CO-CULTIVATING COLOURS

APPENDIX: 1 - 4

PhD Dissertation

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KOLDING
SCHOOL
OF
DESIGN

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Appendix 1: Dialogue Files

In this appendix, the Dialogue Files representing **DIA 1** to **DIA 40** are included. These files represent an annotated portfolio of the experiments conducted during the research project.

Further details can be found in Chapter 3.

DIA 1: DIY Biolab at DSKD

DIA 1

Time period: February to April 2021

Location: DIY Biolab, DSKD

Motivation: Creating a space to enable independent work with microorganisms

Summary

A local ‘Do It Yourself’ biolab was established at Design School Kolding (DSKD) to explore specific aspects of microorganisms, primarily pigment producing bacteria, within the context of the design school. Four different workstations were created: a culture preparation station, a sterilisation station, a cultivation station, and a fridge for storage. These stations are shown in Figure 1.1. The workstations were set up using relatively inexpensive equipment to stay within budget, which imposed certain limitations on the laboratory’s capabilities. The biolab was designed to be easily transportable, but the equipment could also be used in the allocated space. I began conducting small tests with bacteria from my master’s thesis project to evaluate whether the space and equipment functioned effectively.

Evaluation

The DIY Biolab has its limitations, but it allows for some material explorations. It is an open and dynamic space that can be easily adjusted and developed based on the needs and interests of students. However, a responsible person is required to oversee the DIY Biolab.

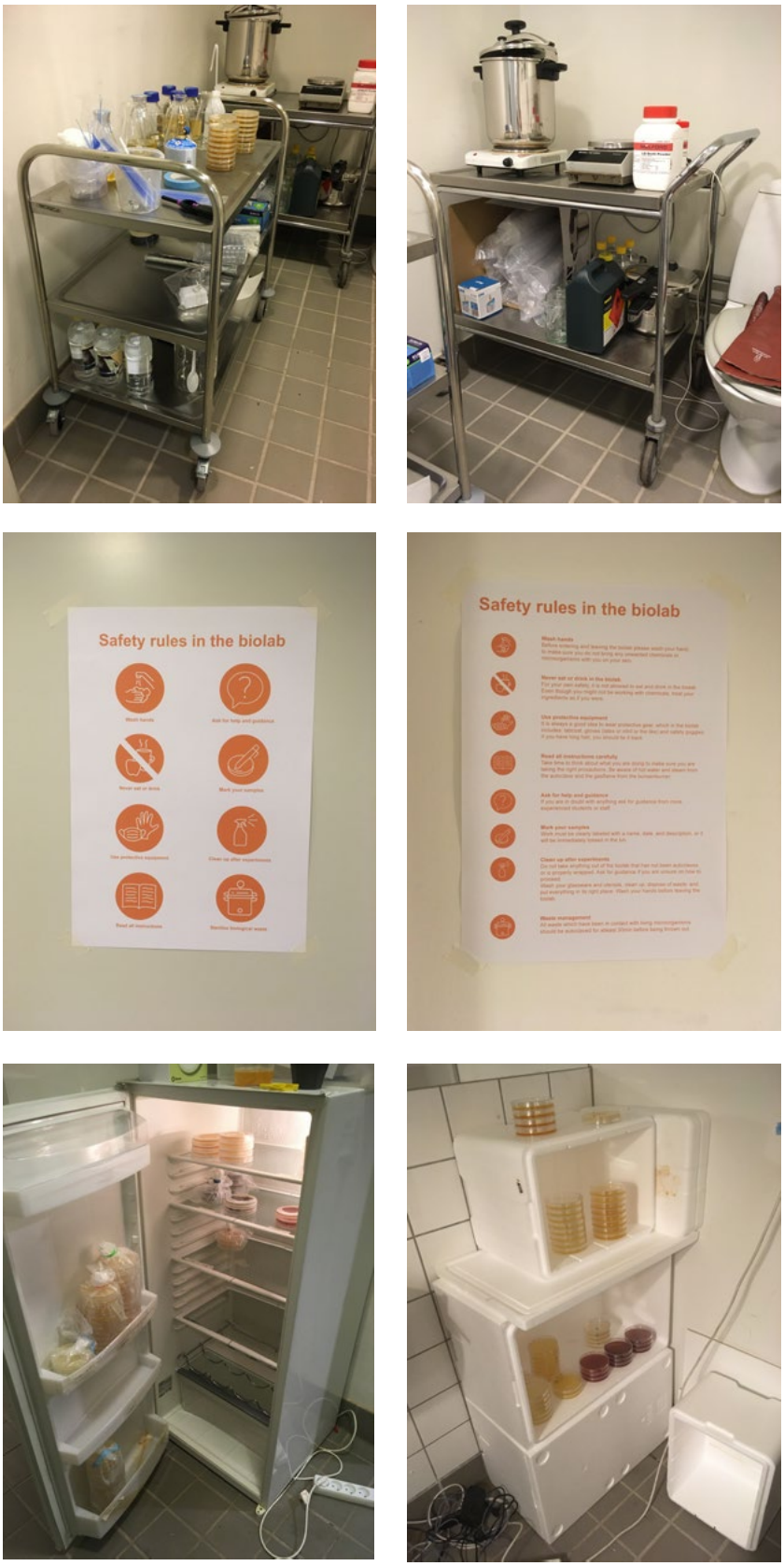


Figure 1.1 DIY Biolab at Design School Kolding.

DIA 2: Biolab interviews

DIA 2

Time period: March to April 2021

Location: Design School Kolding - DSKD

Motivation: Enable students to work safely and independently in the DIY Biolab

Summary

I conducted semi-structured interviews with biolab experts to implement a DIY biolab at DSKD. The experts and the findings from these interviews were as follows:

Shem Johnson postgraduate MA Biodesign Biolab Central Saint Martins:

A lab manager is in place.
Many safety guidelines are followed.
The lab is very similar to a natural science laboratory.
The manager has a natural science background.

Heleen Sintobin and María Boto Ordóñez Laboratorium, the experimental lab for art/ design and biotechnology at KASK, School of Arts Ghent:

Some regulations are in place.
They are searching for second-hand equipment.
The lab is managed by someone with a natural science background.

Roland van Dierendonck facilitator at Oslo Biolab

Previously worked at Waag biolaboratories.
Actively engaged in the citizen science movement, “Citizen Science, Bioart”.

The interviews with the three experts were conducted virtually. While visiting them in person and observing their institutions might have been beneficial, Covid-19 restrictions limited travel opportunities. Virtual interviews, however, allowed me to allocate time to other parts of the project. Following the interviews, the experts

provided extensive information and guidelines on establishing and managing a biolab, which significantly influenced the development of the DIY Biolab guidelines. The questions included:

- Have you worked with bacterial pigments? If yes, how do you do it?
- Do you teach certain courses, or do you mainly do research projects within this field?
- Are students allowed to work on this subject independently, or is a supervisor required to be present?

I also contacted other institutions and engaged in written correspondence with them, though no interviews were conducted. In general, everyone I reached out to was very helpful.
The key insights gained from the interviews and the documents provided were:

- A robust induction method is essential (students should not work alone, as is also the rule in natural science labs).
- How to design an introductory workshop, where students sign a document agreeing to follow the rules.
- The importance of safety guidelines.
- Effective management of a biolab (having a manager responsible for the biolab and its safety).

All the experts were open to discussing how they had established their biolabs, the safety guidelines they had implemented, and how they introduced students to the biolab. They shared information about the guidelines they had developed (although I was not permitted to share these documents with others, they served as inspiration) for the rules to follow in the biolab.

Using this information, I created the rules for the DIY Biolab at Design School Kolding, DSKD.

Evaluation
I produced the guidelines for the DIY Biolab based on the experts' advice and guidelines. An overview of these guidelines can be seen in Figure 1.2.

Wash hands

Ask for help and guidance

Never eat or drink

Mark your samples

Use protective equipment

Clean up after experiments

Read all instructions

Sterilize biological waste

Figure 1.2 Overview of guidelines for the DIY Biolab at DSKD.

DIA 3: Sourcing local bacteria

DIA 3

Time period: March 2021

Locations: DIY Biolab, DSKD
Local nature in Aarhus and Kolding

Motivation: Expanding the bacteria producing colours available in my practice by sourcing local colour producing bacteria.

Summary
In an effort to discover additional colour producing bacteria, beyond those I had already acquired for my master's thesis project, I collected bacterial samples from my local surroundings in Aarhus, Denmark, in March 2021.

Finding bacteria in local environment
To collect bacteria, I prepared sterile Petri dishes with growth media suitable for bacterial cultivation. I utilised two different growth media—Nutrient Broth and Luria Broth—which are commonly used to cultivate a wide range of chemoheterotrophic bacteria. Sterile inoculum loops were employed to swab samples from selected surfaces. Examples of these surfaces are shown in Figure 1.3 below.

Isolating bacteria
After collecting bacterial samples, I cultivated them in Petri dishes at room temperature in the DIY laboratory at DSKD. The growth media, along with the temperature and cultivation environment, influenced which bacteria would grow. Despite the Petri dishes being prepared specifically for bacterial growth, fungi also grew in the dishes, as the growth media are widely used for cultivating various microorganisms, including fungi. Examples of Petri dishes containing a mix of microorganisms are shown in Figure 1.4 and Figure 1.5.

Evaluation
Isolating new bacteria proved challenging due to significant contamination, making

the process highly time-consuming and reliant on trial and error. Using more specialised growth media could potentially reduce contamination and improve the process. Nevertheless, it is possible to discover additional colour producing bacteria.

Figure 1.3 Collecting bacteria samples from various surroundings.

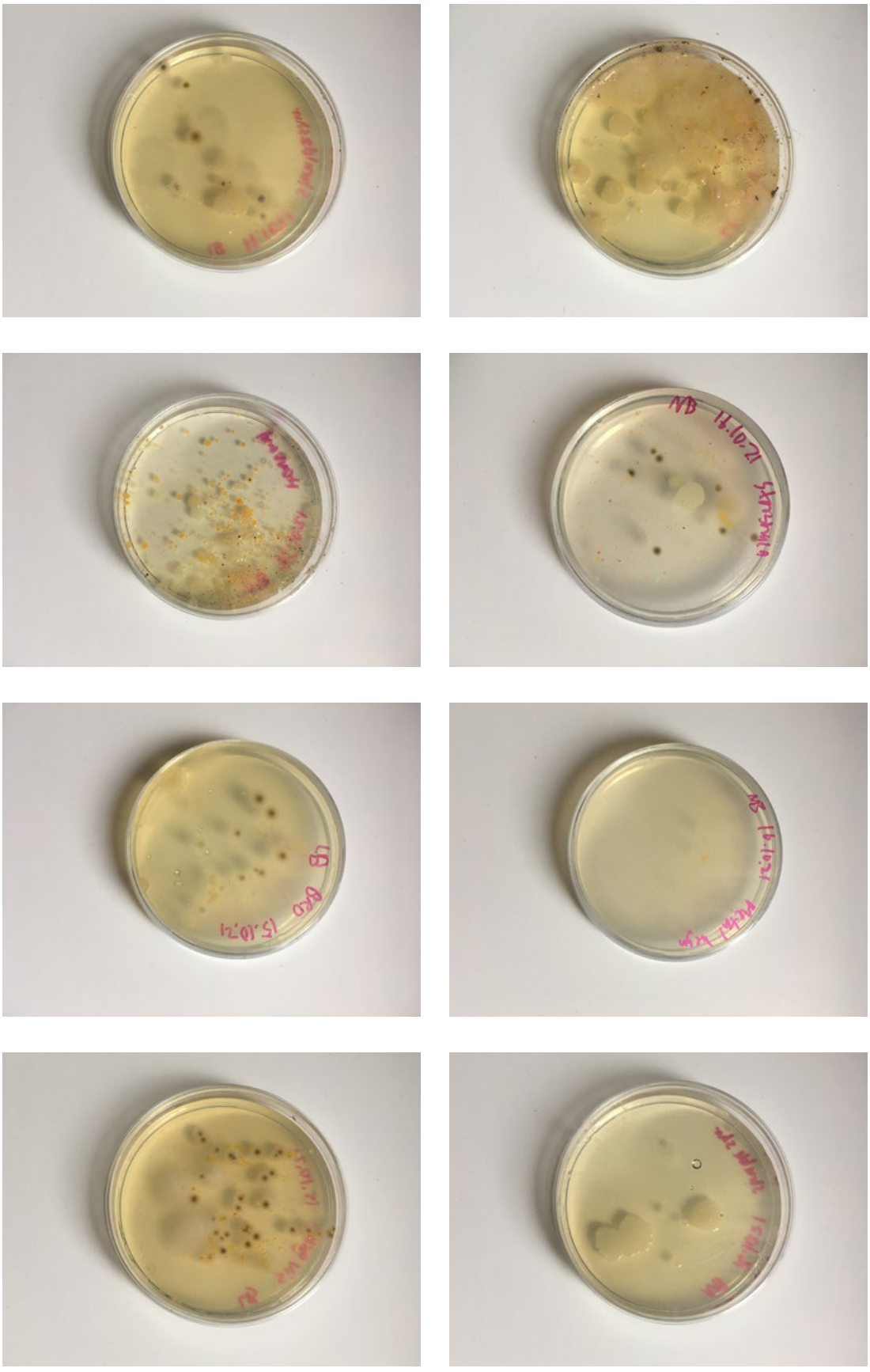


Figure 1.4 Examples of Petri dishes with bacterial and fungal growth.

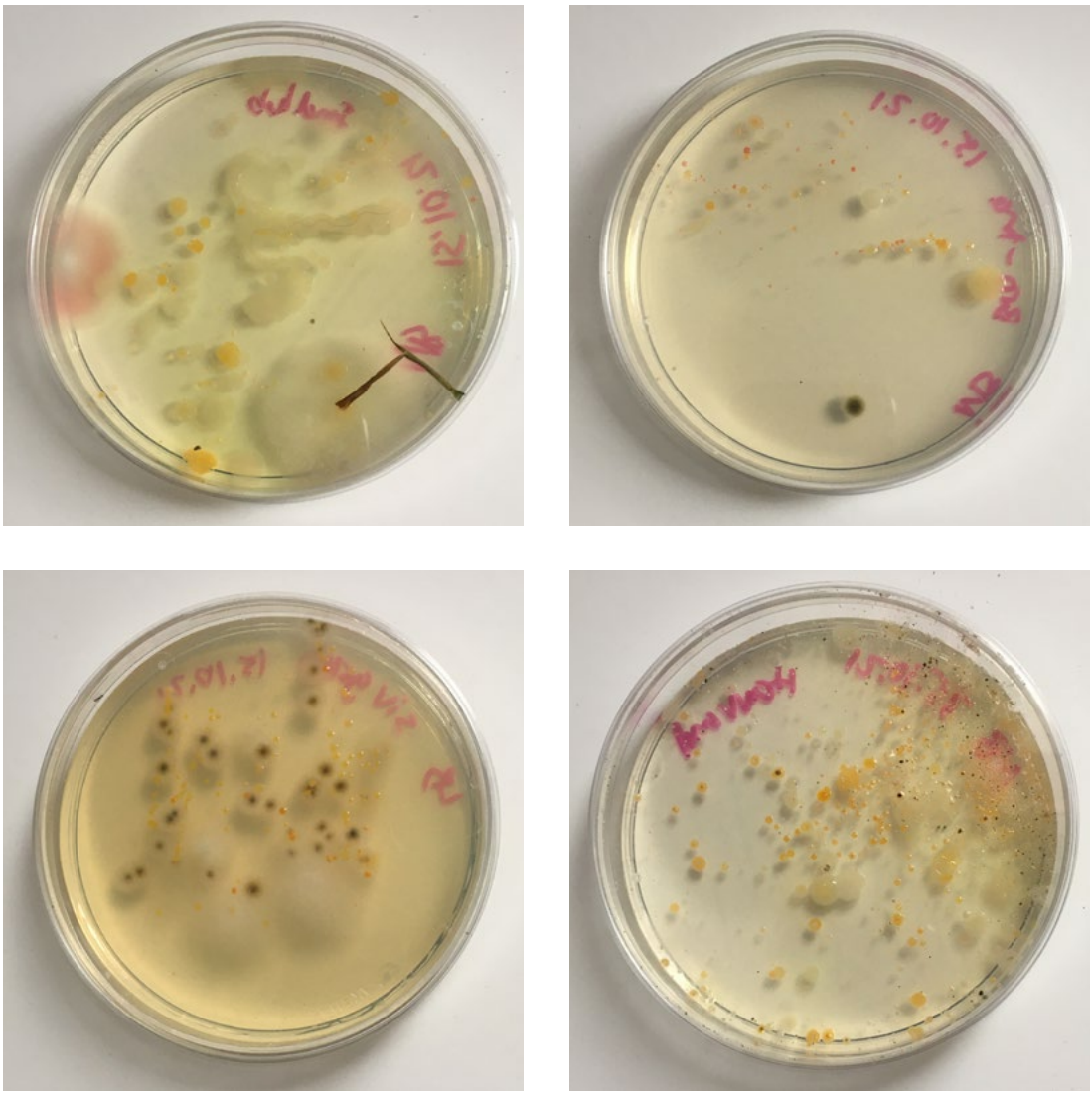


Figure 1.5 Examples of Petri dishes with many orange and yellow bacteria.

