:
 Sage. Chapter 9

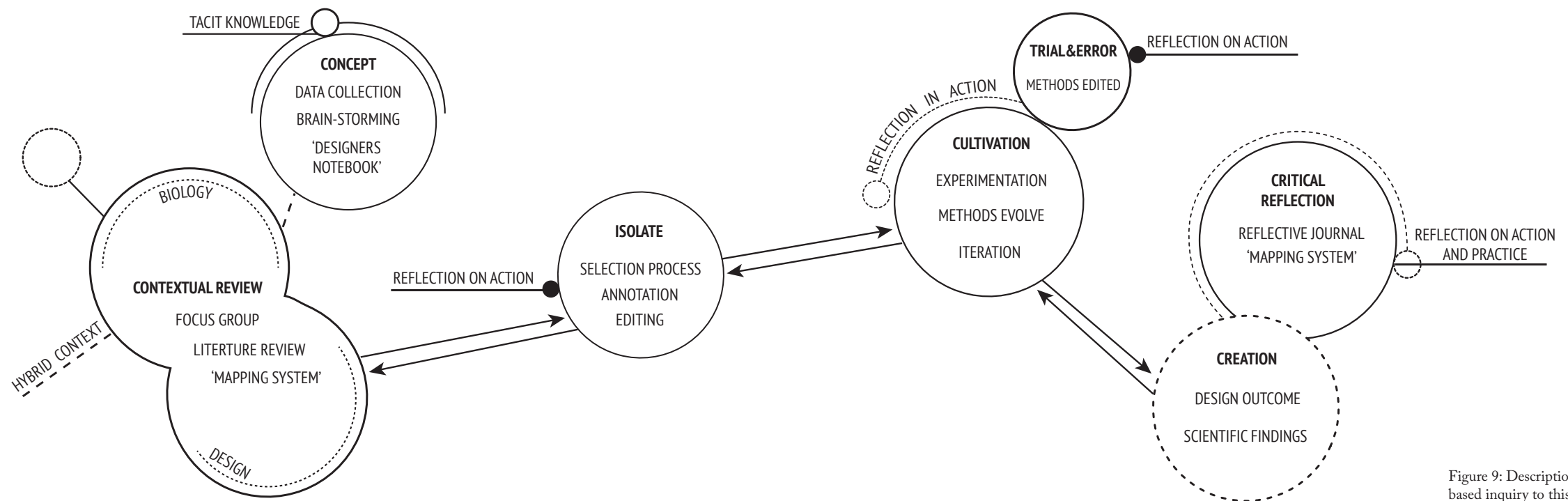


Figure 9: Description of action based inquiry to this research.

Methods of Practice

To display how an action-based inquiry has been employed in this hybrid research, I have designed a matrix diagram (see figure 9). The procedures, processes and tools are employed across the disciplines of biology and design. “Such interdisciplinary projects are challenged by the tension between latent and manifest forms of knowledge” (Schindler, 2015, p. 2). To articulate this knowledge clearly, the *Concept* phase expands inherent skills and scientific methods to formulate a ‘brainstorm’ of ideas. Visually this produces a clear pattern of collated factual knowledge and artistic findings

The use of a ‘Designers Notebook’ allows for active notes, sketching, photos and inspiration to consolidate methods of practice. An inquiry process of filtering and contextualizing knowledge to collate practitioners, artefacts, photos, and methods relevant to the research helps to determine the scope of current knowledge. Through visual documentation and self-discovery of methods, the growth from

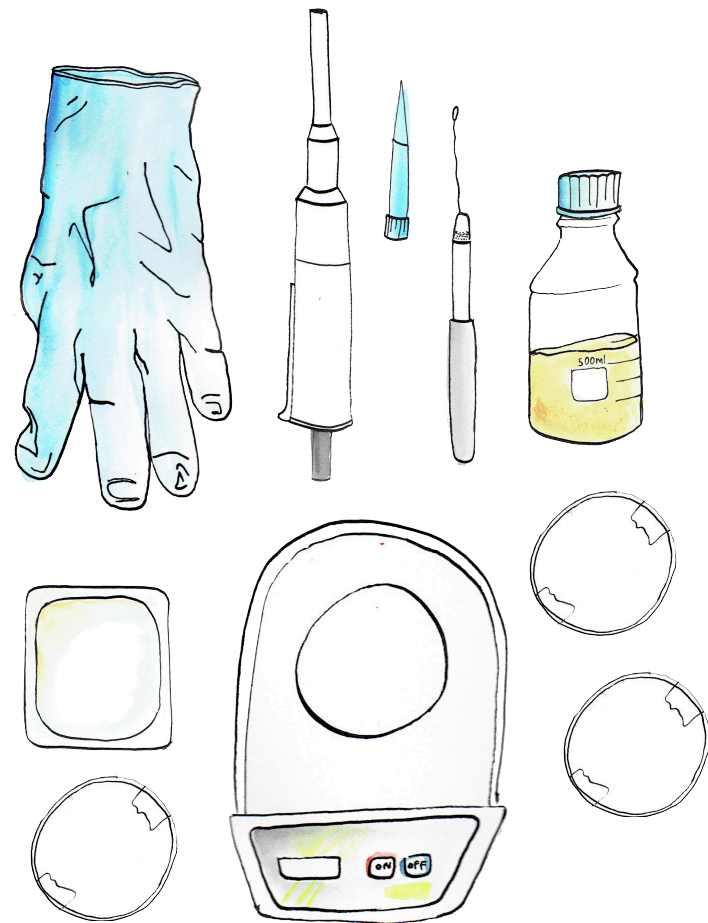
concept to contextual review reveals a clear focus. Tacit knowledge of textile knitwear merges with organic biological systems, which were developed in the laboratory setting. The ‘Contextual Review’ forms bonds with industry researchers, and differentiates this growing discovery and framework. “The integrative use of artistic and scientific practices demands a high level of communication in order to translate between the disciplines, discuss different perspectives, and develop a common vocabulary necessary for joint work” (Schindler, 2015, p. 3). The use of diverse methods systematically across both disciplines provides the ability to produce a visual diary of methods, mistakes and outcomes (see figure 7). This is fundamental to integrating scientific findings with design outcomes. Research manuals produced by organisations such as Faber Futures and AlgiKnit provided a deep exploration into the hybrid nature of this research.

Polanyi’s (1966) concept of tacit knowledge considers that “we know more than we can tell” (p. 4) and illustrates the idea of habits and culture that we do not recognise ourselves (Nonaka, 1994) may spontaneously be applied within our works. Central to this idea is that tacit knowledge could be defined as “fundamentally unfinished critical reflection” (Borgdorff, 2009, p. 79). Stimulating my own individual aesthetic of practice through the application of tacit knowledge and the development of scientific knowledge allows ideas to be edited and ‘isolated’. Tacit skills of hand knitting expand on industry knowledge and merge with the idea of ‘Slow Fashion’. This connection to organic and inherent skills is discussed further and in depth under *Fibre and Fabric*.

Methods evolve through iteration and self-discovery. Emerging patterns of pigmented microorganisms are identified through biological processes in laboratory conditions.

The cultivation or growth of this idea develops through experimentation. New discoveries can be described as “individuals engage to explore their experiences in order to lead to new understandings and appreciation. It may take place in isolation or in association with others” (Boud, Keogh, & Walker, 1985, p. 19). This research idea is central to *The Agency of Agar* section discussed through this body of work, which reveals methods and outcomes conducted from a designer’s perspective, but with aspects of embodied scientific findings imbedded. An example of this is the ‘Microbes & Material Charts’ which form recipes of colour; a self-discovery of hues, colour, and pigment. These examples embody scientific findings through design media as seen in figure 42.

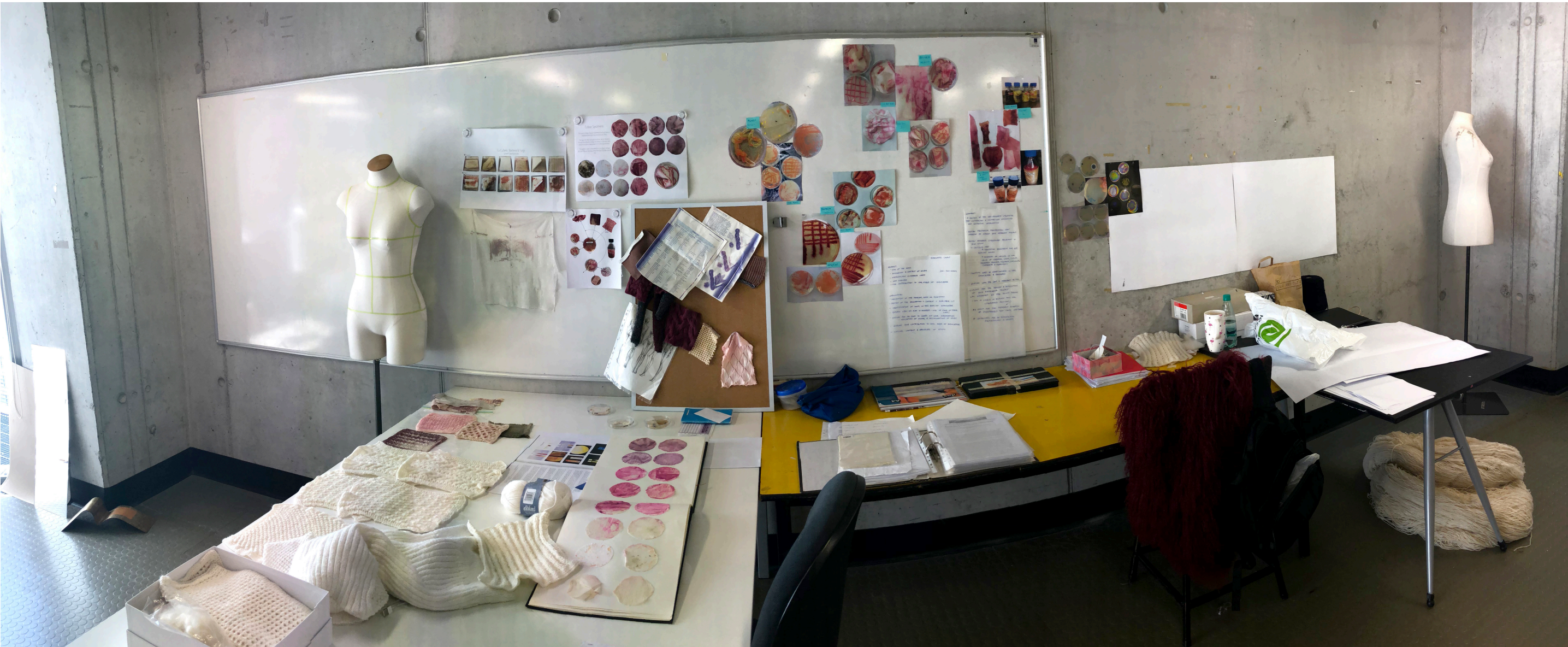
The term ‘Trial and Error’ is loosely used to explain ‘Discovery Through Action’. The outcome may not present the desired results; however, it allows for reflection-on-action to



take place. Spontaneous decisions made in-action reveal new questions and discover new outcomes. This system of inquiry must therefore employ both constructive and critical reflection. “The outcome of reflection may include a new way of doing something, the clarification of an issue, the development of a skill or the resolution of a problem” (Boud et al., 1985, p. 34).

Across disciplines, an outcome may be determined differently. In contrast to design, scientific processes hold potential challenges in providing experimental knowledge. Scientific processes rely on routine practice, whereas design is open to interpretation and conceptual ideas (Schindler, 2015). Challenging existing systems of scientific practice through trial and error generates various methods, processes and reveals innovative tools of inquiry (Keune, 2018). Through trial and error, the designer-perceived limitations within the scientific protocol can be tested. The integration and manipulation of scientific protocol in the form of prototyping and notetaking expresses the growth, ultimately, of both scientific methods of discovery and design thinking.