DIA 4: DNA analysis at Aarhus University

DIA 4

Time period: April 2021

Location: Aarhus University, Department for Biochemical Engineering

Motivation: Isolate and analyse sourced bacteria, to enable further cultivation and colour production

Summary

To isolate a single bacterial species from the Petri dishes, access to a biosafety level 2 laboratory is required. In **Appendix 4, The Biolab Booklet**, a diagram illustrates that it is safe to find and grow microorganisms, where the specific species is unknown, in a biosafety level 1 laboratory, which is the category a DIY laboratory falls under. However, opening a Petri dish and transferring a microbial colony must be conducted in a biosafety level 2 laboratory.

To facilitate this, I arranged an agreement with a laboratory at Aarhus University, within the Department of Biochemical Engineering, to use their facilities for isolating and sequencing the DNA of the bacteria. This ensured that the bacterium was safe to continue working with. With access to a biosafety level 2 laboratory, I successfully isolated some yellow and orange bacteria, which I had collected in **DIA 3**.

At Aarhus University, I established contact with Thomas and his colleague Frederikke, who was working on a project for primary schools. I was able to include my isolated samples in their batch for analysis, which was a valuable opportunity. This collaboration allowed me to identify the type of bacteria I was working with and determine whether they were safe for further experimentation. Some of the yellow and orange bacteria were analysed and identified, as shown in Figure 1.6.

Evaluation

Expert knowledge significantly reduces time wasted in bacterial exploration.

Collaboration is essential for utilising newly discovered colour producing bacteria in further experiments, as it is not possible to proceed with unknown bacteria in a DIY biolab. Gaining access to a biosafety level 2 laboratory through collaboration with Aarhus University opened up new experimental and design opportunities. However, finding opportunities for bacterial analysis was challenging due to Covid-19 restrictions, as the laboratory was closed. Despite these challenges, it is important to seize opportunities for progress. The laboratory I collaborated with was very helpful and actively sought alternative solutions to accommodate my requests.

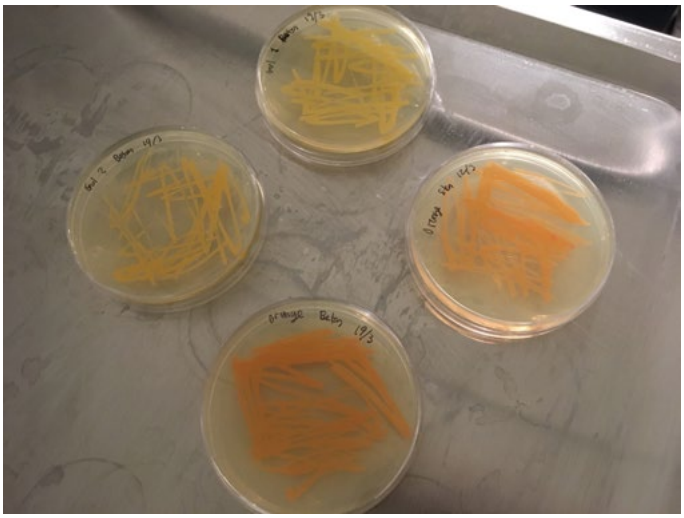


Figure 1.6 Science building at Aarhus University and some of the microorganisms, which was analysed.

DIA 5: DIY Biolab pilot colour study

DIA 5

Time period: April to October 2021

Location: DIY Biolab, DSKD
Design School Kolding

Motivation: Explore the aesthetic and technical possibilities of the bacterial colours available using the DIY Biolab

Summary

This dialogue explores the potential of bacterial pigments for textile and material applications, focusing on their properties, application methods, and challenges. The research involved isolating pigment producing bacteria, exploring their colour properties, and applying them to textiles, yarns, and other materials such as PLA. The dialogue also included collaborations with industry experts and academic institutions to address limitations and identify opportunities for further development.

Explanation of the five bacteria

In Figure 1.7, the five bacteria available for exploration are shown. These are all chemoheterotrophic, pigment producing bacteria capable of growing at room temperature. The chemical structure of the colour molecules they produce influences their suitability for textile colour applications, depending on the molecule itself, the application method, and the type of textile fibre. The bacterial species Pseudoanthrobacter was particularly difficult to cultivate in the DIY Biolab, as it did not produce enough pigment to apply to textiles. However, other studies have successfully produced indigoidine for textile applications, although they used genetically modified organisms (GMOs) to optimise pigment production (Ghiffary et al., 2021).

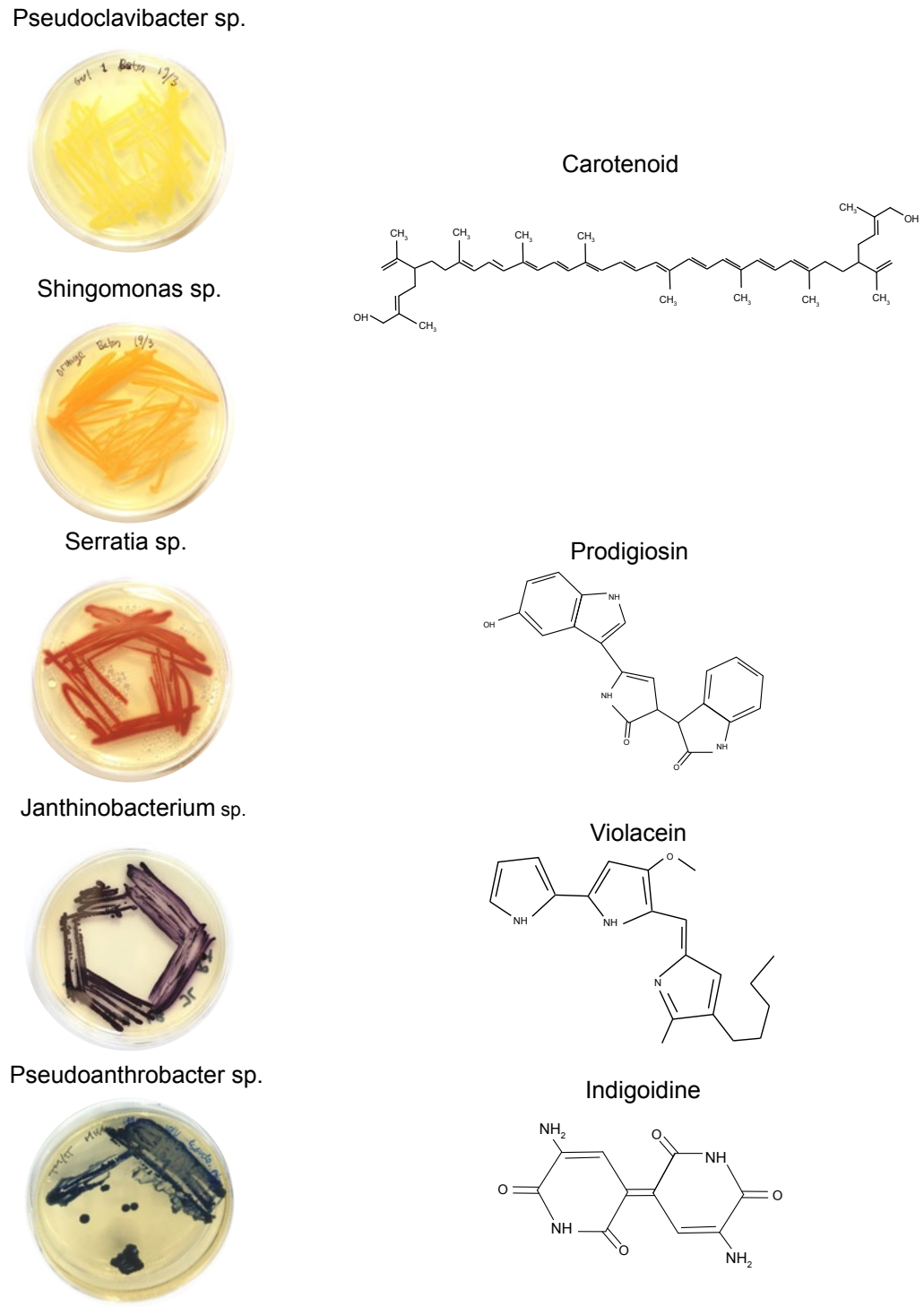


Figure 1.7 Pigment producing bacteria and their associated colour molecules.

Exploring colour properties

Rather than searching for additional pigment producing bacteria, the focus was placed on exploring the colour properties and application potential of three pigments: carotenoid, prodigiosin, and violacein. Although each bacterial species was associated with a single pigment, it is possible for bacteria to produce multiple pigments with similar chemical structures due to shared metabolic pathways. Certain parts of the colour molecules make them suitable for textile

applications. Firstly, the molecules must contain two radicals: a chromophore and an auxochrome, which can have various chemical structures (Gohl & Vilensky, 1984). Secondly, colour molecules are classified into specific classes based on the structure of their colouring components. Carotenoids belong to a class where polyene is the colouring component. Prodigiosin is a single molecule in the pyrrole class, violacein is a single molecule in the indole class, and indigoidine is a single molecule in the N-heterocycle class (Fried et al., 2022). These classifications provide insights into how the pigments can be applied and which textile fibres they are compatible with.

Textiles coloured during bacteria cultivation

As described in the fungi colour application **DIA 9**, it is possible to grow pigment producing bacteria directly on textiles, dyeing them in uncontrolled patterns. First, the growth media and textiles were prepared and sterilised. A Bunsen burner was used to create a sterile environment, and the growth media was poured into Petri dishes, where sterilised textiles were placed. The Petri dishes were incubated in the DIY Biolab for 4–6 days at room temperature, allowing the bacteria to colour the textiles in uncontrolled patterns. After incubation, the coloured textiles were placed in autoclave bags, and the Petri dishes were sterilised in a pressure cooker at 120°C for 1 hour to kill the bacteria and fix the colour. This process, along with an example of a coloured textile, is shown in Figure 1.8 and Figure 1.9.

Two approaches were explored using this technique. In the first approach, bacteria were grown in liquid sterile growth media with sterilised textiles, as shown in Figure 1.10. In the second approach, textiles were sterilised with elastic bands to create patterns, similar to the Japanese Shibori technique, and placed in liquid media with bacteria. This process was repeated to create overlapping patterns, as shown in Figure 1.11. Both approaches resulted in uncontrolled patterns on the textile surfaces, with varying colour hues depending on the bacteria’s growth and pigment production.

In both approaches, after incubation, the textiles were sterilised in a pressure cooker at 120°C for 1 hour to kill the bacteria and fix the colour.

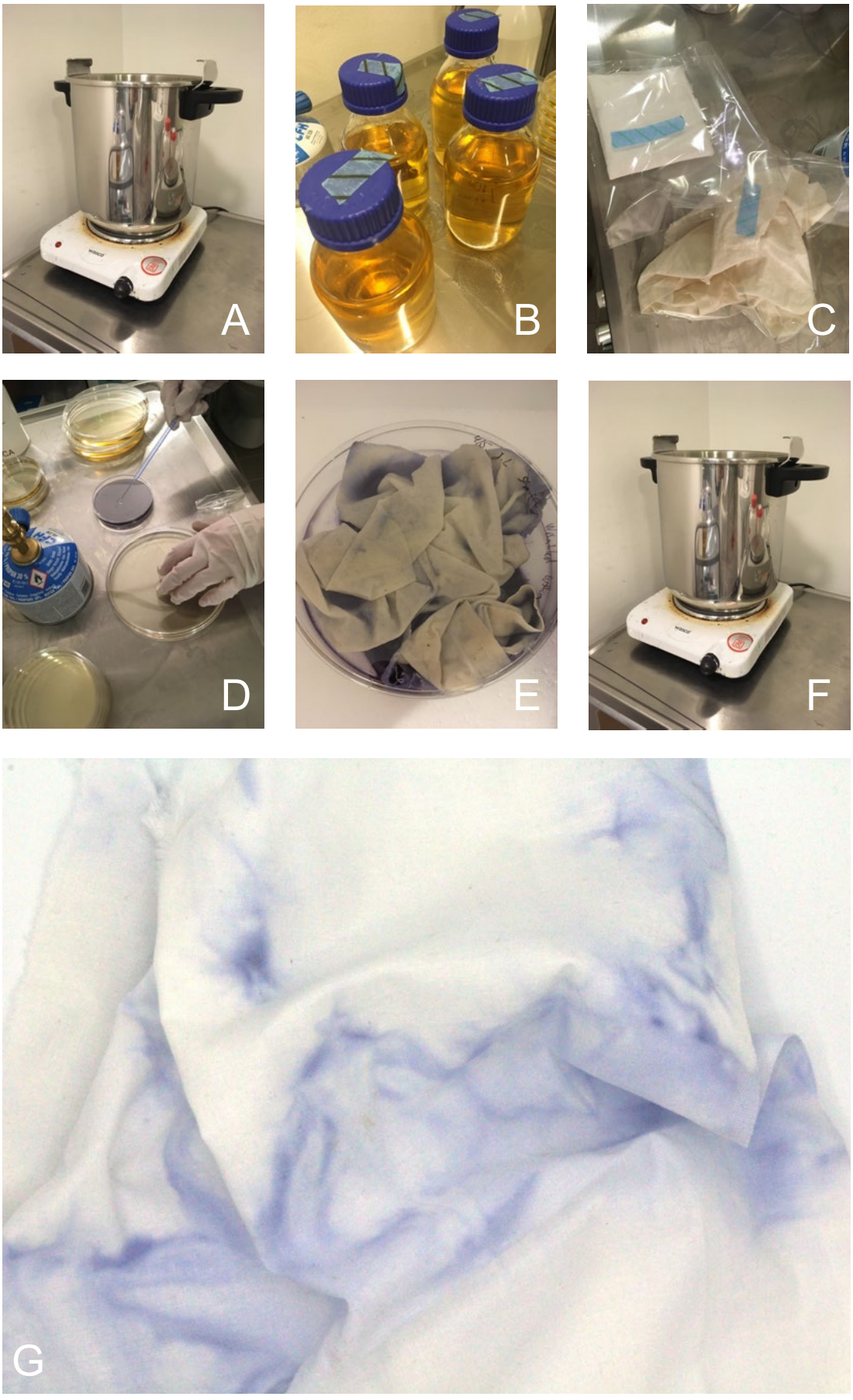


Figure 1.8 Cultivating bacteria producing violacein and colouring cotton textile.

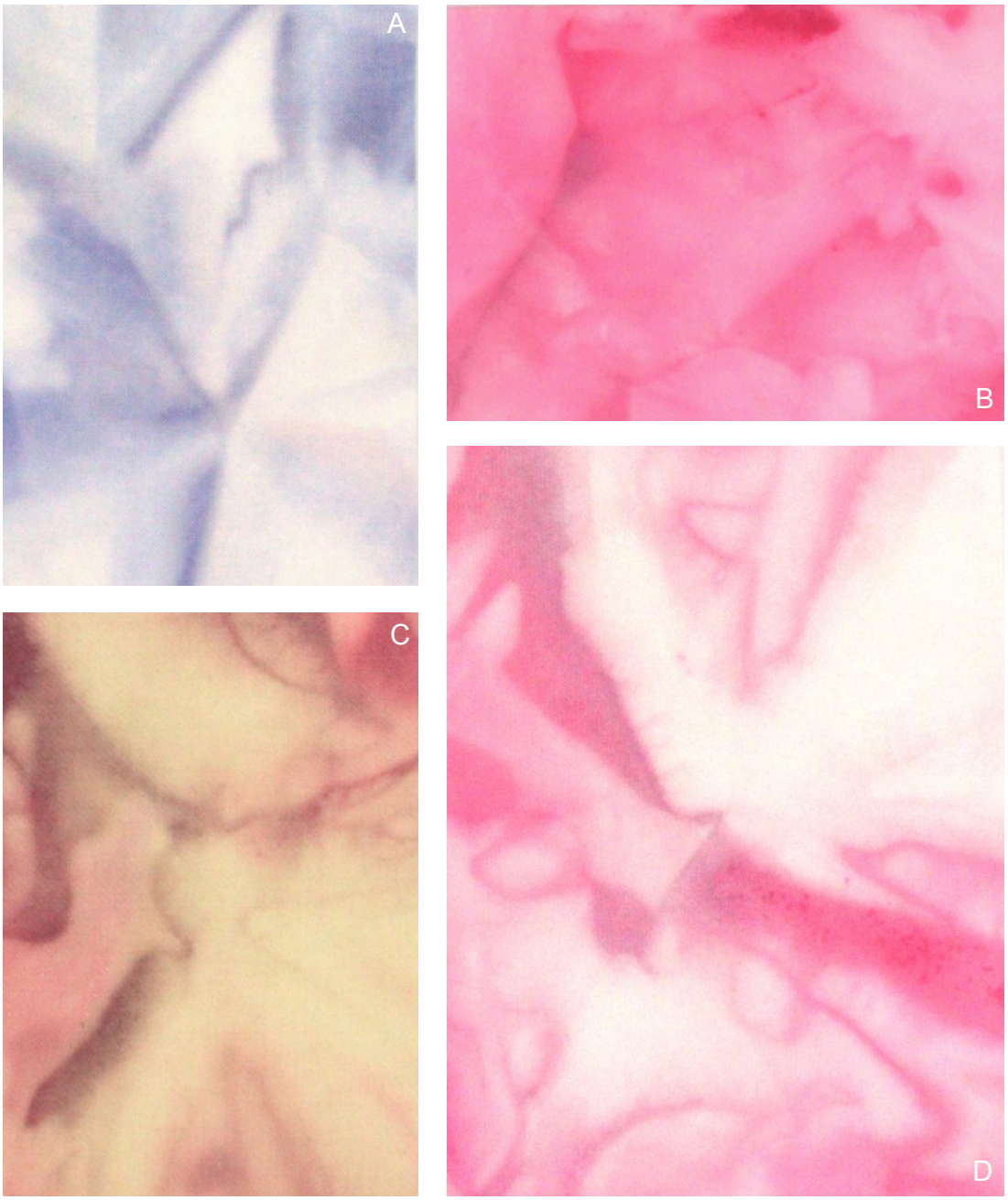


Figure 1.9 Examples of textiles coloured during bacteria cultivation. Cotton coloured with violacein (A), Polyester coloured with prodigiosin (B), Wool coloured with prodigiosin (C), Polyester coloured with prodigiosin (D).

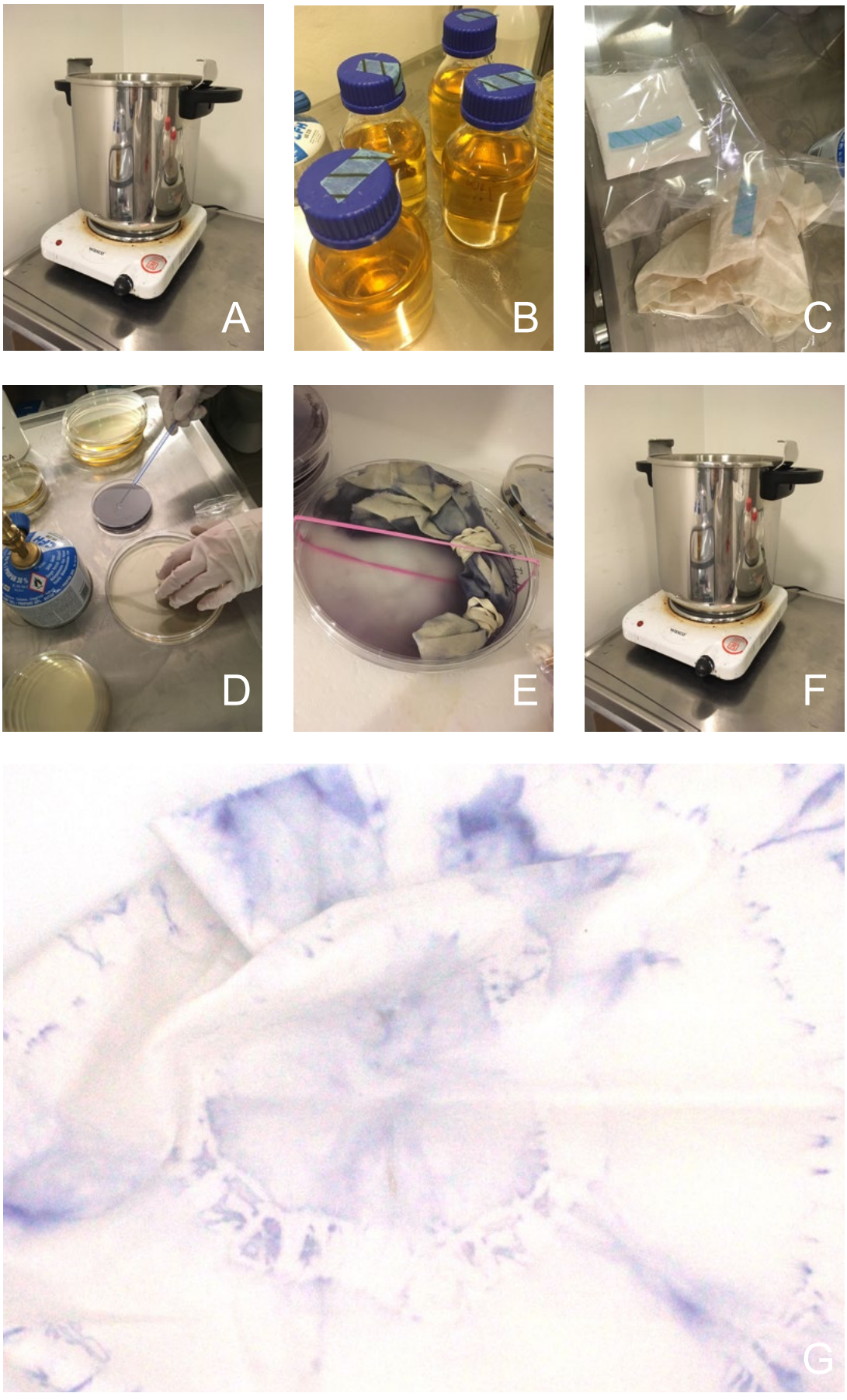


Figure 1.10 Cotton textile coloured with during cultivation with Shibori technique.

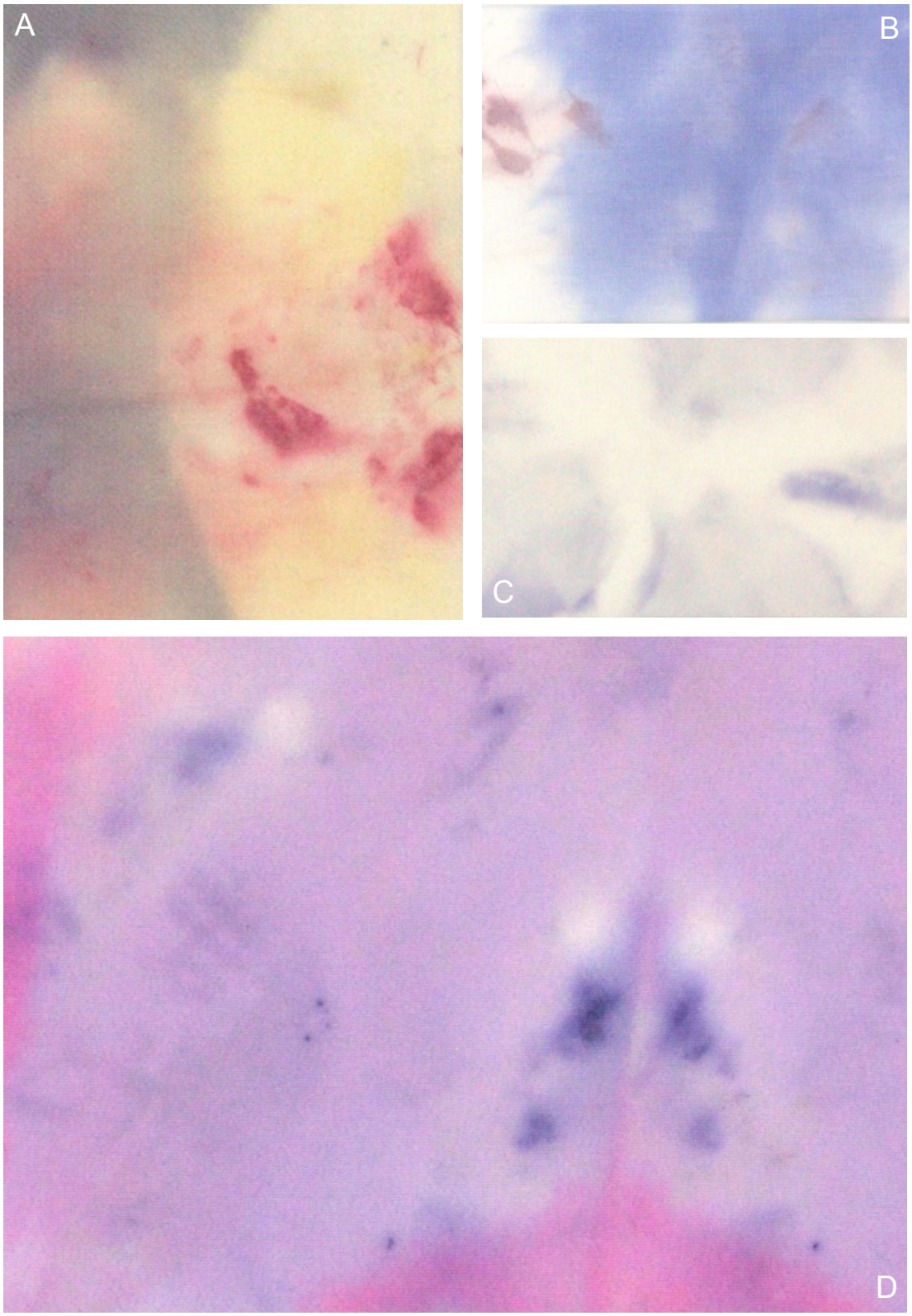


Figure 1.11 Examples of textiles coloured during cultivation with Shibori inspired technique. Wool coloured with violacein, carotenoid and prodigiosin (A), cotton coloured with violacein and prodigiosin (B), Cotton coloured with violacein (C), Polyester coloured with prodigiosin and violacein (D).

Textiles printed with bacteria colours

Two techniques were used to create printed patterns on textiles. The first technique involved cultivating Janthinobacterium lividum to create a print paste by mixing the bacteria in a coloured liquid with the thickening agent Gum Arabic. The paste was printed onto textiles and sterilised in a pressure cooker at 120°C for 1 hour to kill the bacteria and fix the colour, as shown in Figure 1.12 , with examples of surface patterns in Figure 1.13. However, the dilution of the pigment with Gum Arabic limited the colour intensity. Future studies could benefit from isolating the pigment through extraction and filtering processes, which were not possible in the DIY Biolab, to achieve darker prints.

The second technique involved preparing Petri dishes with agar-based growth media. Bacteria were cultivated on the surface of the agar and then transferred onto textile surfaces, creating abstract prints. The printed textiles were sterilised in a pressure cooker at 120°C for 1 hour to kill the bacteria and fix the colour, as shown in Figure 1.14, with examples of surface patterns in Figure 1.15 and Figure 1.16.

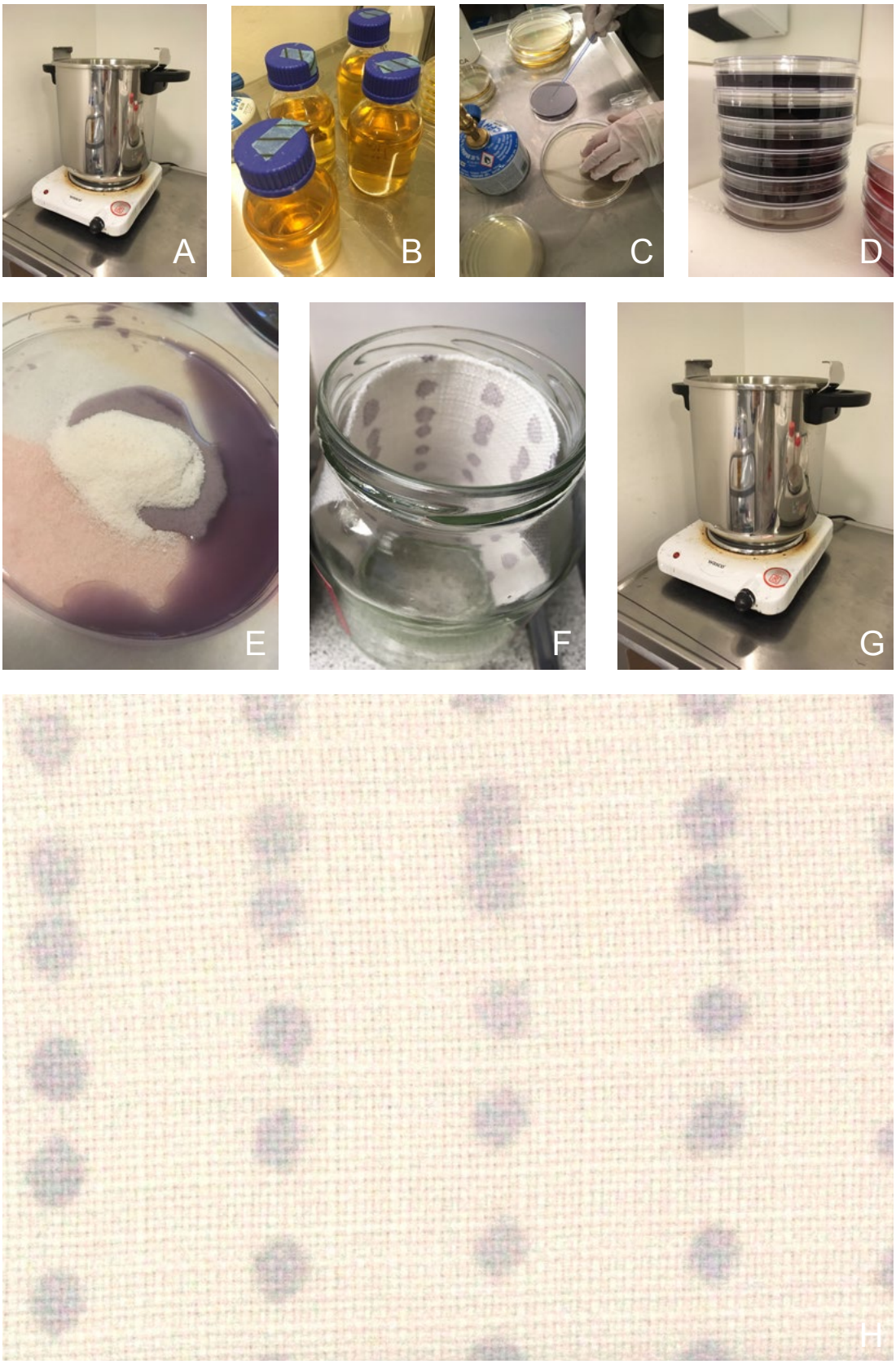


Figure 1.12 Creating a print paste for textile application (A-G). Polyester coloured with print paste made from violacein (H).

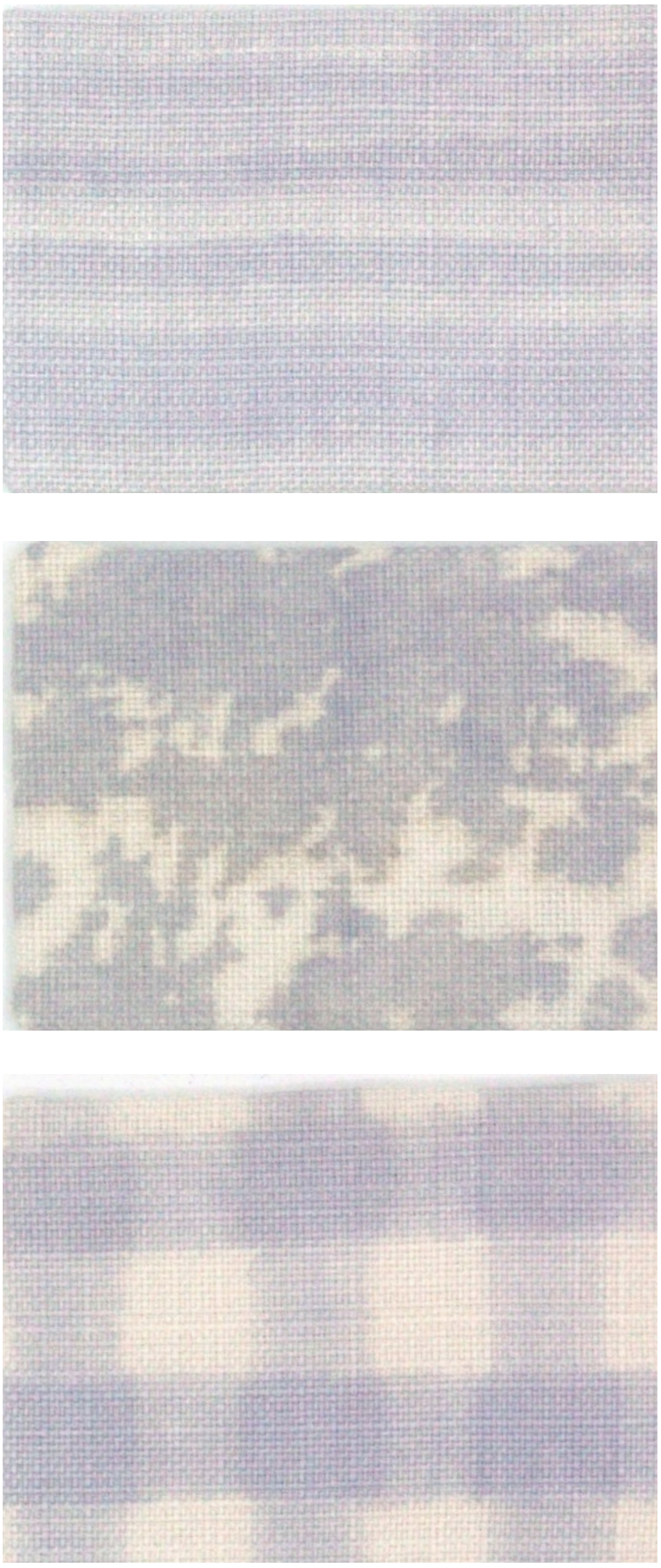


Figure 1.13 Examples of print patterns made with violacein with Gum Arabic on polyester.