The understanding of artistic craftsmanship can be interpreted as “unspoken and uncoded words, that occurred [in the workshop] and became a matter of habit, the thousand little everyday moves that add up in sum to a practice” (Sennett, 2008, p. 77). Building on the concept that processes and procedures need to be questioned to establish new methods of practice, an outcome or design is never static but is constantly growing between the stages of *Cultivation* and *Creation*. This allows for ideas to layer and form new bonds with organic methods of action. With an outcome, I engage with a visual ‘Mapping System’ to form comments on my practice. This mapping system acts as a visual aid to the questioning of outcomes and reflection on new techniques. The use of my ‘Designers Notebook’ is imperative to allow me to remember my process taken in-action. An external review of split-second decisions and actions taken in the laboratory may allow for approaches to be reconsidered and revisited. Often, analysing results may reveal new questions for further development. In this case, the process of finding a solution for dyeing textiles with pigmented microorganisms is identified; however, several underlying possibilities are also observed in-action. This body of work manifests new forms of scientific knowledge; however, it cannot be fully developed due to time constraints. Therefore, the use of clearly marked methods in the form of swatches, notes and photographs are consolidated within the ‘Designer’s Notebook’ for future discovery and development.





Critical Framework

Research Imperative

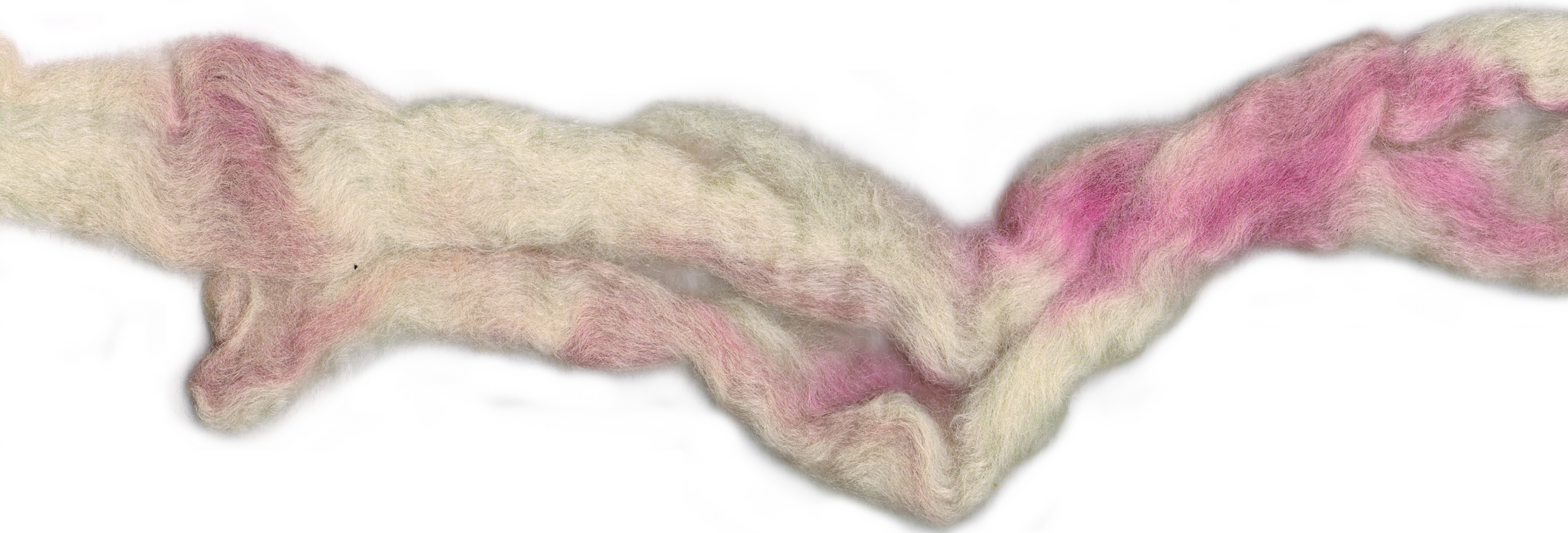
Today, although the emphasis on ‘green’ and sustainable materials is considered a revolution for the fashion industry, many exploitative composition and process elements remain within the industry (Sachs, 2007, p. 273). Emerging technologies such as synthetic spider silk (Wu et al., 2017) blur the boundaries of sustainable production methods. Researchers at the University of Cambridge mimic the attributes of spider silk’s strength with the vision to “make any form of [artificial] fibre green” (Matchar, 2017, para. 10). However, the need for more synthetic artefacts prompts scepticism of the unintended consequences as “synthetic biology may simply become a way of pumping out more of what we have” (Ginsberg, Calvert, Elfick, Endy, & Schyfter, 2014, p. 14).

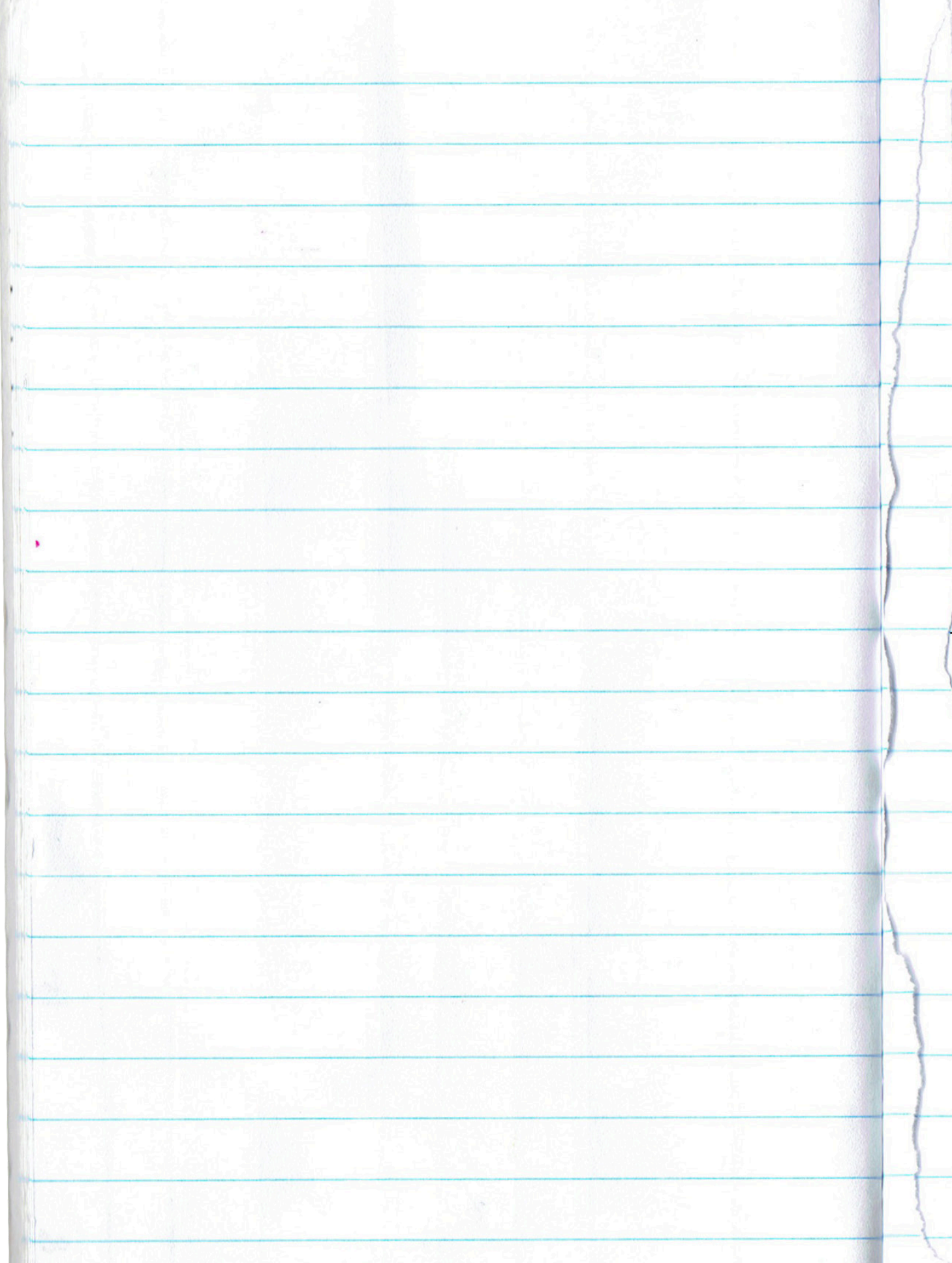
A movement of designers and artists disrupt this formerly exploitive fashion system, looking to develop and implement biological systems into designed artefacts. Works such as

LivingInk (2013), EpiBone (2013) and bioMASON (2012) have explored this threshold between design and science. In a discovery seen across disciplines, these practitioners draw a biodiverse future for textiles, with the ability to harness and ‘grow’ new criteria for biological materials (Narsing Rao, Xiao, & Li, 2017). The efforts of writer and curator William Myers (2012) and MoMA curator Paola Antonelli in *BioDesign: Nature + Science + Creativity* are centred on this discussion, lifting the lid on outdated conventions of practice and raises new questions for designers, as Myers asked: “What are the implications and likely outcomes of these speculative projects? Does the sum of these experiments, including an embrace of natural systems and collaboration with the life sciences, amount to a paradigm shift in design practice?” (p. 9). These ideas and answers to these questions were ultimately explored in works such as Mycoworks (2013), leather made from mushrooms, or BioArt Laboratories (2011), where materials like spider silk, skin, ink and luminous bacteria extracted from octopii are established in response to pressing environmental issues.

As the efforts of bio-inspired researchers across the globe rapidly change how we perceive the possibilities of design, the ethics of this new ideology prompts scepticism (Sachs, 2007, p. 273). Paola Antonelli (2012) discussed this concern in *BioDesign: Nature + Science + Creativity* and suggested that

“the integration of life into design is not a magic bullet to solve these pressing issues. Nor will it be free from harmful missteps, deliberate misuses or controversy” (p. 10). Although this may be true, I address the adoption of biological systems and rediscover how connectivity with nature can guide design outcomes. This concept has the ability to disrupt and challenge negative textile dyeing processes through the implementation navigation of biological technologies (Tuli, Chaudhary, Beniwal, & Sharma, 2015). Design constraints within this research are noticeably absent, as a re-conception of materials and processes is explored in a complex re-adoption of nature.





Focus Group

AlgiKnit

The co-founders of the company AlgiKnit, Tessa Callaghan, Aaron Nesser and Aleksandra Gosiewski, heightened the emphasis on the newfound approach to material composites and the use of biodesign, reclaiming kelp to amalgamate its ‘living’ systems into design outcomes. In the Chromista Kingdom⁵, kelp is among the most important aquatic microorganism in the world today. Not only does it supports the aquatic ecosystems but also forms a key ingredient in many commercial products (Melchiorri, 2017). However, the interpretation of these delicate chromists into textiles forms a new life-cycle for the artefacts created: “When it’s worn out, or you don’t want it, it can be broken down by microorganisms and the nutrients reclaimed to feed the next generation of product” (Gosiewski, as cited in Lutkin, 2018, para. 4).

The kelp is harvested for alginates, compounds derived from a wide range of brown seaweed. Located in the cell walls, the alginic acid⁶ forms a gum substrate ingredient which merges the kelp properties with biopolymers. The outcome is a kelp-based bioyarn⁷, called AlgiKnit, that can be knitted by hand or fully-fashioned to customer requirements. The structure allows for biopigment dyes to be applied, producing a filament that is just as competitive on a commercial scale as acrylic fibres. The research conducted by biodesigners⁸ establishes new systems of practice and lends itself to the questioning of design principles.