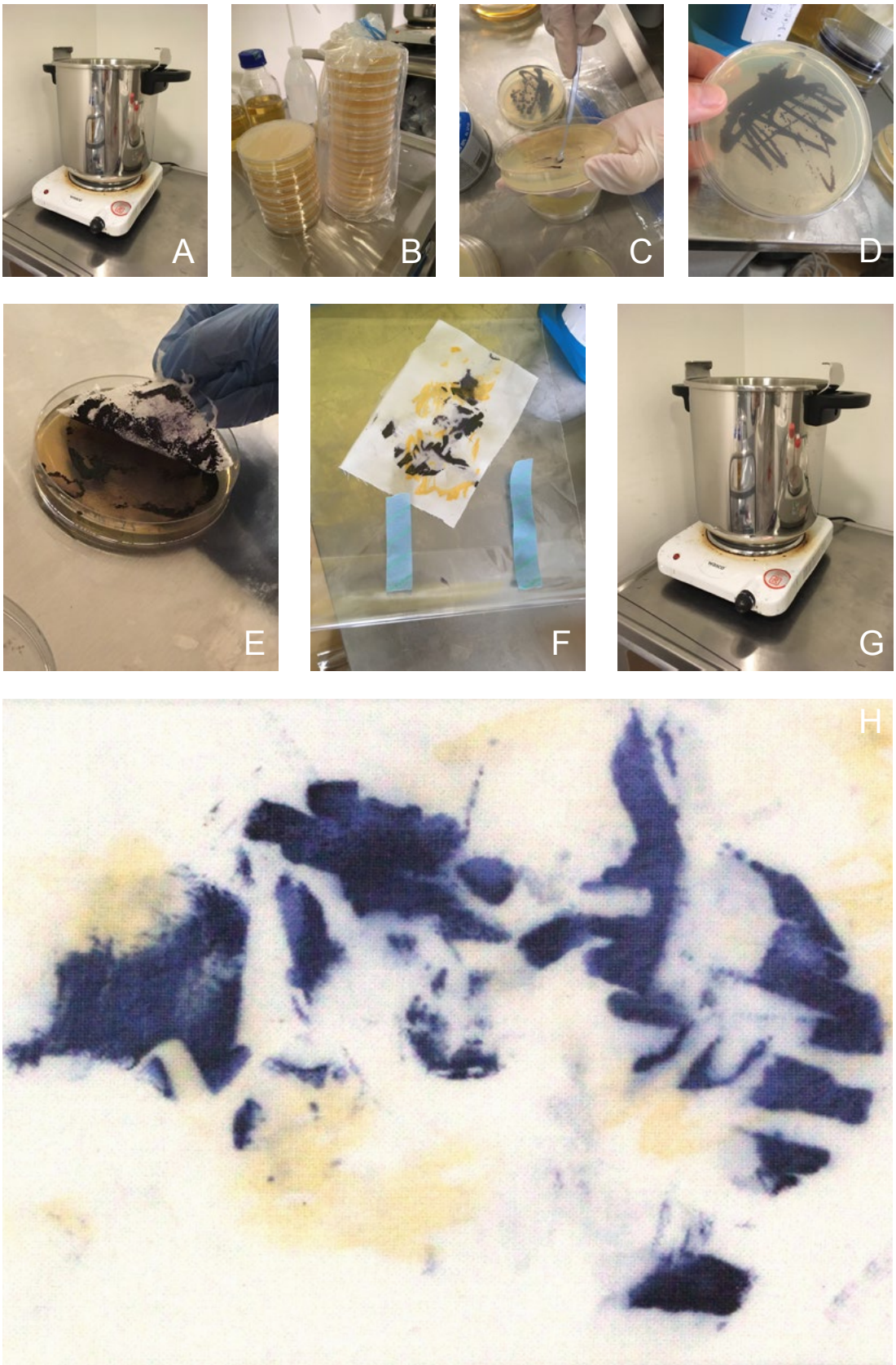


Figure 1.14 Uncontrolled printed patterns created with transferring bacteria cultures from Petri dishes. Textile is polyester coloured with violacein and carotenoid.

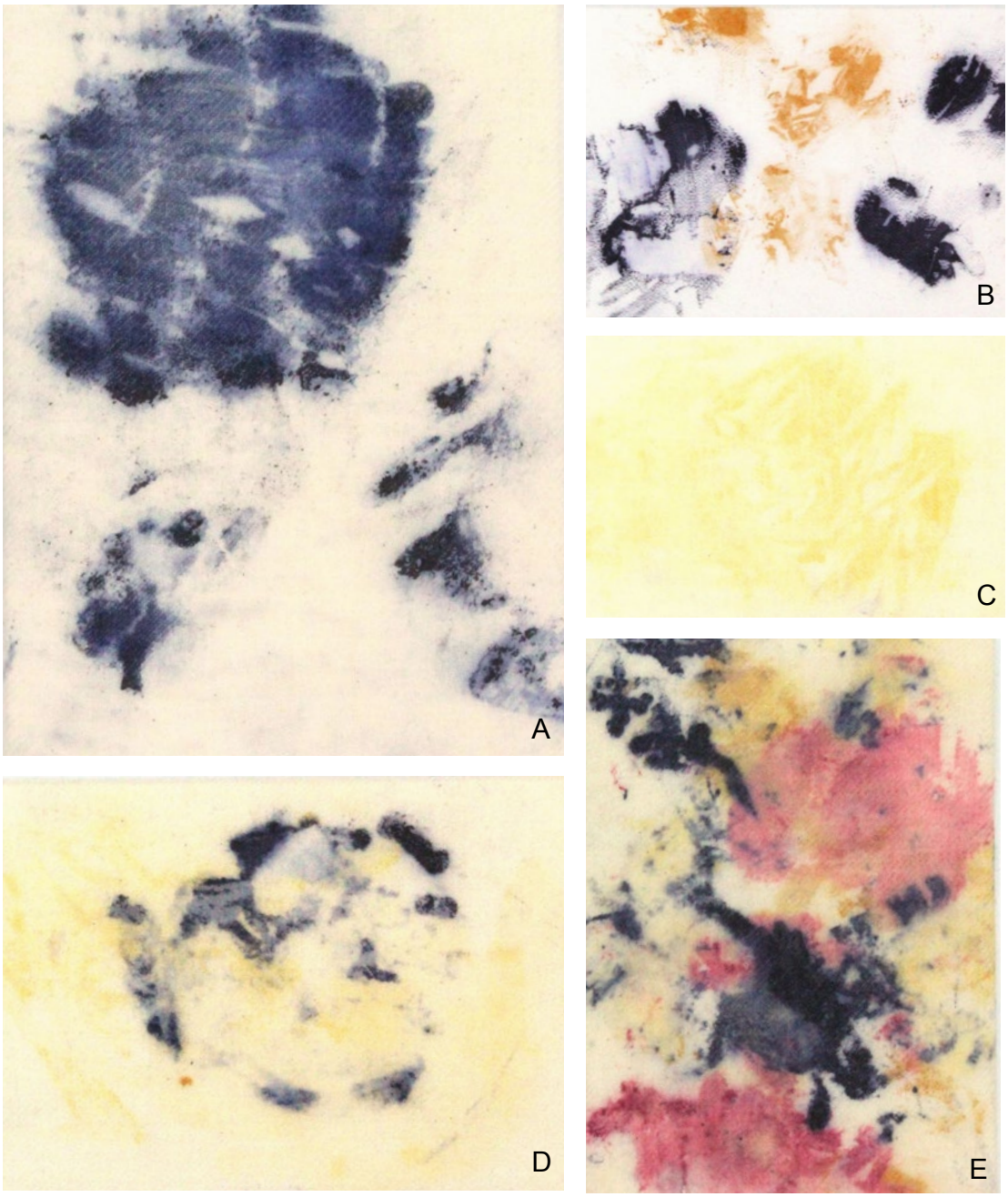


Figure 1.15 Examples of transferred bacteria cultures onto textiles by printing. Wool coloured with violacein (A), Polyester coloured with carotenoid and violacein (B), Wool coloured with carotenoid (C), Wool coloured with carotenoid and violcein (D), Wool coloured with carotenoid, prodigiosin and violacein (E).

Figure 1.16 Results of pattern testing with biocolours.

PLA dyed with bacterial colours

Since bacterial pigments were applicable to polyester, their application to polylactic acid (PLA), a biodegradable thermoplastic polymer often used in 3D-printing, was explored. Bacteria were cultivated in liquid growth media, and fragments or filament pieces of PLA were placed in the liquid. The colour was fixed to the PLA using a pressure cooker at 120°C for 1 hour, with the process shown in Figure 1.17 A-G.

Typically, PLA is coloured using a powder pigment, known as a masterbatch, which is mixed with non-coloured PLA to create an even colour during the melting and 3D-printing process (online conversation, 8th November 2022, with Anja Lund, polymer scientist at RISE). The coloured PLA fragments were later melted together at 120°C for 1 hour to observe how the colour behaved, as shown in Figure 1.17 H. Additionally, 3D-printing was tested using a 3D-doodle pen with the coloured PLA filaments. The melted filament became lighter in colour but retained the same tone, as the bacterial pigment adhered only to the surface and was not distributed throughout the filament.

To test lightfastness, a small experiment was conducted to observe whether the colour faded. The results showed that the colour did fade, returning almost to the original white fragment colour, as shown in Figure 1.18.

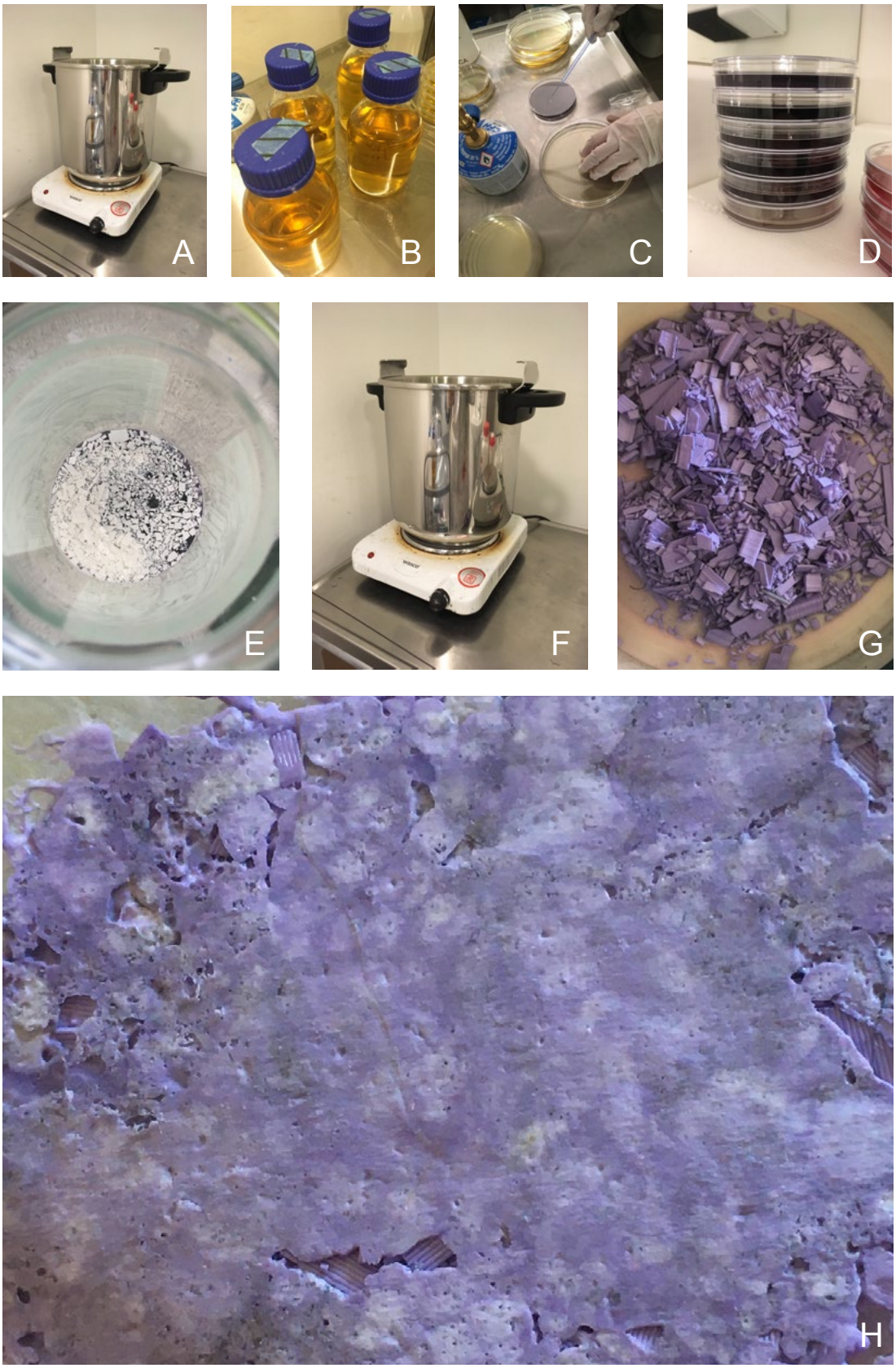


Figure 1.17 PLA fragments coloured with violacein using conventional dyeing technique.

Figure 1.18 PLA dyed with violacein and prodigiosin (Left). PLA dyed with violacein and exposed to sunlight (Right).

Textiles and yarn dyed with bacteria colours through conventional dyeing

One of the widely used textile application techniques is dyeing. Bacterial pigments can be utilised for conventional dyeing, with heat used to fix the colour to the textile fibres. Before dyeing the textiles with bacterial pigments, I cultivated bacteria in sterilised liquid growth media in the DIY Biolab. The liquid pigment was then collected and used for the dyeing process. During this process, the textiles were wetted out to prepare them for dyeing, placed in the liquid containing the bacterial pigment, generally at a ratio of 1:10 of liquid media to water, and dyed for one hour at approximately 90°C. The process is illustrated in Figure 1.19.

I applied this dyeing technique to study how different textile fibre types—cotton, silk, wool, and polyester—absorbed the bacterial pigments, as shown in Figure 1.20. The use of heat to fix the colour also ensured that the bacteria were killed, making the textiles safe for use. As demonstrated in Figure 1.20, carotenoid pigments were only applicable to wool fibres (A7, A9, B2, B7), while prodigiosin (D1–D10) and violacein (C1–C10) were effective on all the studied textile fibre types.

In a subsequent study, I created various yarn winding samples using a mix of wool, cotton, and polyester yarns. The yarns were dyed using the same technique as described above. These yarn winding samples were used to explore how the three pigments—carotenoid, prodigiosin, and violacein—could be combined with different fibre types to create mélange effects. Examples of these effects are shown in Figure

1.21. The mélange effects were achieved by either mixing two or three yarn strands in the winding sample (A1–A8), twisting two or three yarn strands before winding them (B1–B8), or creating stripes where some of the stripes were a mix of two yarn strands (C1–C8).
The different yarn winding samples in Figure 1.21 are as follows:

A1: Wool dyed with violacein and carotenoid, and polyester dyed with violacein/prodigiosin.
A2: Wool dyed with violacein and polyester dyed with violacein.
A3: Cotton dyed with violacein and polyester dyed with violacein.
A4: Polyester dyed with prodigiosin and polyester dyed with violacein.
A5: Wool dyed with carotenoid and cotton dyed with violacein/prodigiosin.
A6: Cotton dyed with violacein and wool dyed with violacein/carotenoid.
A7: Polyester dyed with prodigiosin, wool dyed with carotenoid, and wool dyed with violacein.
A8: Polyester dyed with violacein/prodigiosin, wool dyed with violacein, and cotton dyed with violacein.

B1: Wool dyed with carotenoid and polyester dyed with prodigiosin.
B2: Polyester dyed with prodigiosin and polyester dyed with violacein/prodigiosin.
B3: Wool dyed with violacein/carotenoid, cotton dyed with carotenoid, and polyester dyed with prodigiosin.
B4: Wool dyed with carotenoid and wool dyed with prodigiosin.
B5: Polyester dyed with prodigiosin and wool dyed with violacein.
B6: Polyester dyed with prodigiosin and wool dyed with carotenoid.
B7: Cotton dyed with violacein and wool dyed with violacein.
B8: Polyester dyed with violacein and cotton dyed with violacein.