If clothing is going to continue to be disposable, why not make it disposable in a way that makes sense – that actually benefits the earth? In a way that has a positive impact instead of a negative impact? It takes longer to create a mind shift, so why not first create an alternative that already fits into the same mindset? (Gosiewski, as cited in Lutkin, 2018, para. 6). By questioning the conventional materials and tools used to produce textiles, this adaptation of thinking offers new prospects and forms a closed-loop product life-cycle.

Stemming from and conceptualised within this mode of thinking, the research in *Material Microbes: A Designer’s Colony of Colour* merges across disciplines in a discovery of biopigments. The interplay of techniques uncovers a new language that crosses between scientific and design practice, establishing a feasible hybrid methodology for this research study.



Figure 14: Dyeing bio materials with natural dyes, by Algiknit



15.

“Biology is the future of fashion and kelp is a key ingredient for the future of sustainable manufacturing”

(AlgiKnit, as cited in “Biopolymer yarn”, 2017, para. 8).

Figure 15:
Hand knitted filament.
By AlgiKnit



16.

Figure 16: Hand
knitted filaments.
By AlgiKnit



17.

Figure 17: AlgiKicks
By Aaron Nesser
& AlgiKnit

Faber Futures

The traditional assumption that material forms can only have one purpose no longer applies. An embrace of nature, where worlds of unseen microorganisms highlight new approaches to design, are revealed in Faber Futures' research. This research project "attempts to assert a new craft discipline through the convergence of design practice and synthetic biology" (Chieza & Ward, 2015, p. 6) and the emergence of a hypothesis of 'living' systems co-design outcomes. A focus on colour and pattern conceived through the application of *Streptomyces* (A2)⁹ is explored on silk textiles. Initially isolated from soil, this bacterium is cultured and induced to reveal coliecolor¹⁰ on solid media¹¹. The calculated discovery "has been able to prove the viability of bacterial metabolites to successfully pigment natural fibres" (Chieza & Ward, 2015, p. 14). This project establishes a multi-disciplinary discussion of bacteria used to dye woven silk

fabric. Designer Natsai Audrey Chieza's proven techniques in Faber Futures were a hallmark of biological systems inserted and adapted for textile production of a biopigment. This research and model of inquiry is recognised as being influential in my own; however, the present research paper diverges through becoming a conceptual narrative which explores the New Zealand landscape of pigments.

Researchers at New Zealand Landcare Group determined the *Streptomyces* (A2) isolate¹² referenced in Faber Futures research was not present in New Zealand ecosystem, and under the 1993 Biosecurity Act, Section 22, cannot be brought into the country (B. Weir, personal communication, March 5, 2017). However, in exploring and identifying scientific literature on microorganism pigments, the discovery of localised strains creates a new context of other pigmented strains (Narsing Rao et al., 2017; Venil et al., 2014). This discovery illustrates the diversity and importance of our natural landscape and resources and how we protect and preserve these elements. "In order to live in harmony with the environment and each other, and to ensure our long-term survival, we must respect and protect the environment" (Selby, Moore, & Mulholland, 2010, p. 1).

18.



19.

Figure 18:
Constellations |
Sample 3 of 6, by Faber Futures

Figure 19:
Constellations |
Sample 1 of 6, by Faber Futures

20. —————



————— 21.

Biotechnology is going to touch every part of our lived experience. It is living; it is digital; it is designed, and it can be crafted. This is a material future that we must be bold enough to shape.

Natsai Audrey Chieza
- *Founder of Faber Futures*

Figure 20 & 21:
ASSEMBLAGE .001,
The world's first kaftan
dyed by bacteria. By Faber
Futures in Collaboration
with Ginkgo BioWorks



22.

Figure 22: SCALE .
3 pieces x 5 meters.
An exploration into the
maxims of industrial
scales that give rise to
specific aesthetics
and possibilities.
By Faber Futures
Photography by
IMMATERS Studio



23.

Figure 23: Experiment
no. 5- Rise and Fall
of a Micropolis
By Faber Futures



Issues Addressed

As a designer, deep rooted in the belief that our practices are guided by traditions and cultures that speak to our land, I have employed Māori world view of kaitiakitanga¹³ (Kawharu, 2000). In establishing a narratology of the landscape, the importance of protecting native flora, fauna and taonga¹⁴ emerges through a textile medium. This research forms a critical response to the pressing issues of the textile dyeing industry, creates potential alternative pathways, focuses on a balance between nature and design, and proves the feasibility of the ideas explored across disciplines.

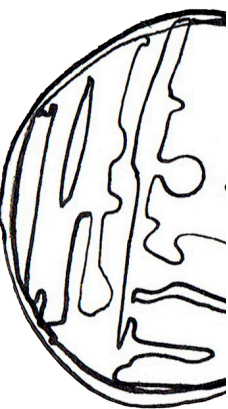
This idea, however, is not new and collaboration between designers and biology was seen as early as the frescoes painted around 1600 BC (“1600 B.C. Frescoes Found in Aegean”, 1972). The organic chemistry of natural dyes and pigments extracted from riverbeds, and binders derived from plants was embedded in cultural knowledge and practice (Te Kanawa, 1994). This sense of human connectivity with

natural systems is still seen within the traditional heritages of many cultures across the globe (Boldizsar, Szucs, Füzfai, & Molnár-Perl, 2006). Pigments retain historical significance, with a deeper identity with respect to culture, and the use of pigments can reveal social change (Selby et al., 2010). Māori are understood to follow these organic methods of practice, where native plants, shellfish and mud, unique to the landscape, were used as colourants. Informing Māori practice was the underlying morals of kaitiakitanga, ensuring a balance of human connectivity to nature. “For over a thousand years Maori lived in harmony with the environment exercising Kaitiakitanga, recognising our needs and those of the realms around us” (Selby et al., 2010, p. 1).

However, 1856 saw the introduction of the first synthetic dye to the world. William Perkin discovered the aniline dye mauveine, extracted from the compounds of coal tar (Smith & Te Kanawa, 2008). This and other synthetic substitutes could offer consistency and faster results for dyeing. It is clear that, by the mid-19th century, this modern approach to dyeing had global effects and had grossly contributed to a textile environmental crisis (Wicker, 2016) with a large amount of the tacit knowledge about natural pigments disappearing during the time period of the rise of the synthetic dye. “With the profusion of artificial colourants so familiar to us today, we forget the ingenuity of our ancestors from

many cultures who discovered how certain coloured natural substances could be fixed or bound to objects” (Smith & Te Kanawa, 2008, para. 3).

Deprived and depleted of our natural resources, our need to connect back with nature and sustainable processes is even more critical. “It would be profoundly unwise, to not look back and learn the lessons of those societies, now we have nowhere else to go” (Montgomery, D. (2011).[Video file]). Motivated by these issues, the intersection of biology, technology and design is seen to have new potential. “New dimensions of function have become increasingly important, such an object’s ability to restore a sense of human connectivity, enable new forms of interaction, or make critical observations about the future trajectory of technologies and behaviours” (Myers, 2012, p. 16). This research seeks to uncover the biological systems compatible with producing a biopigment for natural knitwear fibres and fabrics. It discovers methods centred within biological processes to form a means of creating unique textile dyeing techniques. Uncovered through this research are sustainable applications of colour, where protocols of protection for these engineered biopigments must be questioned (Dunne & Raby, 2013). The implied possibilities of future potential for these biopigments calls for further discussion of the implementation of procedures for preserving and protecting these unique New Zealand organic pigments for the future.



25. _____

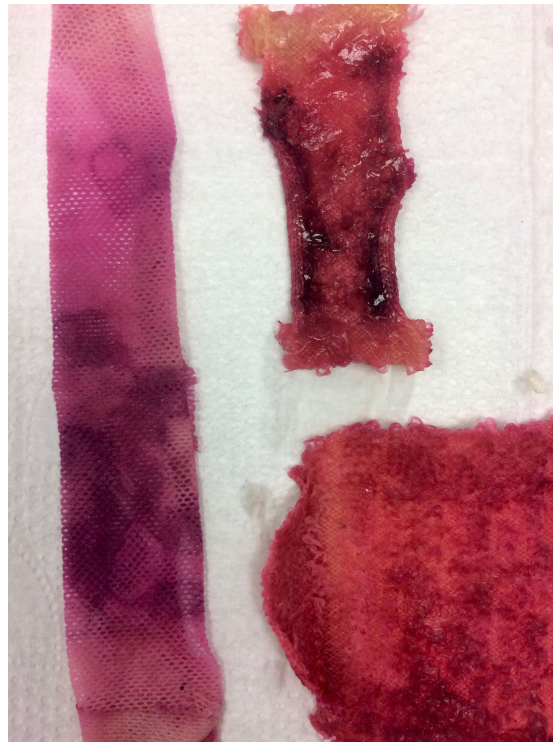
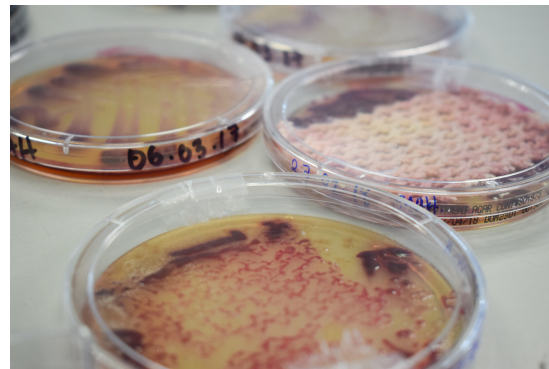


Figure 25: Diverse outcomes of *Serratia marcescens* Prodigiosin on knitted textiles.

Figure 26: Prodigiosin application to silk.

Figure 27: Solid Agar

26. _____



_____ 27.

28. _____

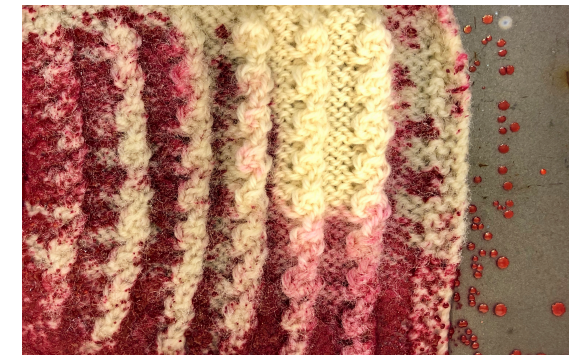


Figure 28: Method (B) developed semi-solid Agar inoculated with the Prodigiosin

Figure 29: Knitted textiles submerged in semi-solid Agar preparation.

Figure 30: Method (A) over sections of textile knit.

29. _____



_____ 30.



These specimens are textile fossils of living colour



Material Microbes

Microbe & Isolation

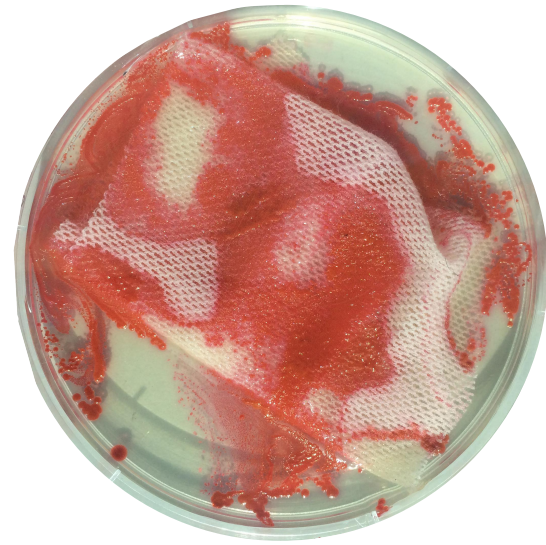
This chapter discusses my methods of design practice and explains my position in the vast field of biodesign research. Within this framework, I have developed and analysed appropriate biological systems and methods with the aim of finding a potential process to dye textiles in a renewable way. *Material Microbes: A Designer's Colony of Colour* depicts collaborative discoveries mediating between a designer's thinking and scientific practices to draw new conclusions in producing textile dyes. It is my understanding as a designer who has researched both biology and textiles that by experimenting and sharing ideas within both disciplines, a greater understanding and a contribution of new knowledge can arise. In this case, inspired by recent scientific literature (Narsing Rao et al., 2017) in the field of microbiology. A discovery of pigmented microorganisms found within the New Zealand landscape is established.