C1: Polyester dyed with prodigiosin and wool dyed with violacein/carotenoid.
C2: Polyester dyed with prodigiosin/violacein, cotton dyed with violacein, and polyester dyed with violacein.
C3: Cotton dyed with violacein and wool dyed with carotenoid/violacein.
C4: Wool dyed with violacein and cotton dyed with prodigiosin.
C5: Cotton dyed with violacein and polyester dyed with violacein/prodigiosin
C6: Wool dyed with carotenoid, wool dyed with violacein, and polyester dyed with violacein.
C7: Wool dyed with violacein and polyester dyed with violacein.
C8: Polyester dyed with prodigiosin, wool dyed with carotenoid, and wool dyed with violacein.

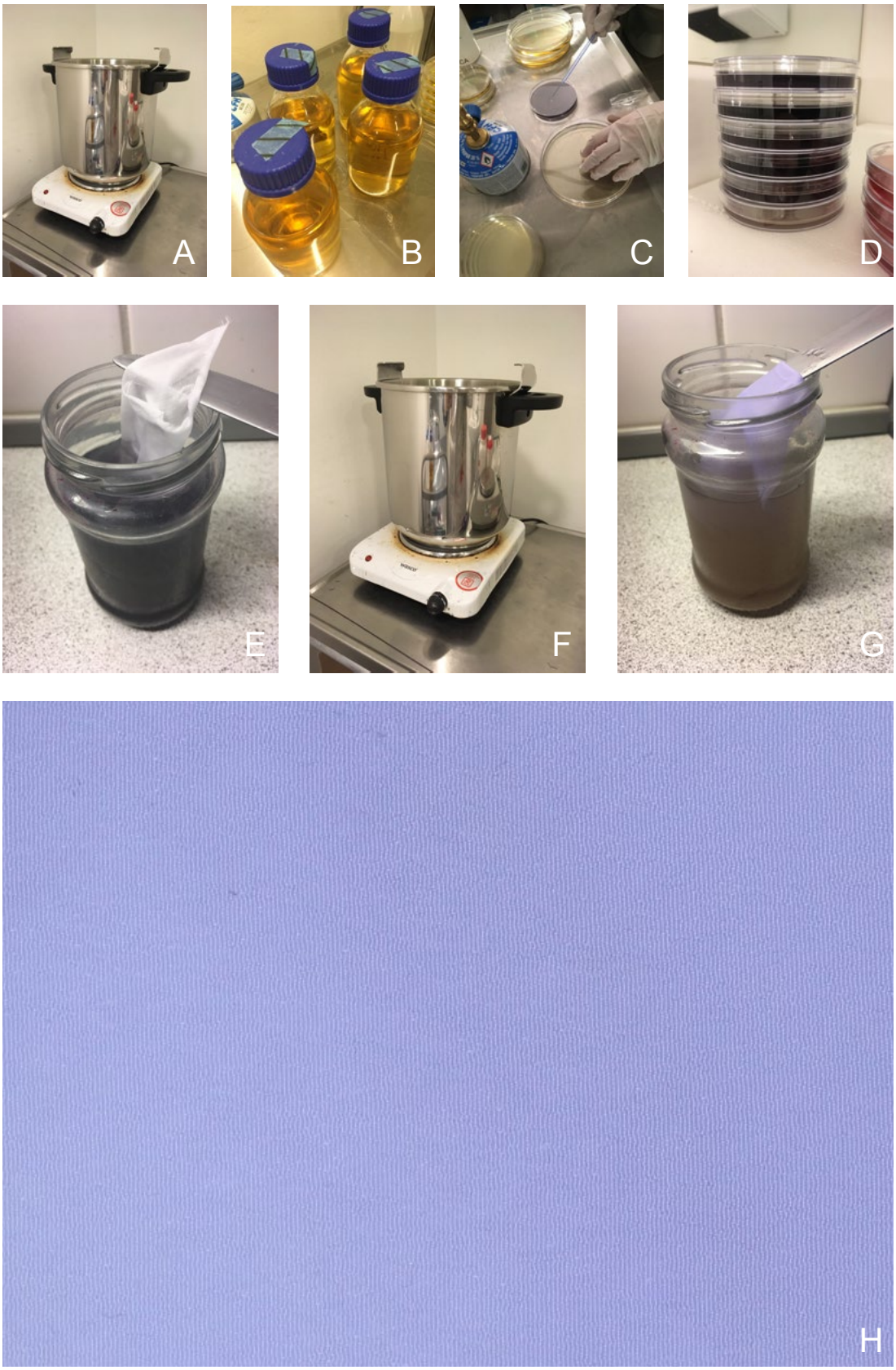


Figure 1.19 Conventional dyeing process. Polyester textile dyed with violacein (H).

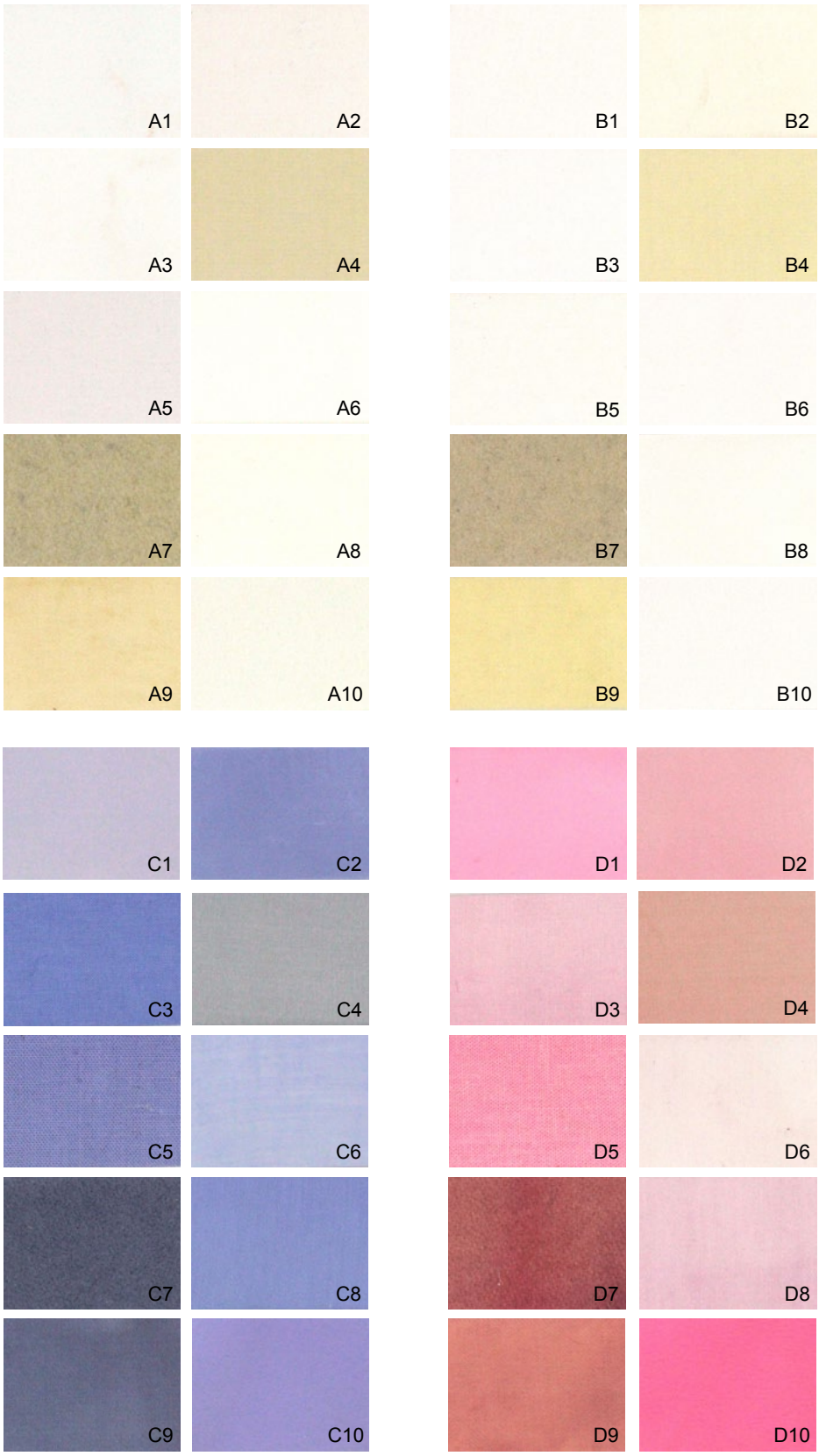


Figure 1.20 Different textile fibre types dyed with carotenoids (A +B), violacein (C) and prodigiosin (D). The numbers indicate the fibre type. Polyester PES woven (1), silk sateen woven (2), cotton mercirrised woven (3), silk shanting woven (4), polyester eco-circle woven (5), cotton batiste woven (6), grey/brown wool woven felt (7), cotton sateen woven (8), wool twill woven (9), polyester CDC woven (10).

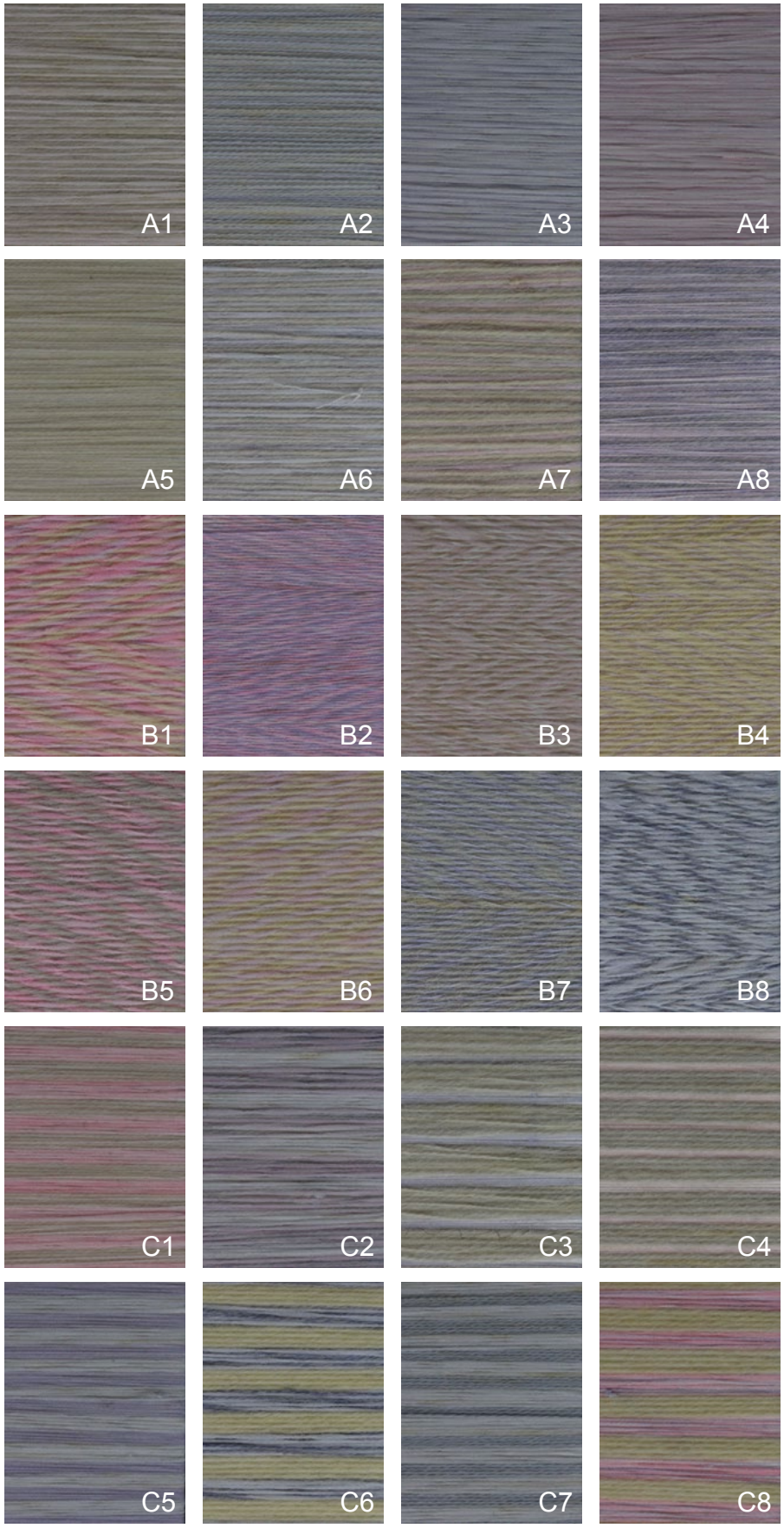


Figure 1.21 Yarn winding samples with mixes of various bacteria coloured yarns and mixed textile fibre types.

Most biobased colours degrade when exposed to sunlight, and this is also true for bacterial-derived colours. I was particularly interested in understanding how these colours fade to gain insights into the changes in their aesthetic expression.

For the initial lightfastness test, cotton, wool, and polyester textiles dyed with either violacein, prodigiosin, carotenoid, or a mix of these pigments were exposed to sunlight for one month (in June). This was done to gain an initial understanding of how the colours faded. The polyester, cotton, and wool textile samples dyed with violacein, prodigiosin, and carotenoids, both independently and in mixtures, are shown in Figure 1.22 and Figure 1.23. These figures illustrate how three different concentrations of the same colour, 1:5, 1:10 and 1:20 liquid media to water ratio, fade when exposed to sunlight. It is evident that the colours faded significantly, with prodigiosin being particularly affected, as it degraded almost completely after one month of direct sunlight exposure.

Interestingly, polyester fibres exhibited the least fading, and violacein proved to be the most lightfast pigment. It is also noteworthy that the colours faded to lighter shades within the same hue, rather than undergoing a sudden or unexpected shift to a different hue. This gradual fading is often considered a more desirable material quality, as abrupt colour changes are typically less favourable (Lilley et al., 2019).

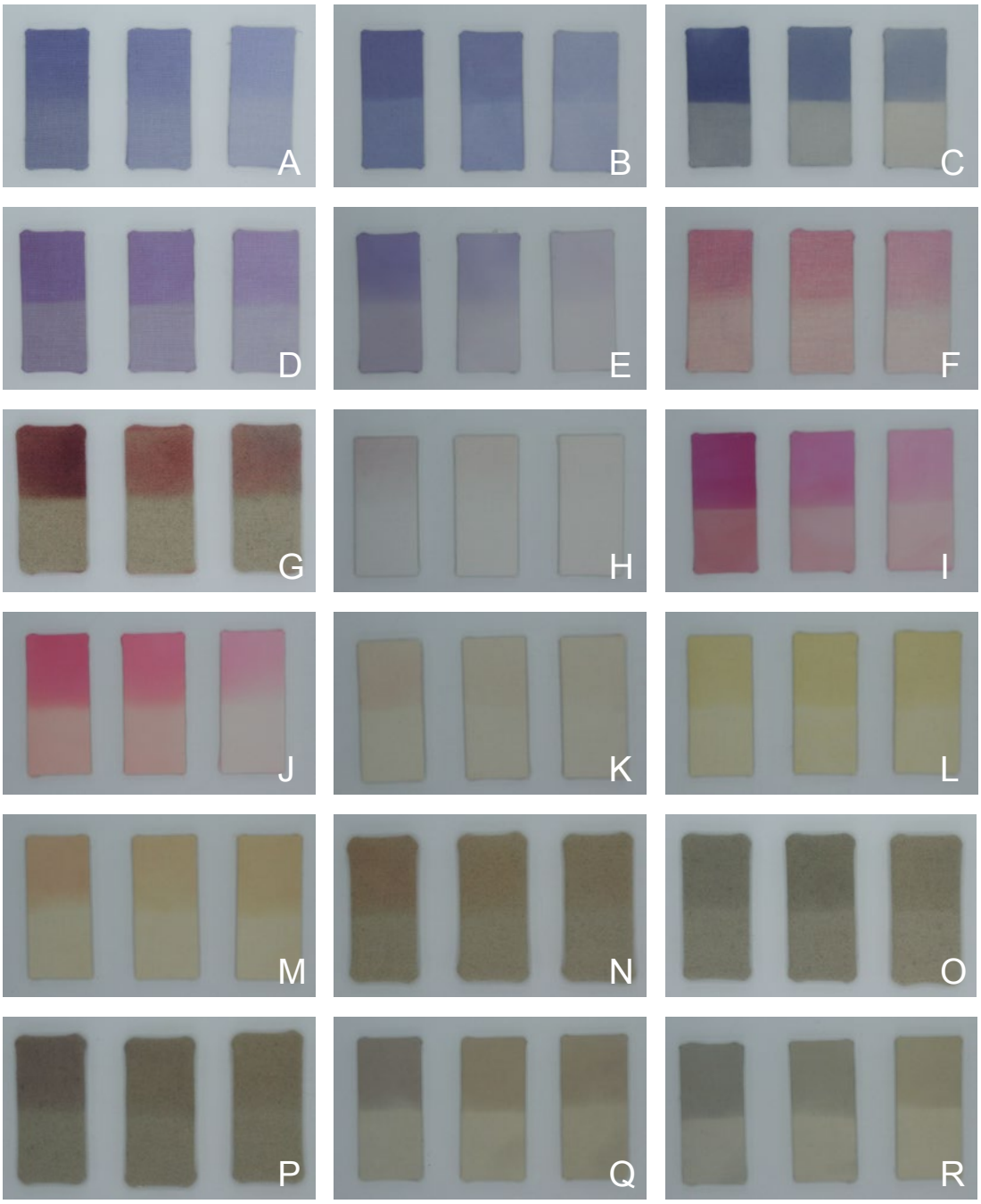


Figure 1.22 Overview of initial lightfastness testing. Polyester + violacein (A), cotton + violacein (B), wool + violacein (C), polyester + violacein and prodigiosin (D), polyester + violacein and prodigiosin (E), polyester + prodigiosin (F), wool + prodigiosin (G), cotton + violacein (H), polyester + prodigiosin (I), cotton + prodigiosin (J), wool + prodigiosin (K), wool + carotenoid (L), wool + prodigiosin + carotenoid (M), wool + carotenoid (N), wool + prodigiosin, violacein and carotenoid (O), wool + prodigiosin, violacein and carotenoid (P), wool + prodigiosin, violacein and carotenoid (Q), wool + prodigiosin, violacein and carotenoid (R).