The methodology was far from straightforward, looking to integrate the fundamental values of textile knit (design, texture and aesthetics) with biological processes (science-based outputs). The design of this research initially started in identifying and selecting a pigmented microbe for the production of a biopigment for textile applications. Many research efforts reveal biopigments and colourants for a wide range of commercial applications including food and cosmetics (Tuli et al., 2015). However, further investigation and development of biopigments, especially localised New Zealand strains, are reviewed in more detail.

The *Serratia marcescens*¹⁵ species is part of the Enterobacteriaceae¹⁶ family, a gram-negative bacillus¹⁷ that is abundant in damp environment conditions (Williams, Green, & Rappoport, 1956). Although naturally occurring in soil and water, some subspecies are human pathogens that may cause a wide variety of infections. Scientific reviews (Williams et al., 1956) revealed the selected bacterial strain has characteristics of pigmented mucoid, known as prodigiosin¹⁸ pigment as a result of a secondary metabolic process which appear in colonies as red pigment. Based on the preliminary tests and pigment of *Serratia marcescens*, this microorganism was selected as a suitable species for developing dye for material textiles.

Work was carried out under strict physical containment 1 (PC1) guidelines and in the confines of the Auckland University of Technology's (AUT's) science laboratory,





the *Serratia marcescens* was cultured in nutrient broth culture media and incubated at 28°C until the sporulation¹⁹ of pigmented colonies occurred (see figure 27 collection of agar plates). This isolate was subcultured²⁰ in fresh media on a weekly cycle. This is necessary to maintain a 'Colour Bank' as a future resource. The pigment characteristics (rapid growth, and vivid pigmentation) are proven viable in recent studies on microbial production of natural food colourants (Dufossé, 2006) indicating the possibility of merging this biopigment with textiles. Methods of practice and further development of this biopigment are revealed in the *Agency of Agar* and *Colour Membrane* sections.



Figure 35:
Experimental plates.
Cotton and silk swatches
on solid Agar.



Fibre & Fabric

An emphasis on natural fibres prompts a wider conversation about the artefacts we create as designers. “Textiles [are] fourth in the ranking of product category which cause the greatest environmental impact, just after food & drinks, transport and housing” (Retail Forum for Sustainability, 2013, p. 1). Where mass consumption rules, it is essential to question the necessity of these fibres since “more than half of the fibres we wear today are man-made” (O’Connor, 2005, p. 3). As a textile designer working in a commercial fashion environment, I have become aware of the destructive nature synthetic fibres have on the environment (Wicker, 2016). For designers, this motivates the need to re-establish connectivity with organic fibres derived from natural compounds. “Brings together diverse materials and combining or redirecting their flow in the anticipation of what might emerge” (Ingold, 2010). This section will focus on the potential of protein-based fibre connectivity with the *Serratia marcescens* biopigment. A range of raw, spun, woven and knitted fibres was

examined in relation to final intensity of colour and hue obtained whilst investigating methods of application of the isolated *Serratia marcescens* pigment.

**“In my end is my beginning”
(1943, T.S Eliot)**

An important concept in this development stage was addressed in questioning how I could determine a design outcome through living systems. In a similar way, artist and researcher Marta De Menezes (2015) engaged in this way of thinking, stating: “This is a new art practice, based on a ‘risk-based’ situation; a timeless research strategy to develop new methods of practice, new media and new ways to manipulate materials for artistic expression” (p. 115). A critical aspect for a textile designer to consider when working on a substrate and textile design aesthetic is how to represent and form a desired outcome. This model of research follows clear scientific protocol, yet inserts artistic techniques through the choice of fibre and fabric to obtain a variation

of colour. Surface, structure and even the composition of the fibre and fabric can influence the outcomes of the biopigment. As a result, I have explored qualitative methods of identifying numerous natural base cloths, structures and compositions in relation to the microbiological pigmentation.

Initially, silk and cotton fabrics were chosen as base cloths for *Experiment One* (see figure 35). Proven applications of the genus *Streptomyces* (A2) bacteria investigated in Faber Futures’ research revealed examples of a biopigment successfully colouring woven silk. Natural protein fibres are not only “highly absorbent” but also “bind tightly” with the biopigments (Chezia & Ward, 2015, p. 10). This research and its findings offered compelling insight and provided a grounding for my own research as a fabrication starting point. In recent scientific literature (Rana & Salam, 2014; Narsing Rao et al., 2017), the *Serratia marcescens* prodigiosin pigment was scientifically proven to absorb into and react with organic textiles. The above research

informed methods of practice and experimentation processes for this study to follow and gain knowledge from. It created a systematic foundation, where experimentation resulted in the formation of methods able to produce a viable textile dyeing process.

Trial and error was determined an appropriate method to progress in this research, as it allowed for reflection on actions to take place. Schön (2008) suggested a practitioner who reflects-in-action “is not dependent on the categories of established theory and technique but constructs a new theory of the unique case” (p. 68). In the trialing stages of developing a feasible methodology, a series of silk and cotton swatches were placed on the surface of nutrient agar and then inoculated with the *Serratia marcescens* bacterium. The use of variables of ‘treated’ and ‘un-treated’²¹ fibres uncovered a surprising relationship between the material composite and the final pigmentation (see figure 35).

37. —



Figure 37: Sarah Hickey,
Fabric swatches
from left: cotton, silk
organza, bleach cotton
knit, greige yarn

38. _____



Figure 38: Sarah Hickey,
After agar/isolate
application.
From left: Recycled
cotton paper, greige yarn,
cotton knit, bleached
cotton knit, wool/acrylic
knit, silk organza



Agency of Agar

Media manipulation

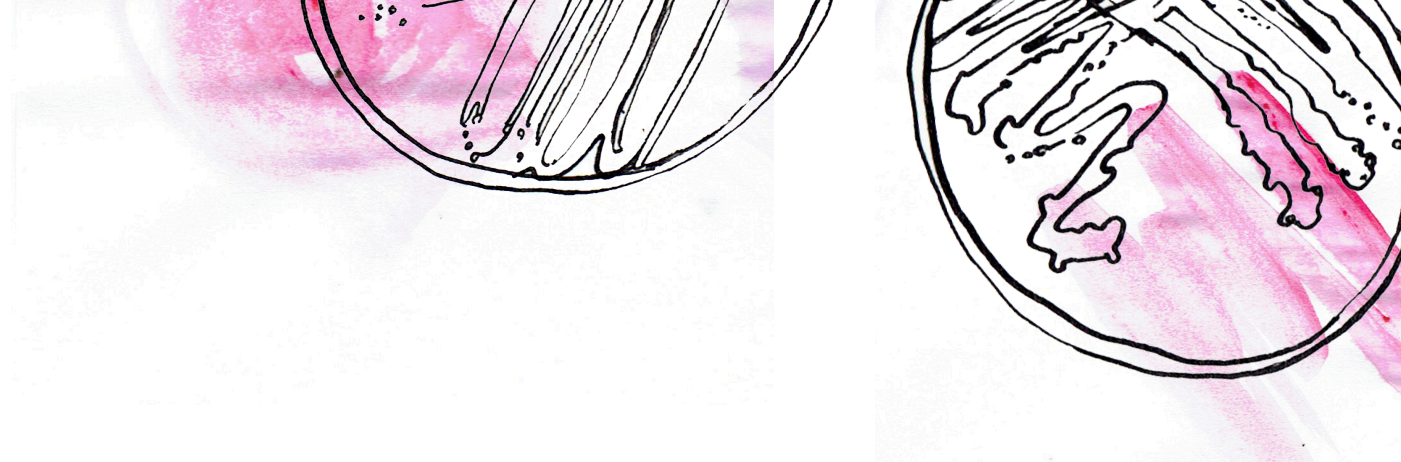
As a designer, my inquiry into biological tools and processes used within the science laboratory was critical for the development of this research. In merging my design methods with those of a scientific technique, the discovery of innovative tools, materials and processes expanded my knowledge and developed a greater understanding of biological-based systems. Methods being used across disciplines were guided by scientific literature, yet a self-discovery through experimentation led to unique understandings and new knowledge and outcomes. Quantifiable data formulated an outline of methods within the science laboratory and reflection on action took place. Through the use of clear annotations for each experiment and for each result, failure or success were established.

Schön (2008) explained that reflection enables the uncovering of knowledge in- and on-action and often begins when routine has an unexpected outcome, positive or negative. Through action-based inquiry, this hybrid of methodology propels my tacit designer skills (Polyanyi, 1966) to engage with reflective and active feedback. Ghaye (2000) suggested “Maybe reflective practices offer us a way of trying to make sense of the uncertainty in our workplaces and the courage to work competently and ethically at the edge of order and chaos...” (p. 7). Contextualising the current models of research and exploring the multiple sources from both a design and science background, a greater understanding of the *Agency of Agar* was uncovered through this research. Certain components of the culture media can mould, manipulate or even change the outcome of the microbiological pigment (De la Maza, 2004). Fascinating scientific literature in the area of microbiology served as a basis for new methods of growth media preparation. “Many factors such as ...

raw materials used, bacteria, pigment, type of fermentation (batch, feed-batch or continuous) must be taken into consideration. These features play a very important role to achieve the desired yields of a target pigment” (Stankovic, Senerovic, Tomic, Vasiljevic, & Runic, 2014, para. 32-34).

This chapter discusses my discoveries about how the influence of various preparation methods to culture media have the ability to transform the final pigmentation of *Serratia marcescens* (Stankovic et al., 2014). Noticeably, the solidified media not only forms the artist’s canvas but becomes a fundamental tool in shaping the design outcome because, as noted by Okami, Arima and Suzuki (1963), “Agar has been used for a long time to solidify microbiological culture media” (p. 1). Agar²² is a key component of solid and liquid media used in the cultivation of microorganism. Agar, which is derived from seaweed and combined with algae, assists in microbiological pigmentation of *Serratia marcescens* prodigiosin.

Exploring the technical approach to preparing and encasing the agar (see figure 42) was important to this study because it developed colour embedded within the fabric as well as pattern and surface designs. Initial testing of various *Difco*^{TM23} agars was conducted to gain insight into how different agars may influence the hues and final pigmentation results. In Venil et al.’s (2014) study of the current perspective on bacterial pigments, their research revealed that “Medium optimization is one of the important processes for getting maximum pigment yield and it involves several factors such as medium components, operating conditions, pH, temperature, aeration and agitation etc” (p. 4). Based on this idea, I employed the use of scientific methods to prepare and study various media and determine how they may influence the *Serratia marcescens* pigment. Via note-taking the study of agar compositions, preparation techniques and methods of incubation were recorded, ensuring a viable and repeatable methodology was achieved.





Engaging with diverse methods to prepare the culture media removed the constraints of routine practice, and meant the use of experimentation from a designer's perspective was acknowledged. Originally the agar was poured and was confined by shape and size through the use of round petri dishes. However, experimental techniques and a developing knowledge, which included a greater understanding of agar preparation, proved that it may be possible to use a semi-solid agar for this microbe. This discovery of the ability to use a semi-solid agar moved the idea of growing microbes on a flat agar 'canvas' into a volumetric flask. Dramatically, this shift of constraints meant a 'bath' of pigments could be created. For a designer, this imitated the fabric dye bath. Textile knit swatches were submerged in the volumetric flask²⁴ of semi-solid agar. Initially inoculated²⁵ with the *Serratia marcescens* isolate and then introduced to the agar 'bath', this isolate rapidly took hold of the substrate and formed biopigments. Incubated over a two-week period, the bottle

was agitated daily to move the bacterial pigment across the textile and gave a consistent all-over pigmentation on the knit swatches (see figure 28).