Figure 1.23 Results of initial lightfastness test of biocolours.

Interview with Joy Boutrup

I conducted a semi-structured interview with Joy Boutrup, a textile engineer and chemist, to discuss the potential of bacterial pigments and possible scientific or technological advancements. We also addressed the limitations of the DIY Biolab. This interview provided valuable insights and helped inform my decisions for the next steps in developing bio-coloured textiles. See Figure 1.24.

Selected samples of textiles coloured with bacteria produced pigments can be seen in Figure 1.25 and Figure 1.26.

Figure 1.24 Overview of textile experiments with bacterial colourant.

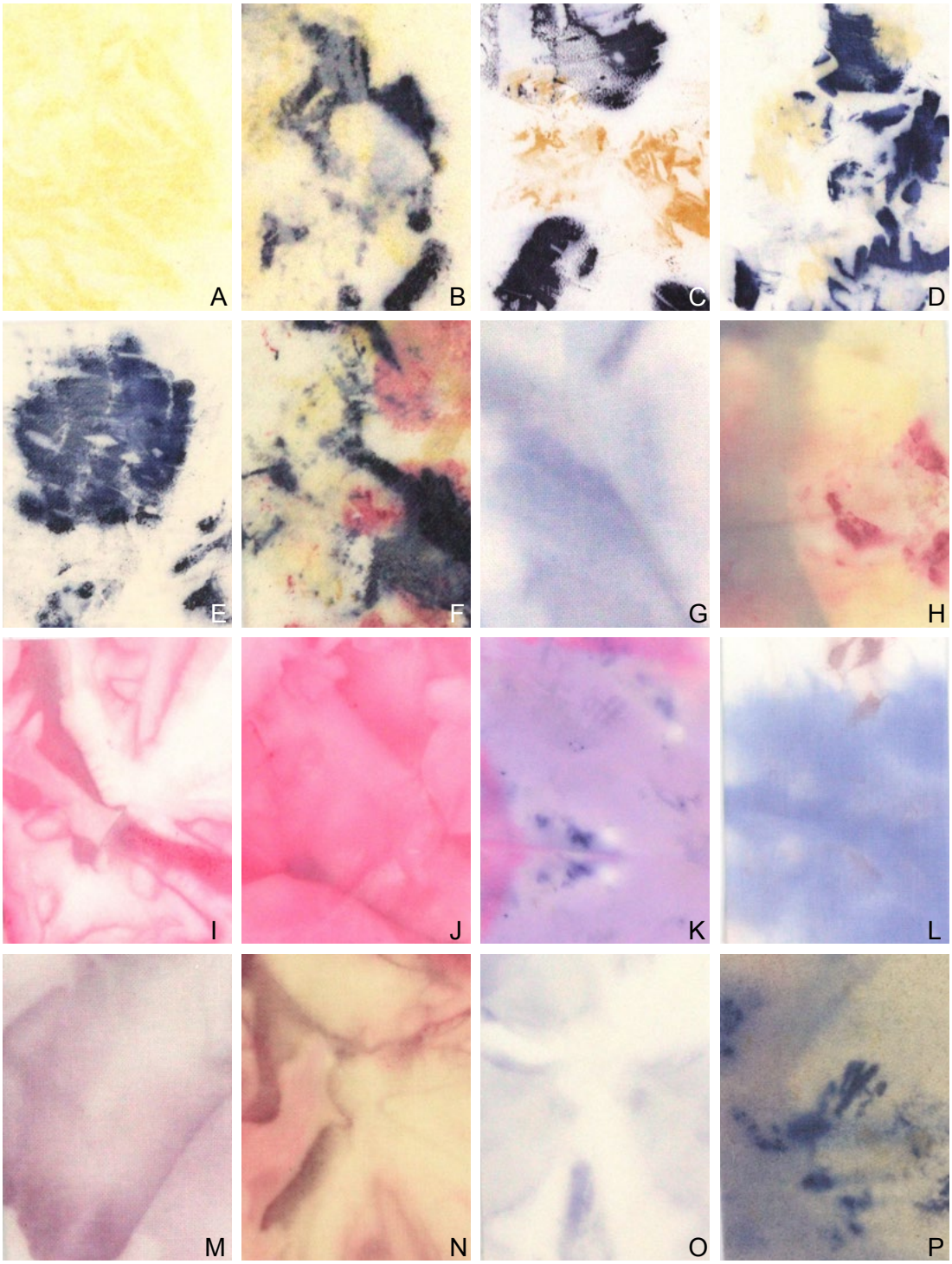


Figure 1.25 Overview of textiles colour with printing and Shibori inspired techniques. Wool coloured with carotenoid (A), wool coloured with violacein and carotenoid (B), polyester coloured with violacein and carotenoid (C), cotton coloured with violacein and carotenoid (D), wool coloured with violacein (E), wool coloured with violacein, carotenoid and prodigiosin (F), cotton coloured with violacein (G), wool coloured with violacein, carotenoid and prodigiosin (H), polyester coloured with prodigiosin (I), polyester coloured with prodigiosin (J), polyester coloured with prodigiosin and violacein (K), cotton coloured with violacein and prodigiosin (L), cotton dyed with prodigiosin (M), wool dyed with prodigiosin (N), polyester coloured with violacein (O), wool coloured with violacein and prodigiosin (P).

Figure 1.26 Overview of different textiles coloured with microbial colours. Silk coloured with violacein (A), polyester coloured with violacein (B), wool coloured with prodigiosin (C), polyester coloured with prodigiosin (D), wool coloured with violacein (E), polyester coloured with prodigiosin (F), wool coloured with prodigiosin (G), wool coloured with carotenoid (H), cotton coloured with prodigiosin (I), wool coloured with violacein (J), polyester coloured with violacein (K), cotton coloured with violacein (L), silk coloured with prodigiosin (M), polyester coloured with violacein (N), wool coloured with carotenoid (O), wool coloured with carotenoid (P).

Presentation of pilot study results for industry experts

I presented selected samples to partners and experts from Kvadrat, and we engaged in an open and honest discussion about the challenges and potential of bacterial colouring from their perspective. The primary challenge identified by Kvadrat was the issue of lightfastness. As a result, we agreed to leverage both their network and mine to explore more advanced colouring methods, such as CO_2 dyeing, dope dyeing, and fibre spinning, to improve lightfastness.

We also concluded that polyester-based textiles currently showed the most potential for further development. Kvadrat utilised their network to invite Laura Woods, a colour expert from Wooltex, to join a subsequent meeting. During this meeting, I presented the same samples, and we continued our discussion about the challenges and opportunities associated with bacterial pigments.

Evaluation

The study faced clear limitations in the size and number of experiments, as producing the pigments required significant time and effort. The primary technological challenge was the poor lightfastness of bacterial pigments. Conducting experiments aimed at improving lightfastness was a productive approach, but some of these experiments could not be carried out in the current DIY Biolab, necessitating collaboration with external partners.

Wool proved to be a challenging material, as it was difficult to apply the pigments effectively, and the colours faded quickly. Advanced methods, such as dope dyeing or fibre spinning, should be explored as potential solutions for increasing lightfastness. Collaboration and the sharing of networks between Kvadrat, Wooltex, and myself were essential for pushing the experiments further and addressing these challenges.

DIA 6: Biolab Booklet

DIA 6

Time period: April to May 2021

Location: Design School Kolding

Motivation: Create a tool for students to work more independently and freely at the DIY Biolab, while potentially inspiring other institutions

Summary

As the workshops at the design school are often unsupervised and students are encouraged to explore the workshop spaces independently, I wanted to create a booklet to enable students to navigate the biolab and use its facilities on their own after receiving an introduction. This booklet is particularly aimed at students interested in cultivating bacteria for textile colouring, as shown in Figure 1.27.

The booklet was developed to ensure that students had access to the relevant information after their induction, allowing them to work independently in the DIY Biolab. It was important to clearly explain the procedures permitted in the DIY Biolab and those that were not. This information is included in the booklet to remind users of the biolab's rules and guidelines.

I began developing the booklet by filming the various processes. These videos were integrated with the recipes or guides in the booklet to teach design students how to navigate the biolab. The videos are accessible via QR codes or links placed at the back of the booklet, with examples shown in Figure 1.28.

The booklet contains experimental procedures as well as safety and cleaning regulations. It was published (Hartvigsen, 2021) and can be found in Appendix 4. The booklet is open source, allowing other institutions, designers, or students to draw inspiration from its contents. I identified a general lack of accessible, easy-to-understand DIY bacterial colouring procedures, which motivated me to create the

booklet in a recipe-book format, complete with step-by-step instructions, photos, and videos.

Figure 1.27 Biolab Booklet developed at Design School Kolding.

Experiment #1: Preparing LB liquid media

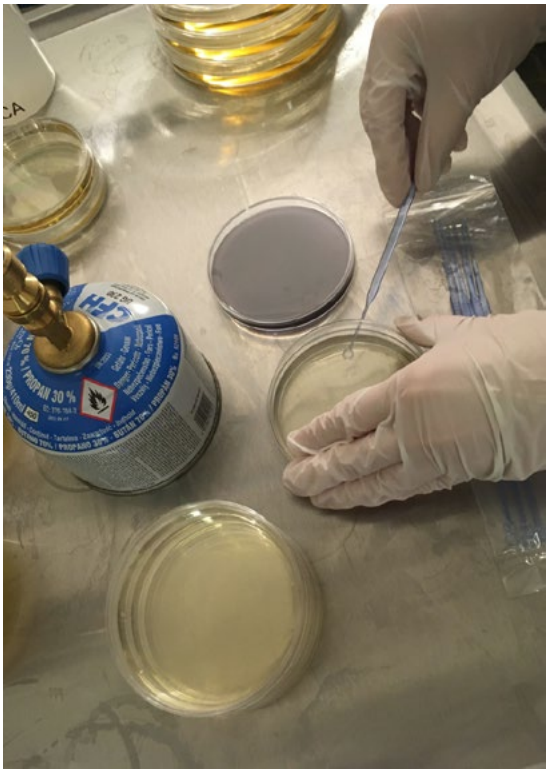
Equipment:
Ethanol
Gloves
Mask
Sterile petri dishes
Bunsen burner
LB Broth
Agar
Demineralised water
Pressure cooker
Fridge
Paper towel
Autoclave tape

Prepare LB medium:
1. Measure 20g LB broth powder and 1L demineralised water.
2. Put in glass container suitable for autoclaving and shake.
3. Put a piece of autoclave tape on the lid of the glass containers.
4. Place in pressure cooker with the lid placed loosely on the top and cook for minimum 30min.
   OBS! Remember to add water to the pressure cooker.
5. Let it cool a bit.
6. Close the lids to make it as airtight as possible.
7. Store until use.

Make sterile LB liquid medium plates:
1. Put on gloves and a mask.
2. Wipe the table surface with ethanol. Wait for the ethanol to evaporate.
3. Turn on the bunsen burner.
4. Pour in sterile petridishes. If you use a bunsenburner, heat the edge of the glass between each pour. You should fill approx. 1/2 of the petri dish.
5. Turn off the bunsen burner.
6. Clean the table surface with ethanol.

Storage:
Keep in fridge. Remember to write name, date and content on your petri dishes e.g. *Monica, 12.05.12, LB.*
If you keep the prepared medium in the fridge, do not place it together with food.

35



Experiment #3: Bacteria inoculation to LB liquid media

Equipment:
Ethanol
Gloves
Mask
Sterile petri dishes
Sterile inoculations loop
Lighter
Bunsen burner
Bacterial sample
Sterile LB liquid medium
Paper towel
Incubator

Bacterial inoculation:
1. Put on gloves and a mask.
2. Wipe the table with ethanol and let it dry.
3. Take your bacterial sample out of the fridge and take it to you sterile workarea.
4. Write name, date and content on the sterile petri dish. E.g. *Monica, 12.05.12, LB, S. Marcescens.*
5. Turn on the bunsen burner.
6. Find your sterile inoculation loop.
7. Take a small sample from the liquid sample and try to keep the lid as closed as possible.
8. Take the sample to your fresh petridish and shake the sterile loop in the liquid LB medium.
9. Turn off the bunsen burner.
10. Clean the table surface with ethanol.

Growth conditions and storage:
1. The newly prepared bacterial samples are stored in the incubator (the white styrofoam boxes placed in the biolab) at room temperature and the light turned on.
2. Check the bacteria specie to find out about the exact growth conditions. The bacteria we have in the biolab grow at room temperature.
3. Leave it to grow for some days (3-5 days).
4. Wrap the bacterial sample in parafilm and store it in the fridge to keep it alive.

Waste management:
5. The gloves should be autoclaved before thrown in the waste bin.
6. Find an autoclave bag and put the gloves in. Close it with a piece of striped autoclaved tape. Cook for 30min. in the pressure cooker.

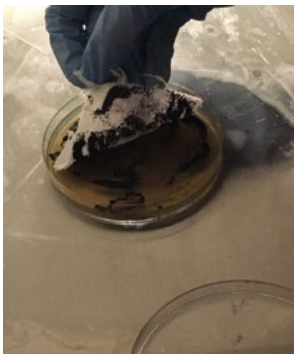
39

Figure 1.28 Recipe examples from the DIY Biolab Booklet.

Evaluation

The booklet effectively simplifies and disseminates the knowledge I have accumulated about working in a DIY biolab, particularly in the context of bacterial colouring. It is important to establish a common ground, which this booklet and the accompanying inductions help to create. The booklet aligns with the school's pedagogical framework and provides students with the freedom to work independently in the biolab. By making the booklet open source, it also spreads knowledge beyond the school, contributing to the advancement of the biodesign field.

DIA 7: Pilot study biolab



DIA 7

Time period: May 2021

Location: DIY Biolab, DSKD

Motivation: Mapping out challenges for how to introduce students to the work possible in the DIY Biolab

Summary

The students I encountered during the courses I taught at DSKD introduced the DIY Biolab as a potential tool for use in their own projects. They expressed an interest in exploring microbes within their work. This pilot study involved three distinct projects.

One master's student, Shanice, collaborated with me to test the DIY Biolab for bacterial colouring, aiming to provide insights into how students might engage with the biolab. Part of the bacterial growth experiments was conducted in the DIY Biolab available at the school. I introduced Shanice to various methods for working with bacteria to produce pigment. Together, we conducted experiments that involved growing bacteria directly on textiles, producing pigment as a liquid dye in Petri dishes, and using agar plates for stamping purposes.

A significant challenge in growing bacteria directly on textiles was scalability, as the available equipment imposed limitations. Additionally, time proved to be a critical factor, as natural processes cannot be rushed. This constraint sometimes hindered exploratory testing, as ideas could not always be immediately executed.

After completing the initial exploration, Shanice decided on her next steps, which involved preparing the bacterial samples she intended to use for her final application. Working with new methods required patience and a highly structured approach to minimise contamination. This process turned out to be more challenging than I had anticipated, leading to some complications. A potential next step for Shanice could involve creating her own protocol, which would allow her

greater control. Alternatively, I could have developed a template for her to use. See Figure 1.29 and Figure 1.30 for photographs documenting the process.

The experiments Shanice conducted provided valuable insights into both my own practice and project. I employed a move-testing experiment approach, as we were working within a specific context and I had a clear plan for what I wanted to introduce to her. Additionally, I observed how she navigated the biolab, utilising the various processes I had explained and demonstrated. Her feedback revealed that understanding the methods and their execution is not straightforward; it requires time to learn. However, the hands-on approach, where I demonstrated the steps and she repeated them in a master-apprentice dynamic, proved effective.

Our collaboration also offered insights into the Biolab Booklet I developed in **DIA 6.** This experience helped me identify the type of knowledge that should be included in the booklet to make it more useful for future users.

Evaluation

An instructor is essential for guiding students through the processes. Students require more practice to perform the tasks independently, as mistakes can easily occur and compromise the experiments.