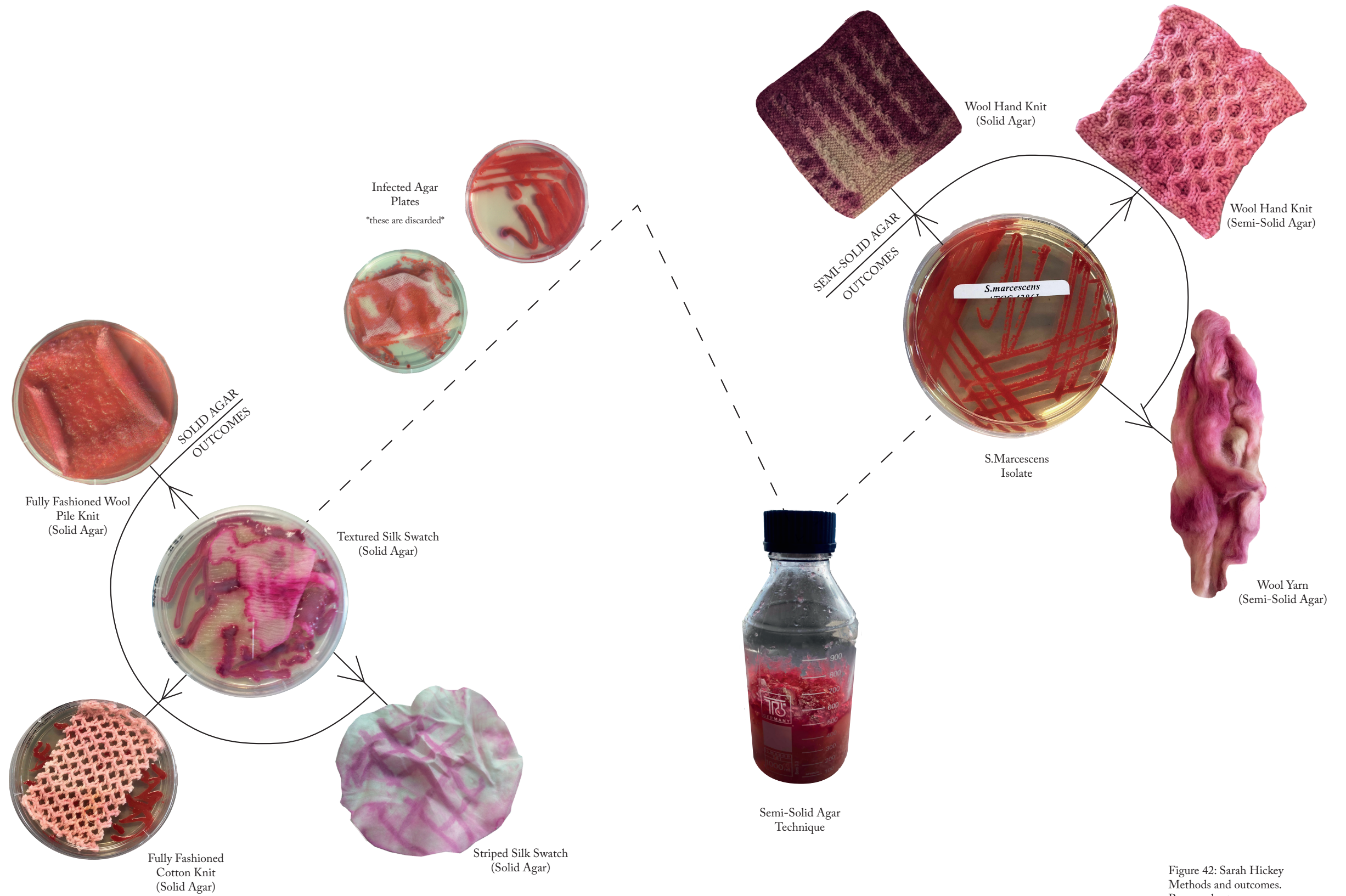
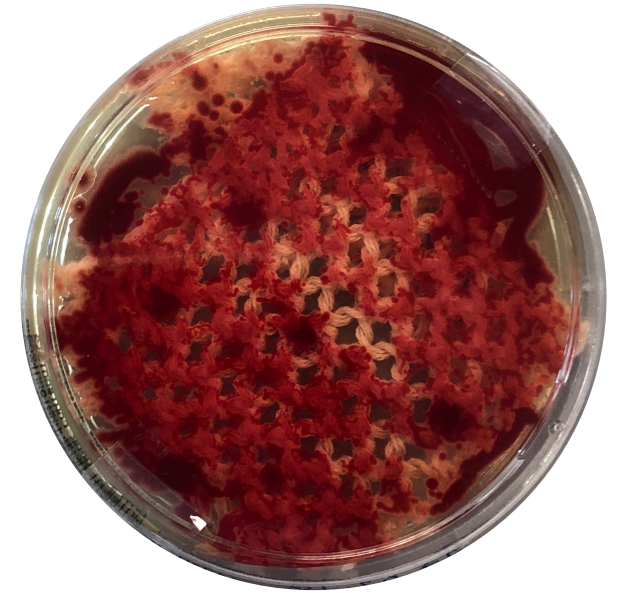
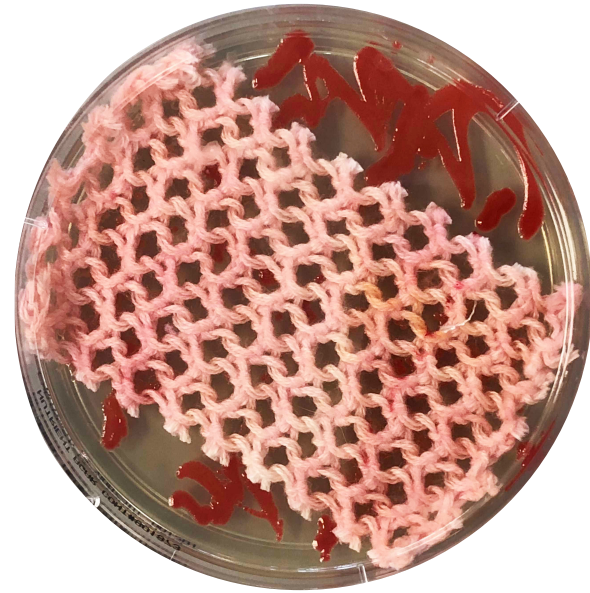


Figure 42: Sarah Hickey Methods and outcomes. Process chart

Discussion

This form of discovery-based learning meant a secondary method for textile dyeing of fabric using microbes was developed. Through previous experimentations and reflective processes being combined, the outcome of pigmentation using this secondary method was achieved. However, the process, application and results varied. Artistically the microbe pigments worked as a liquid dye, colouring the surface of the textile whilst also synthesising with the textile form. This meant the idea of layering colour and repeatedly introducing this textile back into the pigment 'bath' to create new patterns was achievable. The interplay of organic patterns and colour created by the microbe could be mixed with deliberate design outcomes, as seen in *Experiment One*.

The results of each process were captured by the use of photography, allowing for an illustrative collation of work to be established. The success of *Serratia marcescens* pigmentation of knitted wool swatches presented varying results due to the influence of agar, incubation times and methods of preparation. It was clear that further development of these technical aspects could expand knowledge and uncover new findings. Comparing my work with those of my peer researchers (e.g., Cheiza & Ward, 2015), this research uncovered new methods of pigment preparation and developed a greater understanding of biopigment applications to textile knitwear. This manifest new form of knowledge contributes to the on-going discussion of implementing biodesign as a new paradigm within design (Myers, 2012). The embodied knowledge of biopigments as colourants for knitted textiles cannot end the use of synthetic dyes; it merely forms a conscious notion of synthesising across disciplines to present new outcomes. Yet, the epistemic potential of this integrative approach to cross-disciplinary practice could see new applications and the integration of biology into design.





Colour Membrane



Experiment 1: Silk & Cotton Swatches

Method:

Aspects of design techniques merge with scientific methods in *Experiment One*. The application of silk and cotton textiles onto agar reveals the growth of *Serratia marcescens* prodigiosin. Swatches are modified (pressed, pleated or twisted) and then layered before applying to the nutrient agar. These techniques formulate a self-discovery of action-based methods to achieve innovative applications of colour, pattern and final hue of *Serratia marcescens* prodigiosin on the silk and cotton fabrics.

The agar medium is poured into sterile petri dishes²⁶ at temperatures below of 50°C. This allows for the agar to cool and solidify. After removal from the autoclave²⁷ which sterilises the silk swatches, they are placed on top of the agar (semi-solid) allowing for the fabric to absorb some of the liquid, yet still float visibly on the surface. Each individual swatch

is inoculated across the fabric, creating unique striped or criss-cross patterns, dependent on the designer acting as creator. Rich prodigiosin pigments are produced on the surface of the solid agar revealing an interplay of artistic patterns and saturation of colour. To better understand how the microbe moves across the fabric, some swatches were only isolated in corners or folds of the fabric. In experimenting with this idea, it became clear that this aerobic culture was sensitive to agar nutrients and therefore only produced pigments onto the parts of fabric that absorbed the agar. The emphasis on producing a desired outcome with the microbe informed these developmental swatches (see figure 35). After resting until solid, the petri dishes are then flipped and incubated at 28°C for three to five days.

To test the success of pigment fixation to the fabric, the variables of fabric placement onto the agar, inoculation technique, oxygen and duration of incubation were studied. In addition to prodigiosin fixation, varied patterns such as lines that crossed or uniform dyeing were achieved through the development of colour on each swatch.



Discussion

The above experimentation shows how adopting a design aesthetic within laboratory conditions has been achieved through the use of folding techniques such as pre-pleating and gathering to transform flat swatches to textured and disrupted surfaces. Once these fabrics were placed onto the solid agar, the folds and lines acted as linear guides which separated pigments. This allowed for deliberate outlines and folds to guide the microbe and to develop 'controlled' designs such as mirrored patterns. The above experimentation also found that the individual colonies of *Serratia marcescens* did not react in any predictable way, with no direct links between the 'treated' or 'untreated' properties of silk and cotton fibres and fabrics.