With proper guidance, the students were able to complete all the steps on their own without significant issues. The master-apprentice model, employing a hands-on approach, was particularly successful.

Figure 1.29 Postgraduate student exploring bacterial colouring in the DIY Biolab at Design School Kolding as part of her master project.

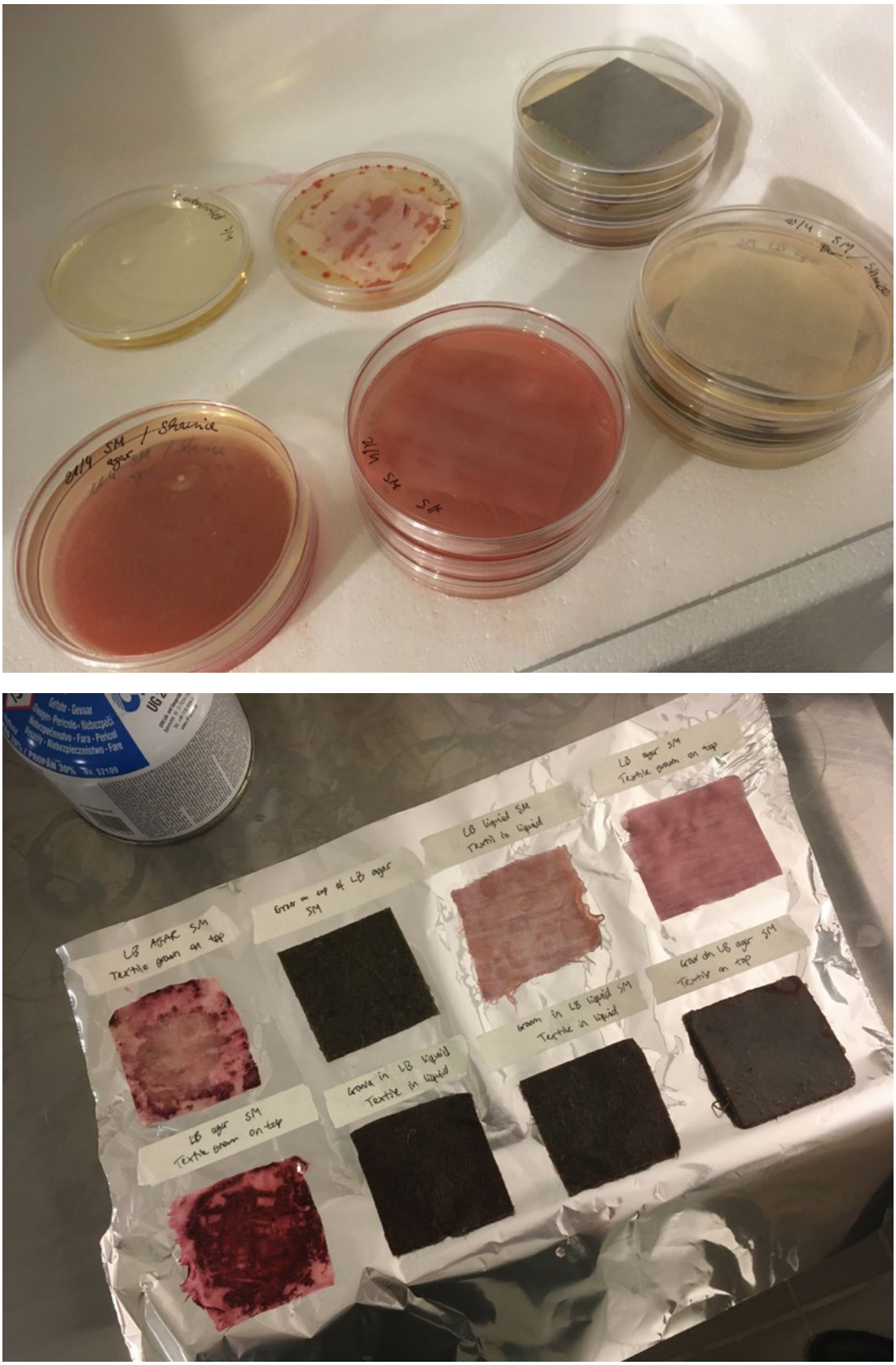


Figure 1.30 Samples from student engagement in the DIY Biolab at Design School Kolding.

DIA 8: Sensuous soil

DIA 8

Time period: May 2021

Location: DIY Biolab, DSKD

Motivation: Exploring collaboration possibilities with Louise Permiin and her studies

Summary

As part of her artistic research project at Design School Kolding, Louise Permiin investigated the relationship between textile colour production and the associated environment, employing sensory approaches to explore a multispecies speculative design practice. Her studies included examining soil from former dye houses in Denmark, such as “Brødrene Mathiasens klædefabrik” (translated as “the garment factory of the Mathiasen brothers”), a former textile dye house in Løgstør.

While I was exploring microbial colours as part of my PhD studies, we were both curious to determine whether any microorganisms were present in the soil and whether they produced colours.

We collected soil samples and cultivated them in Petri dishes prepared with Nutrient Broth at the DIY Biolab at Design School Kolding. The process is illustrated in Figure 1.31. A variety of microorganisms grew in the Petri dishes. However, as the Petri dishes could not be opened at the DIY Biolab, I transported one of the dishes to a biosafety level 2 laboratory at Aarhus University. There, I was able to transfer one of the bacterial colonies to a new Petri dish with growth nutrients for further analysis. The bacterial colony was sequenced, and it was identified as the species Micrococcus.

It is important to note that many other microbial species were present in the Petri dishes containing soil from the former dye house. However, as we used a specific growth medium and maintained certain growth conditions (approximately 20°C), only microorganisms capable of thriving under these conditions were cultivated.

Evaluation

It was possible to grow, isolate, and analyse at least one type of bacterium from the soil. To identify other bacteria, more specialised media or alternative growth conditions would be required.

The bacterium Micrococcus, which we identified, did not initially produce any useful pigment. However, other bacteria present in the soil might have the potential to do so. This experiment provided a foundation for further speculative exploration in collaboration with my PhD colleague, Louise Permiin.

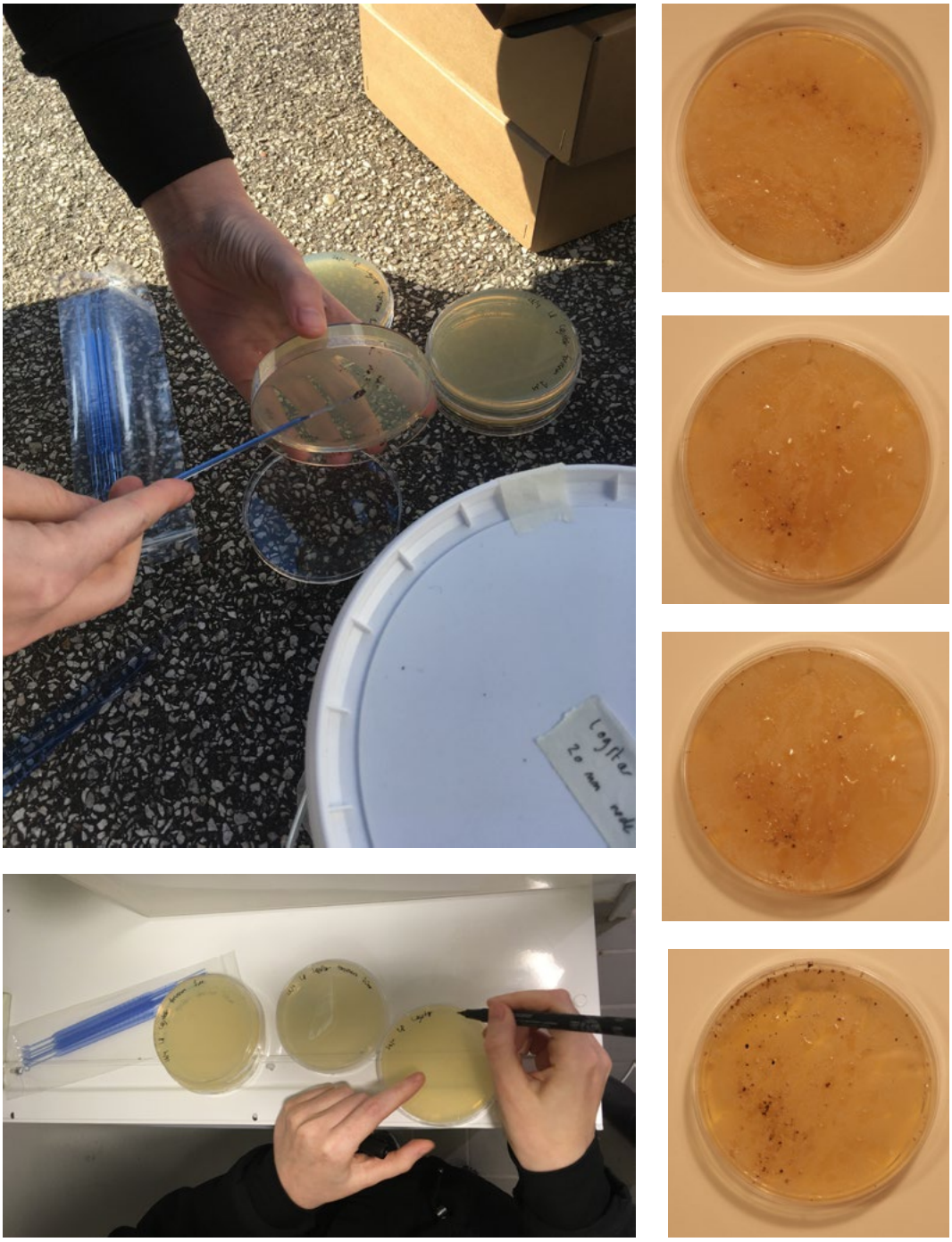


Figure 1.31 Cultivating microorganisms from former dye house soil.

DIA 9: VTT visit

DIA 9

Time period: June to August 2021

Location: VTT Research Center - Helsinki

Motivation: Learning how to work with fungi to expand the microbial colours available, and getting insights into GMO and industrial upscaling.

Summary

I contacted VTT to discuss the possibility of a research stay, and we agreed that I would assist them in preparing for the BioColour exhibition while exchanging knowledge. This collaboration was made possible due to my design expertise, natural science background, and their ongoing collaboration with designers from Aalto University.

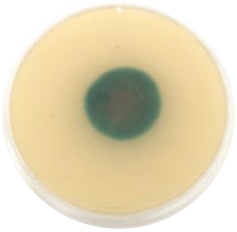
When I began my PhD project in December 2020, an interdisciplinary study on biocolours was already underway in Finland. The BioColour project, funded by the Strategic Research Council at the Research Council of Finland (2019–2025), focuses on three sources of colourants: agriculture, forest industry waste, and microbes. The project investigates these colourants for large-scale production, characterisation, and application in textiles, packaging, and coatings, while also addressing societal and ethical aspects of biocolour production and use. The research consortium includes participants from various Finnish research institutions, as well as institutions in the United States and Brazil, covering disciplines such as natural sciences, toxicology, applied technology, cultural studies, design studies, and consumer studies (Niinimäki & Lohmann, 2023).

In August 2021, I was invited to visit the Technical Research Centre (VTT) in Helsinki, where I met members of the BioColour consortium and collaborated with them to prepare exhibition materials for the BioColour – Exploring Sustainable

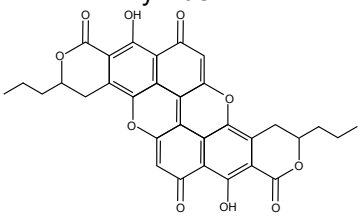
Colour exhibition at Arktikum in Rovaniemi, held from October to December 2021 (Alanko, 2021).

During my stay at VTT, I worked with three different fungi, cultivating them and using them to colour wool textiles, both through direct cultivation on the textiles and via conventional dyeing methods. At VTT, I collaborated with the science team to cultivate fungi. Figure 1.32 shows the three fungi species: Chlorociboria aeruginascens, Penicillium purpurogenum, and Trichoderma reesei, along with the chemical structures of their respective colour molecules: xylindein, azaphilone, and bisorbicillinol. The research team at VTT was focused on upscaling production and optimising the cultivation process through biochemical engineering, using both external approaches (e.g., altering growth media and cultivation conditions) and internal approaches (e.g., genetic modification of the fungi) to enhance colour yield. The cultivated fungi colourants were only applied to wool textiles, as this material had shown potential for success in Räisänen's (2002) PhD project titled "Anthraquinones from the fungus Dermocybe sanguinea as textile dyes".

:Chlorociboria aeruginascens

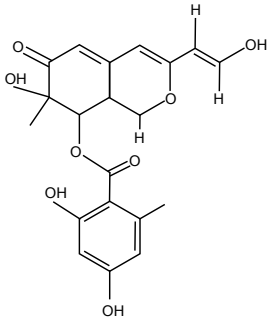


Xylindein



Penicillium purpurogenum

Azaphilon



Trichoderma reesei

Bisorbicillinol

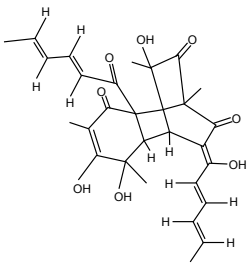


Figure 1.32 The three fungi species I was introduced to and cultivated during my stay at VTT.

In the laboratory at VTT, I applied two colouring methods, as shown in Figure 1.33 and Figure 1.34 . Upon discovering my prior laboratory training, the scientists allowed me to work more independently, though they ensured I was familiar with the laboratory's safety rules.

The first method involved cultivating the fungi in shake flasks. Using a flow bench, I prepared the shake flasks by adding sterile growth media and fungal inoculum (starter culture). The flasks were placed in a shaking incubator in a controlled-temperature room at 22°C and grown for five days. The fungi had been genetically modified to produce colour more quickly than non-GMO fungi. Once the fungi had produced colour, I removed them using a vacuum filtration system to isolate the colour liquid. Unlike conventional methods that require autoclaving to kill the fungi, filtration was sufficient to separate the fungi from the colour liquid (Figure 1.33 C). The liquid could then be used to dye textiles in a manner similar to conventional dyeing, the textiles were wetted out to prepare them for dyeing, placed in the liquid containing the bacterial pigment and dyed for one hour at approximately 50°C.

The second method involved cultivating the fungi directly on the textiles. I sterilised the textiles by autoclaving them before placing them in shake flasks with growth media and fungal inoculum. These flasks were incubated under the same conditions as the first method. After five days, the now-coloured textiles were sterilised in an autoclave at 120°C for 1 hour to kill the fungi and spores, which also fixed the colour to the textiles. Filtration was not possible in this method, as the fungi were grown directly on the textiles.

Instead of using a Bunsen burner to create a sterile environment, I worked in a flow bench (Figure 1.34 B), which provides a sterile environment through a continuous flow of filtered air. This was necessary because the fungi produce spores that could contaminate the entire laboratory if not handled carefully. To prevent contamination, the laboratory was divided into separate rooms for different fungal species. Additionally, due to the use of GMO fungi, strict cultivation controls and proper waste management were required. The use of a flow bench highlighted the challenges of working with colour producing fungi in a DIY laboratory, as such equipment or an isolated room would be necessary to prevent contamination. Working with GMO fungi in a DIY laboratory is not feasible, as it requires a biosafety level 3 laboratory and trained personnel.