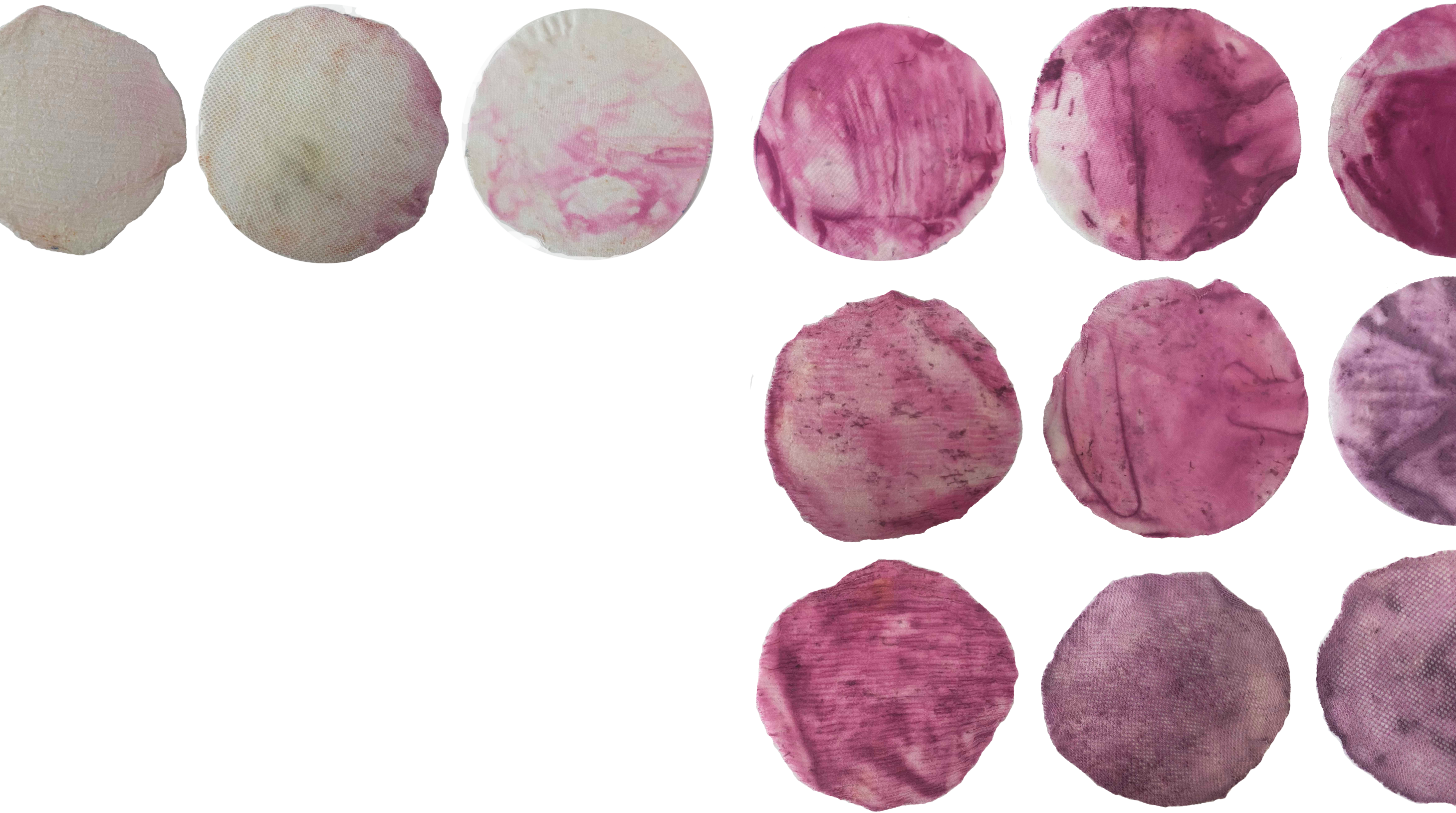
Analysis of the spectrum of colour achieved in these swatches (see figure 35) supports the assumption that the properties of the fibre potentially contribute to the final microbe hue. This theory cannot be overlooked; however, within the time constraints of this investigation, the criteria to expand this hypothesis could not be successfully achieved but could form part of further research.

The above experimentation did demonstrate that the very organic nature of this living microbe became repressed over "form-giving is life" (Ingold, 2010, p. 213) through the regimented aspects of application by the designer. The technical approach of linear guides enforced a deliberate designed outcome in the microbe pigmentation with a focus on designed aesthetic control and development. Consideration of scientific practice and constraints generated a discussion about methods used in this research and how, as designers, we can insert design control into this living system and if there is a need to manipulate this natural process for a commercial approach. Although this approach has the potential to impact textile colouration and patterning, it is said that "A new outlook must prevail if nature is to be mastered rather than degraded. The utmost caution is imperative. This calls for an attitude turning radically away from the idolatry of

production" (Giedion, 1948, p. 256). Noticeably, the complexity of results achieved using these biopigments meant further experimentation of application, pattern and depth of colour was needed. It was through drawing on a tacit knowledge of textile techniques and manipulation of fabrics that a new direction to explore and experiment through was developed, which included inoculating techniques and other methods of agar preparation.

Reflecting on the outcomes, each manipulated swatch gave surprising and contrasting results. Collectively, the silk and cotton swatches were useful for initial experimental methods, to see how the microbes would pigment lightweight fabrics. However, the ability to dye woven textiles simply formed a research and practice framework to work from as a good base of understanding of methods, practice and outcomes which had, to a certain extent, already been achieved in other studies overseas (Chieza & Ward, 2015). The knowledge gained from the first phase of the research helped to formulate a plan to move forward from, onto the desired substrate of wool-based fibres for the next stage of the research. The next phase of inoculating textile knit swatches is discussed through experimentation and practice within *Experiment Two*.

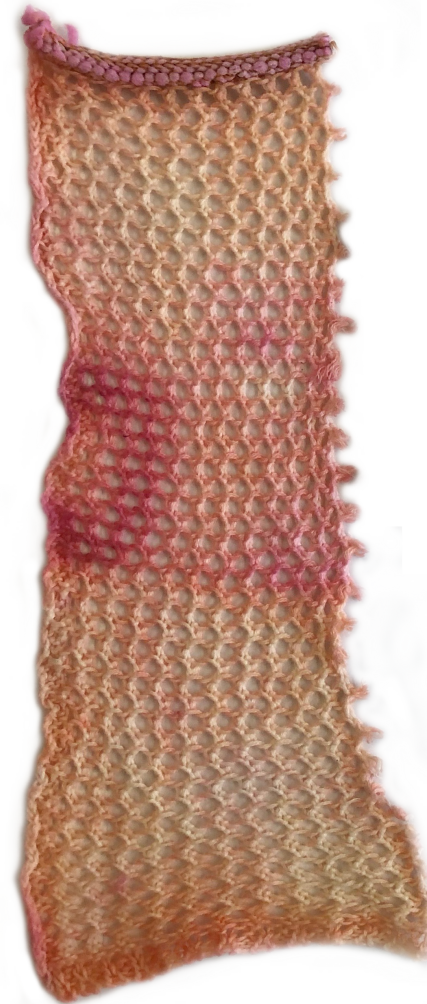


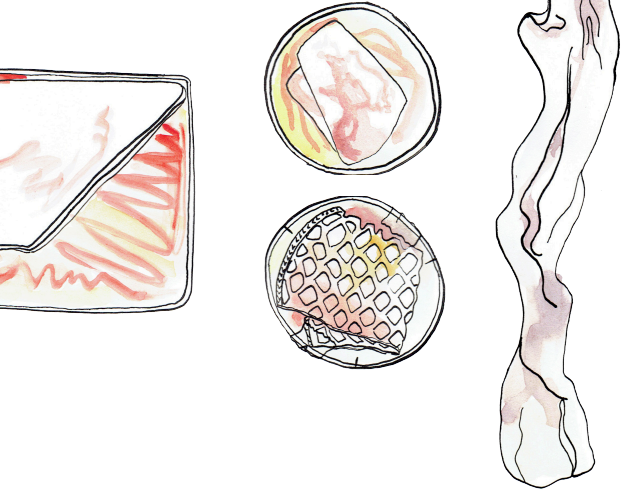






Fully Fashioned





Experiment 2: Hand Knitting & Pigments Emerge

Reacting to the overwhelming production and use of human-made fibres within the textile industry (Changing Markets, 2018), an informed decision to connect with localised New Zealand wool emerges within this research and grounds this study. The emphasis on knitwear expands on the researcher's own tacit understanding, whilst also addressing sustainable practices. "Designers face an unprecedented urgency to alter their methods and reprioritize their goals to address the accelerating degradation of the environment" (Myers, 2012, p. 10).

The series of work developed in *Experiment Two* identifies greige²⁸ yarn as the fibre and hand-knit as the production method which, when combined with the *Serratia marcescens* biopigment, provide a localised, sustainable

textile fibre make and design system. In addition to providing structural methods and processes, the knitted base cloth captures timeless traditions through the use of hand-knitting techniques. Cables, articulate tacit knowledge, artistry and artisanship combine in three-dimensional structural forms; "Yarn is neither metaphorical nor literal, but quite simply a material, a gathering of threads which twist and turn through the history of computing, technology, sciences and the arts" (Plant, 1995, p. 12). Applying bacterial pigment onto a traditional cloth such as a hand-knitted fabric shows the importance of inherent skills and sustainable practices, by intersecting biology and design.

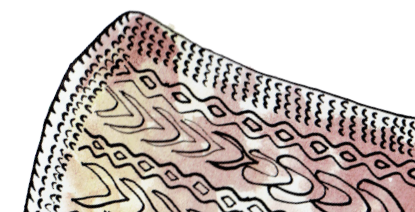
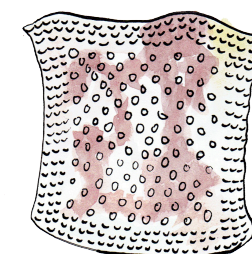
The method of dyeing the hand-knitted swatches was initially tested within the confines of a petri dish. With the fabric placed on the surface of the solid agar, the interaction between the microbe pigmentation and textile structure was observed. The properties of the wool (absorbability, durability and resilient structure) proved highly responsive to the *Serratia marcescens* prodigiosin and, over a three- to five-day incubation period, pigment dispersed over the textile. This suggested that wool greige yarn is an optimal fibre for this unique strain of bacteria. This research moved forward by adapting and developing the existing semi-solid agar method for the application of knitted swatches (see figures 53 & 54) as initially seen on the silk and cotton in *Experiment One*. The development of complementary methods of inoculating the

knitted swatches added new methods and further depth and value to this study. The hand knits were autoclaved to produce a sterile swatch for inoculation. Using the inoculation technique as a means to place the pigments in desired areas meant aspects of design thinking merged with scientific methods of practice. The hand-knits were brushed on the surface with the *Serratia marcescens* which connects the microbe with the textile surface. Once coated in the nutrient agar, clear pigments and patterns formed.

Once inoculated with *Serratia marcescens*, each swatch was processed using a different method of cultivation. These alternative methods of biopigment production were (A) flat metal tray and (B) 500ml volumetric flask. These methods of cultivation stems from those used in *Experiment One* and further progressed and developed the idea of how to achieve a pigmented dye onto knitted textiles.

In method (A) the nutrient agar broth is poured over sections of the textile knit. The application of agar is used to inhibit the growth of the prodigiosin pigment so, effectively, by not covering the full swatch, this design process 'tailors' the outcomes of pigment development. Controlling the placement of agar onto the surface of the textile inserts a unique design aesthetic, optimising the function of agar as a fixing agent for the pigments.

Method (B) develops batches of prodigiosin biopigment in the confines of a 500ml volumetric flask. The inoculated knit swatch is submerged in semi-solid agar, allowing the bottle to form a dye bath for the pigment. The rapid growth of this bacteria allows for an all-over 'coating' of dye to be achieved. Collectively the identification of the preparation of varying methods allows for unique dye patterns and generates a contrast level within the final hue of the biopigment. After both methods of cultivation have been incubated for an extended period of time, the samples are autoclaved to effectively terminate the presence of bacterial organisms. On completion of the autoclave process all that is left is the transferred and grown coloration of the biopigment fixed permanently to the wool fibre.



53. ———



Figure 53: *Serratia marcescens* Pigment inoculated on hand knit swatch, before autoclave.



————— 54.

Figure 54: *Serratia marcescens* Pigment inoculated on hand knit swatch, after autoclave.

Discussion

It is clear that successful colouring of a textile knit has been achieved in *Experiment Two*. The contrasting methods both effectively produce the fixation of biopigment in both solid and semi-solid agar yet introduced alternative outcomes of colour. Method (A) inserts design techniques into scientific practice to achieve desired patterns of pigment. This method allows for the microbe to form on the surface of the textile knit. The design relates to the reaction of pigment with the placement of agar. In method (B) the knitted textile is submerged in agar, producing a final textile which is saturated by the pigment, which is evenly distributed over the knit textile. This method imitates a dye bath and may be suitable for the textile dyeing industry.

The two designed artefacts ultimately respond to the research question, concluding that a textile colourant is feasible with microbes. This research also shows that both methods reveal exciting dyeing outcomes and proves that there

are some significant properties of the microbe and its colouration ability that should be investigated further. Areas for further research such as the longevity of this biopigment on the textile and the practicability of this biopigment on other fibres could be pursued.

Reflecting on the methods and findings mentioned in the above section, it can be argued that the fact of whether this research was successful or not is open for interpretation by the researcher (Corbin & Strauss, 2008, p. 10). The results presented are discoveries from a designer's perspective, obtained through insightful questioning and, in some cases, by pushing against the methods of routine scientific practice. Arguably, if this method was repeated by another researcher, different results and findings may be obtained, due to the expertise and tacit knowledge required of these cross-discipline methods. As a result, this research reflects the efforts of a textile design researcher engaging with scientific methods to produce a biopigment feasible for textile design use on knitwear. In developing this body of work, I suggest it contributes to a larger conversation on biodesign research, and generates a re-conception of human connectivity to sustainable systems found in nature.





Research Outcomes

This research develops the hypothesis that localised microbes can interrupt current textile dyeing methods with sustainable biological systems, and the research has also discovered a biopigment for textile applications. Currently the industry is saturated in synthetic substitutes and exhausted methods of dyeing that are no longer credible, and so this research removes the constraint placed on the designer and inserts new value into design artefacts, alleviating the negative impacts of current industrial dyeing technologies (Hill, 1997).

As a variety of case studies have encouraged the integration of 'living' systems to address multiple environmental issues, the calculated conditions in which this research was undertaken build a sense of human connectivity to nature. Maintaining a strong consideration for the morals of kaitiakitanga, this research works to communicate the importance of natural microbiological systems as a design tool to produce colour. The results of biopigment and the organic patterns are illustrated on textile knitwear. The outcomes are subject to the methods of cultivation. Highlighting the possibilities of organic microbe systems as colourants by combining science and design practice, this research argues and demonstrates that biopigments may offer a more sustainable approach to dyeing textiles.

Systematic processes of biological agar preparation and cultivation reveal potential techniques to influence the successful pigmentation of textile designs on knitwear. Developing two methods (solid and semi-solid agar preparation) allowed the possibilities of achieving colour but also creating pattern to be explored. These methods became a designing tool to form creative outcomes of colour whilst also addressing the need for a sustainable dyeing method. The applications of this biopigment to textiles are endless (Venil et al., 2014), and of particular interest for future research are the exciting colours this microbe could produce and how a desired colour could be achieved. However, in this research, the method of dyeing knitted textiles was ultimately achieved, along with the focus on application and pattern which both reveals new methods of design and adds to the larger biodesign discovery and knowledge.



Conclusion

The emphasis of *Material Microbes: A Designer's Colony of Colour* has been on identifying and exploring localised pigment-producing microorganisms for the application of knitted textiles. Captivating parallels between biology and design unearth 'living' material systems suitable for textile dyeing. This enquiry has displayed how an embrace of cross-disciplinary methods can formulate new knowledge, challenge routine and generate a re-conception of human connectivity to sustainable dyeing practices. This formula reveals a narratology of the New Zealand landscape as pigment and pattern illustrate the importance of protecting and preserving our natural resources for the future.

The potential of these microorganisms is intriguing, and we have only begun to explore it.

Final Pieces

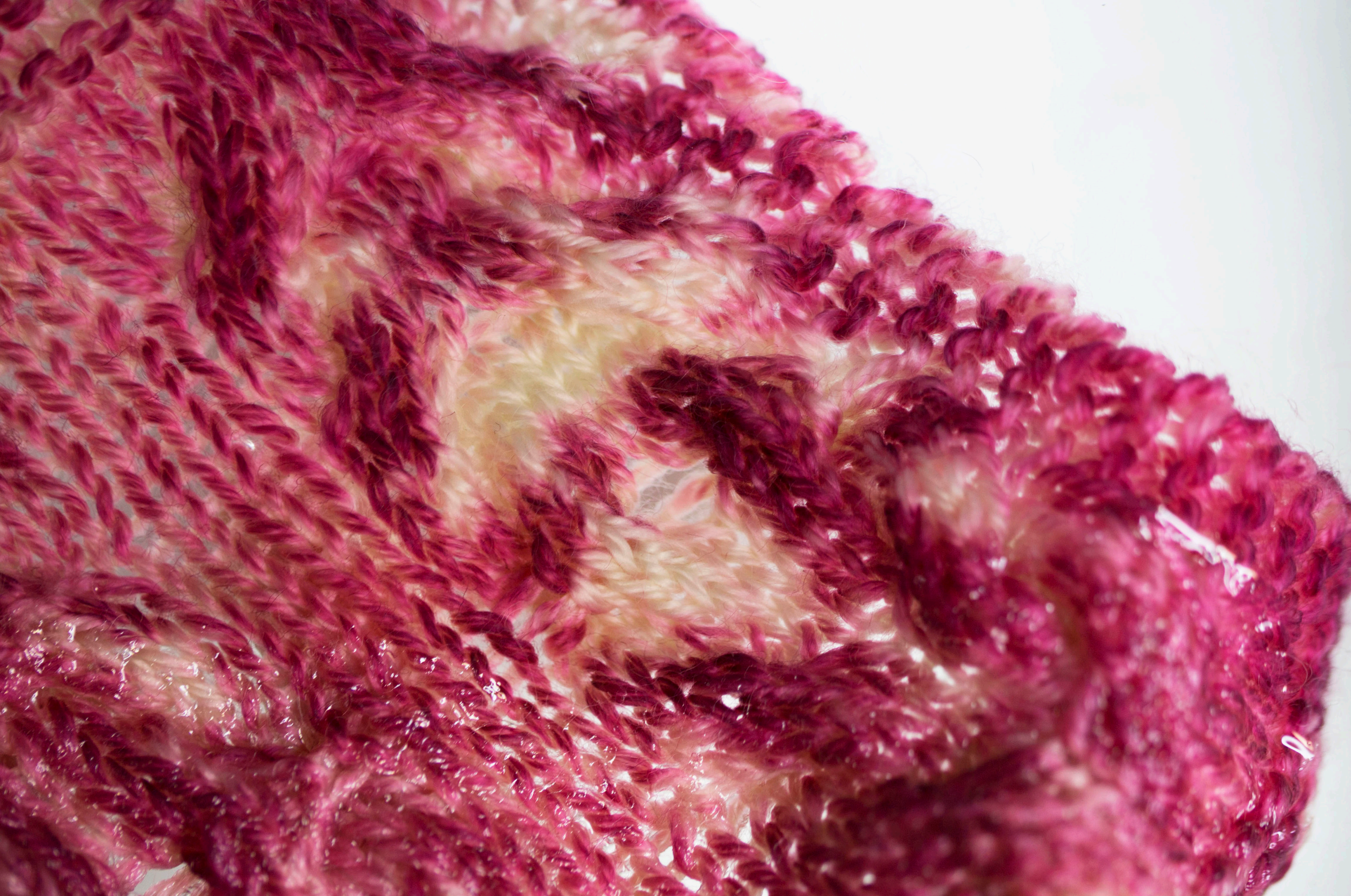
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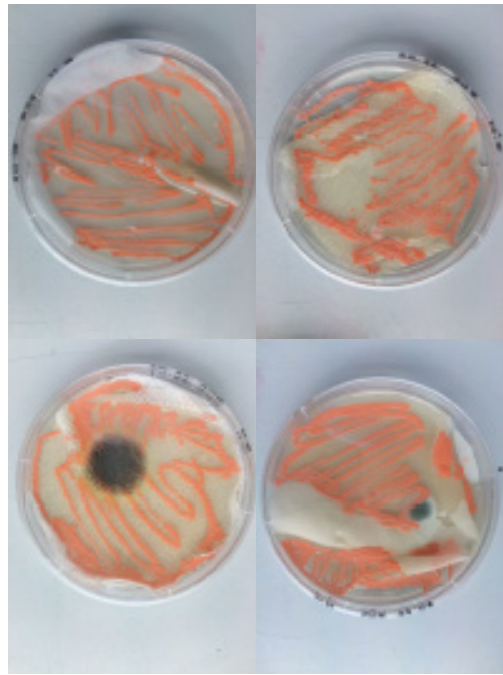
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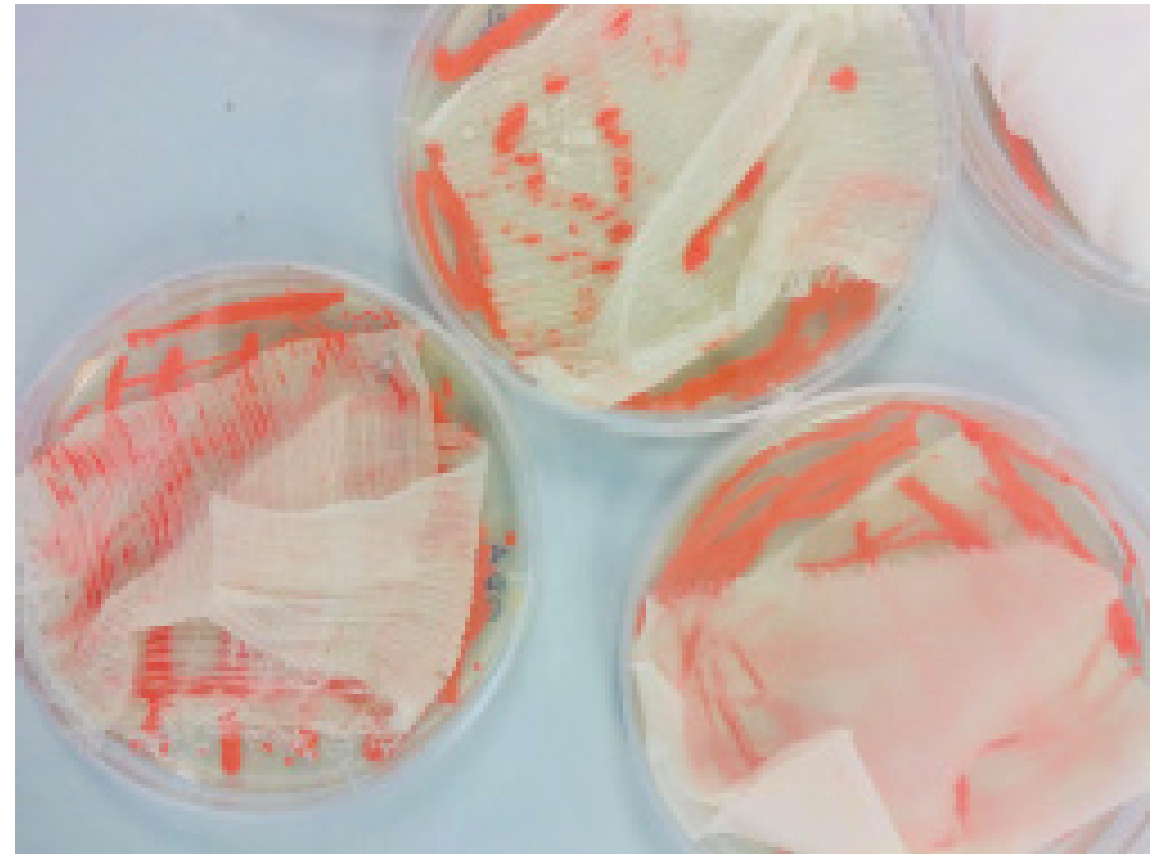
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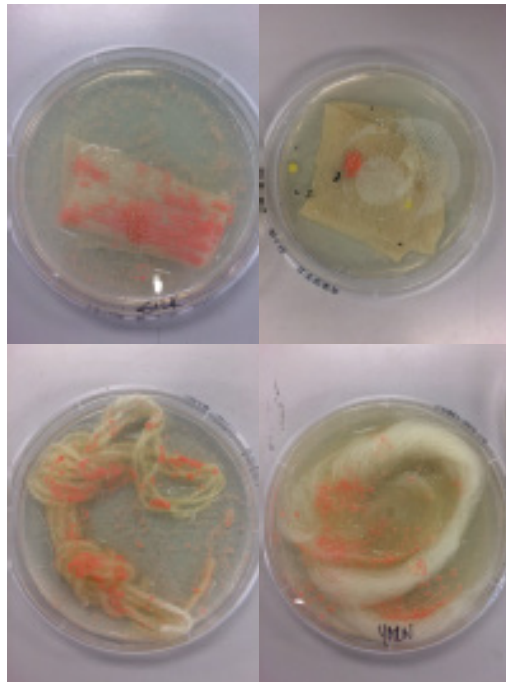
Appendix A

Fungi *Rhodotorula*

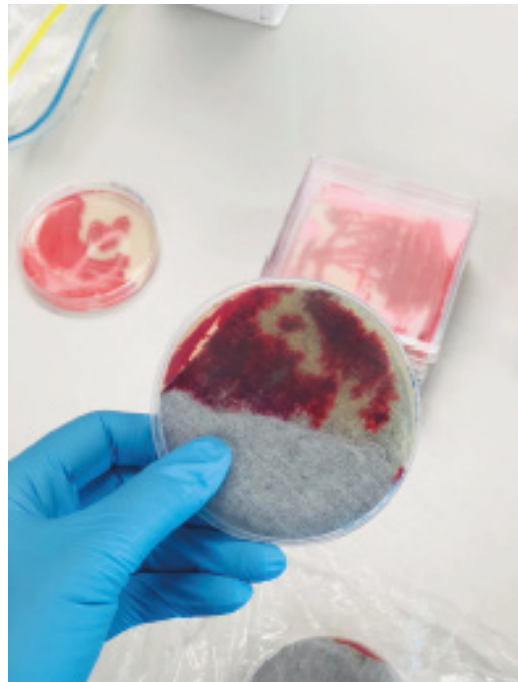
Cultured on PDA Agar

This experiment develops Fungi (*Rhodotorula*) on PDA culture media. A method was trailed for the placement of Silk and Cotton fabric on the surface of the culture media. Developed as a separate pathway, to discover other pigment producing microorganisms, this method produced an orange pigment. Subject to the time constraints of this project this method was not able to be reviewed and developed further onto knitted textiles. However, with a visible pigment being established it can be revisited.

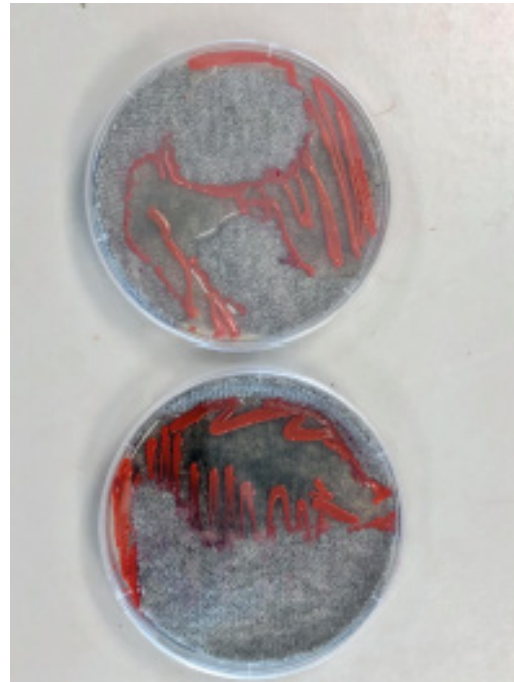
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Appendix B

Bacteria Serratia marcescens

Cultured on Nutrient Agar

To determine the constraints of this biopigment on fibre and fabric, acrylic and coloured knit swatches were trialled. Submerged in nutrient agar the prodigiosin pigment effectively dyed the fabrics. It was fascinating to discover that this natural system could merge with a man-made fibre. However, this study was not the focus of my research and could not be developed further. Even though it was not investigated, this process expanded my knowledge of biopigments and their applications to textiles. It would be valuable to develop this idea further for material composites of 50/50(Wool, Acrylic etc) to determine if this produced a different outcome or hue of biopigment.

68.———



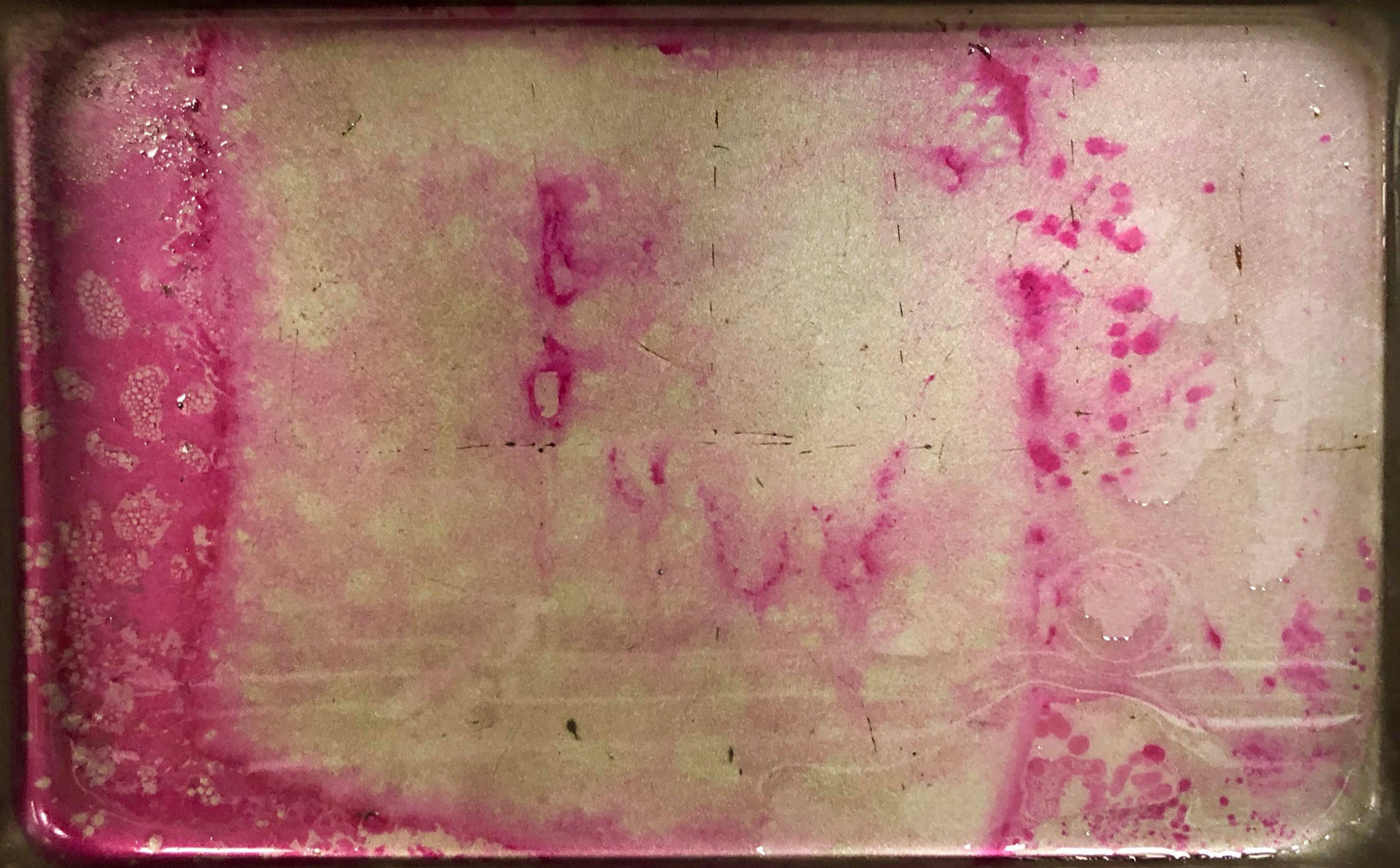


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Glossary

1. **Biodesign:** In his 2012 book, *BioDesign: Nature + Science + Creativity*, produced in collaboration with the Museum of Modern Art (MoMa), New York, William Myers discusses this term as a collaboration of scientists and designers using biology systems interfacing with design ideas. This term may be thought of as an emerging concept, process, technique that harnesses living system to inform practice.
2. **Kaitiaki:** A Māori concept describing a person or group who takes actions to guard or protect the natural world.
3. **Biopigments:** A pigment produced from a living organism. The structure, colour and properties of the pigment can vary within species.
4. **Microbe:** A tiny individual microscopic organism (bacterium).
5. **Chromista Kingdom:** The over-arching kingdom that the algae, kelp, is classified within. This kingdom is home to eukaryotic organisms. These specific organisms' cells have a nucleus enclosed in membranes.
6. **Alginate acid:** Also referred to as an alginate, it is a biomaterial produced in the cell walls of brown algae. It can be extracted and when binding with water produces a viscose gum. This is used in disciplines such a medical science
7. **Bioyarn:** A yarn fibre derived from kelp and associated with the research company AlgiKnit
8. **Biodesigner(s):** Researcher(s) working across the disciplines of life sciences and design. This terms covers a wide range of researchers from Interior, Textiles, Architecture and similar backgrounds.
9. **Streptomyces(A2):** A gram-positive aerobic species of bacteria. These are commonly found in soil. Certain strains can produce a blue pigment
10. **Coliicolor:** A gram-positive bacterium that belongs to the genus *Streptomyces*. It is located in soil and produces a biopigment.
11. **Media:** Solid, liquid or semi-solid food media used for the growth of microorganisms
12. **Isolate:** Refers to a separate a strain of bacteria
13. **Kaitiakitanga:** A Māori world view of managing the environment (flora, fauna and taonga) which could also include attitudes, values, practices and policies.
14. **Taonga:** A Māori term for 'treasure'. It encompasses socially or culturally valuable objects, resources, phenomena, ideas and techniques.
15. **Serratia marcescens:** A gram-negative rod-shaped species of bacteria. This bacterium occurs in soil, water and can produce a red pigment.
16. **Enterobacteriaceae:** A term used to refer to the family of gram-negative bacteria. These non-spore forming bacteria can be found in water, soil, animals and plants.
17. **Bacillus:** Refers to the gram-positive genus of rod-shaped bacteria.
18. **Prodigiosin:** The red pigment produced by many strains of *Serratia marcescens* bacteria.
19. **Sporulation:** Refers to the bacterial reproduction of spores.
20. **Subcultured:** A term used to describe cultivating a bacterial strain onto fresh media
21. **Treated or Untreated fibres:** Treated fibres refers to the fibre being altered (bleached). These fibres are white or coloured. Untreated fibres are in organic form (un-bleached) and are slightly tinted in colour.
22. **Agar:** Refers to an ingredient found in culture media, used for the cultivation of microbes.
23. **Difco™:** A widely used dehydrated culture medium. It is produced in Difco Laboratories, for the purpose of growing microbes. The medium used in this study was sourced from Fort Richard Laboratories (<http://www.fortrichard.com/>).
24. **Volumetric flask:** A glass measuring flask (bottle) used for preparing solutions/dilutions.
25. **Inoculate:** Refers to introducing a microbe to a surface. This is done using a wire rod. However, in saying this, the microbe does not have to be introduced this way. This is up to the interpretation of the designer.
26. **Petri-dishes:** A plastic plate used within a science discipline for the pouring of culture media.
27. **Autoclave(d):** A steam pressure chamber used for chemical reactions/processes to occur. In this research it is used to sterilize swatches (before inoculation) and also after cultivation to kill off the bacteria and leave the biopigment. A range of temperatures and times can be set on this machine. The same word (autoclave) is used as the verb to describe the process carried out by the machine.
28. **Greige:** Refers to non-bleached/non-dyed yarn.

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