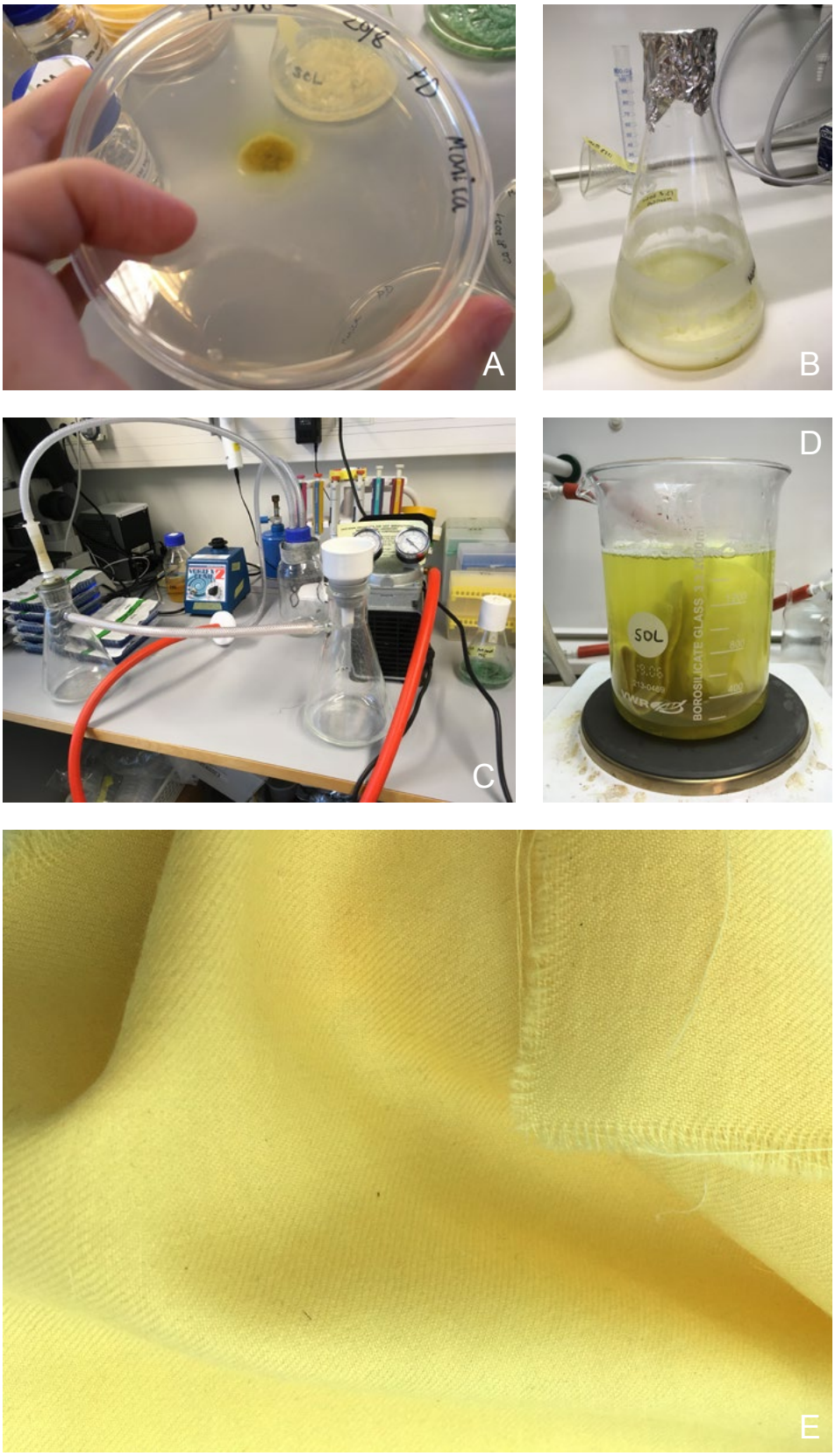


Figure 1.33 Cultivating colour producing fungi and subsequently apply them to wool textile via conventional dyeing methods.

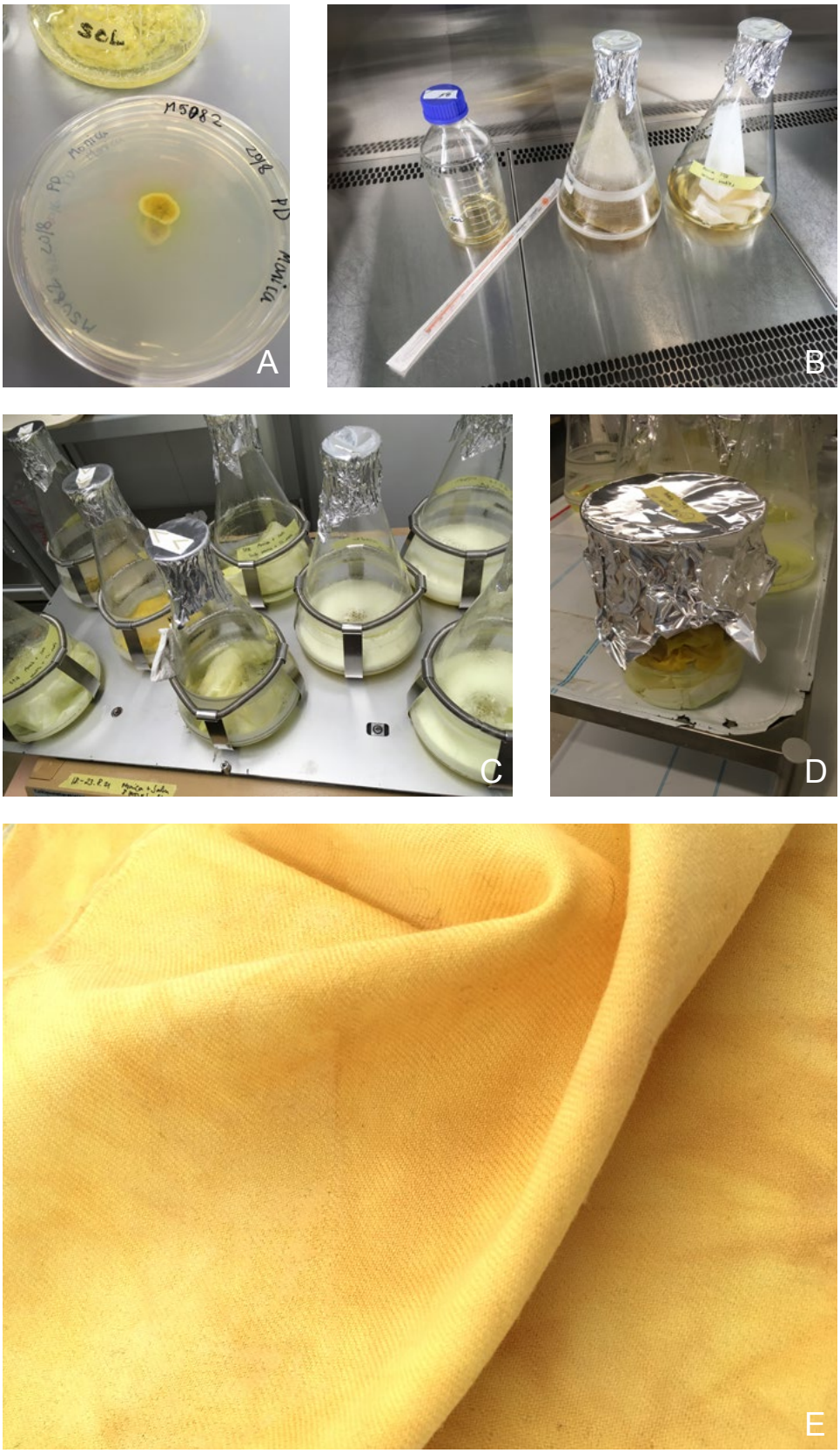


Figure 1.34 Colouring wool textiles directly in shake flasks.

The colours produced by the fungi faded when exposed to sunlight, though the textiles retained their original colour tone. Figure 1.35 shows the uneven colour distribution of the green dye. It should be noted that this was an initial exploration of fungal colouration, and the processes could be improved. For example, I did not use mordants, which could enhance colour distribution and fastness. Repeating the experiments with different textile fibres and testing other application temperatures could also yield better results.

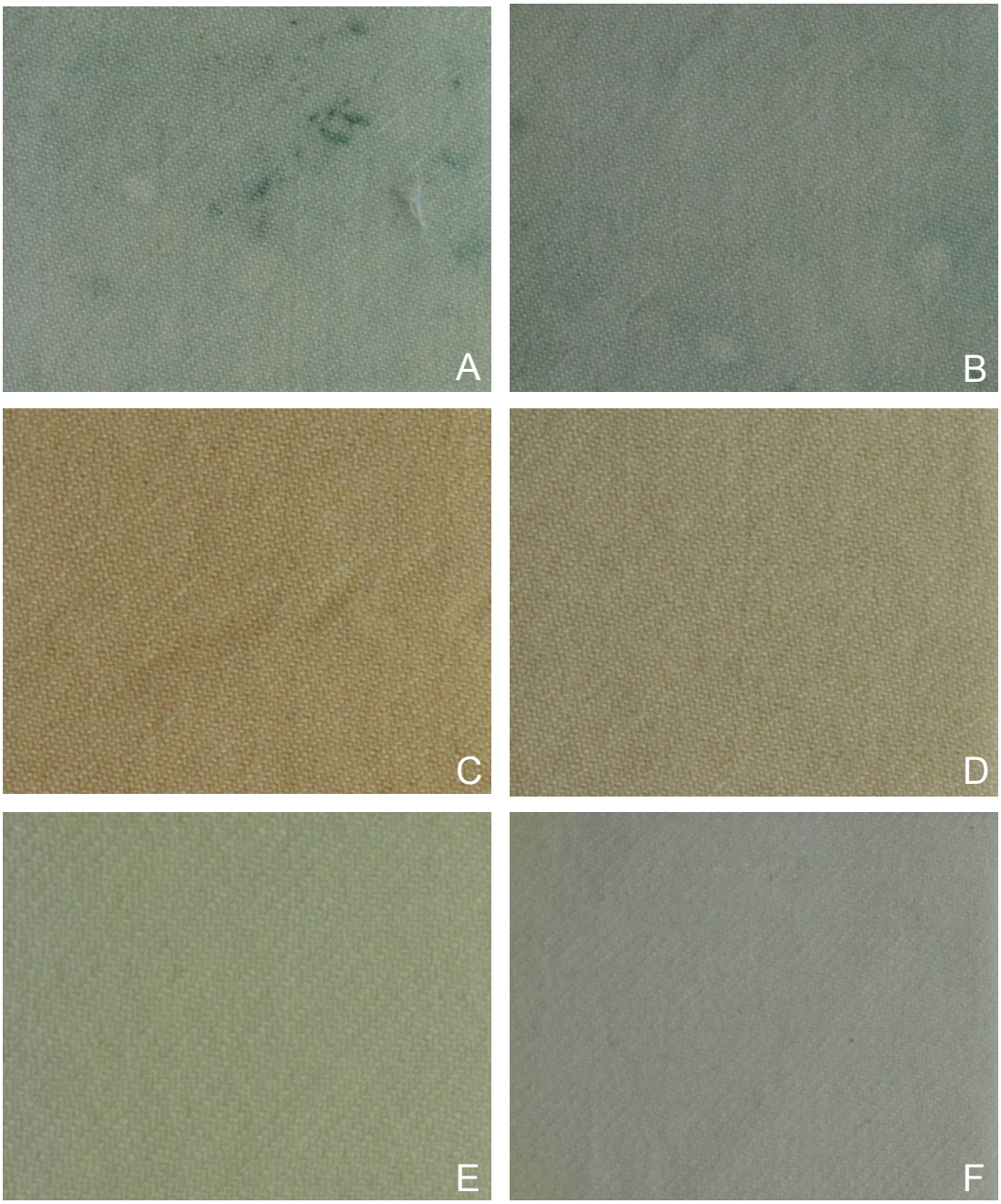


Figure 1.35 The fungi dyed wool textile samples A, C and E show the fungi coloured textiles before exposure to light while B, D and F show the samples after fading.

During my visit to VTT, I gained first-hand knowledge of large-scale biocolour production in bioreactors and the challenges of maintaining high colour yields, as shown in Figure 1.36.

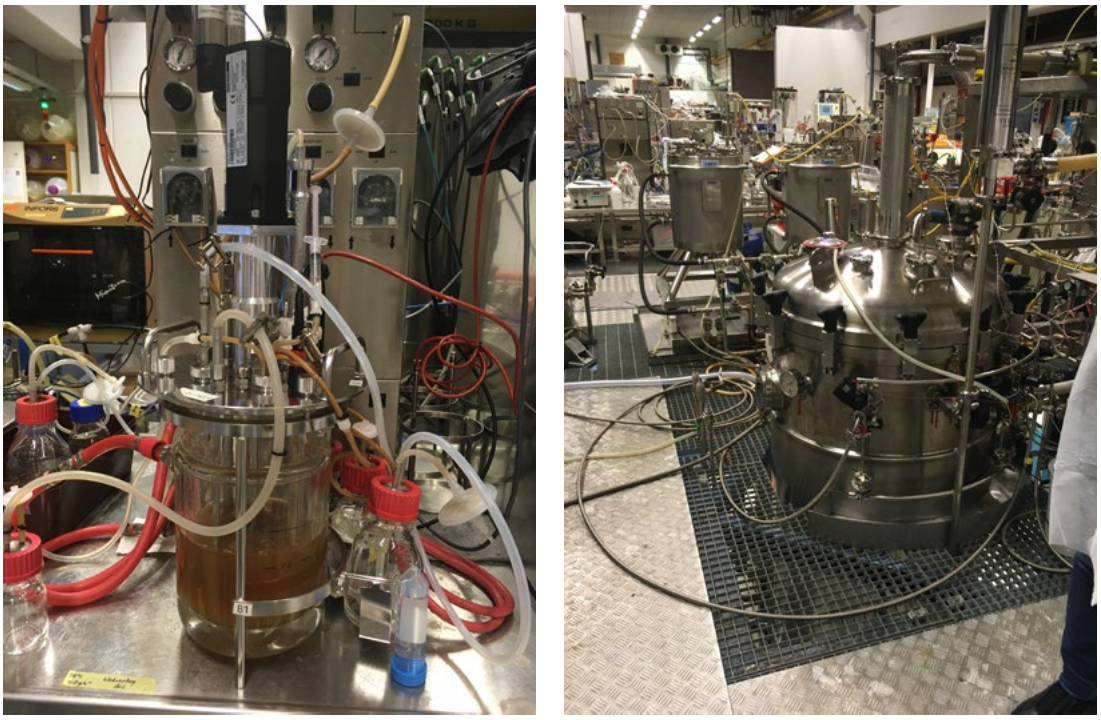


Figure 1.36 Bioreactors from the production hall at VTT for upscaling microorganism cultivation.

Evaluation

During the summer of 2021, I had the opportunity to join VTT, where I worked with fungi that produced dull or pale colours. However, the fungi I encountered during my stay cannot be used in a DIY biolab due to the specific requirements for their cultivation and handling.

The experience allowed me to gain valuable insights into the differences between working with microbial colourants in large-scale production settings compared to DIY environments. My role as a facilitator or bridge builder for the BioColour exhibition proved to be valuable to VTT, as it helped connect their scientific work with design perspectives.

Initially, the scientists underestimated my prior laboratory training but were surprised by how easily and independently I was able to work in the laboratory. They were very open and inclusive, involving me in their daily activities, which provided me with a strong connection to a group of experts and their knowledge.

DIA 10: BioColour exhibition

DIA 10

Time period: August to December 2021

Location: VTT Research Centre, Helsinki
Aktikum, Science Centre, Rovaniemi

Motivation: Getting insights into the challenges of communicating the aspects of biocolorants

Summary

Before the BioColour exhibition, the researchers at VTT, the curators, and I discussed the samples and how they should be displayed to effectively communicate the story behind the colourants. We planned how the fungi coloured textiles, which I helped develop at VTT, along with some of my bacterial coloured textiles, could be presented at the exhibition. As the scientists from VTT were not familiar with exhibitions or designing samples with a 'high degree' of finish, I assisted them in understanding the requirements for the exhibition and in creating the textile samples. Similarly, as the curators were not familiar with fungi cultivation and the limitations associated with exhibiting living samples in Petri dishes, I acted as a facilitator between the two disciplines. This role enabled smoother communication and supported the scientists at VTT in preparing the exhibition material. By employing T-shaped competences, I helped foster a shared understanding of the exhibition, aligning with the collaborative project principles highlighted by Niinimäki and her colleagues (Niinimäki et al., 2017).

Our goal with the fungi coloured textiles, fungi colours in small glass bottles, and living fungi in sealed Petri dishes was to showcase the origin of the colours and their potential applications. Figure 1.37 provides photographs of the exhibition material, including some of my samples and a sealed fungus.

Figure 1.37 Photos of exhibition material.

From October to December 2021, I participated in the exhibition BioColour – Exploring Sustainable Colour at Arktikum in Rovaniemi. The exhibition was curated by consortium researchers from the design department at Aalto University, led by Professor Julia Lohmann and PhD student Ingvill Fossheim. The curators aimed to create an immersive experience for visitors to explore biocolours and their diverse nature, guided by the research question: *"How will biocolourant discoveries impact lives, our behaviours and the way we think of colour?"* (Alanko, 2021).

The exhibition featured material from various BioColour projects, including microorganism coloured textile samples, plant dyed textiles, organic waste dyed textiles, and biomaterials such as seaweed dyed with biocolours. It also included samples showcasing the origins of the colours. Additionally, a pop-up indigo textile dyeing demonstration was conducted by Aalto University PhD student Pirita Lauri.

Before the exhibition, the researchers at VTT, the curators, and I collaborated to plan how the fungi coloured textiles I helped develop at VTT, along with some of my bacterial coloured textiles, could be presented. As the scientists from VTT were unfamiliar with exhibition practices and the need for a polished finish, I guided them in understanding these requirements and assisted in creating the textile samples. Similarly, I facilitated communication between the curators, who were unfamiliar with fungi cultivation and its limitations, such as exhibiting living samples in Petri dishes. This role allowed me to bridge the gap between the two disciplines, using T-shaped competences to foster a shared understanding of the exhibition, as suggested by Niinimäki et al. (2017).

Our aim with the fungi coloured textiles, fungi colours in small glass bottles, and living fungi in sealed Petri dishes was to highlight the origins of the colours and their potential applications. Examples from the exhibition are shown in Figure 1.38.

During my stay at VTT, we engaged in numerous discussions about how design and science can benefit from each other, particularly the role of designers as a link between scientific discovery and commercial application. The scientists expressed their appreciation for the value of employing designers and shared examples of their collaborations with designers from Aalto University on projects such as mycelium material production and application (Mycelium Leather, 2021).

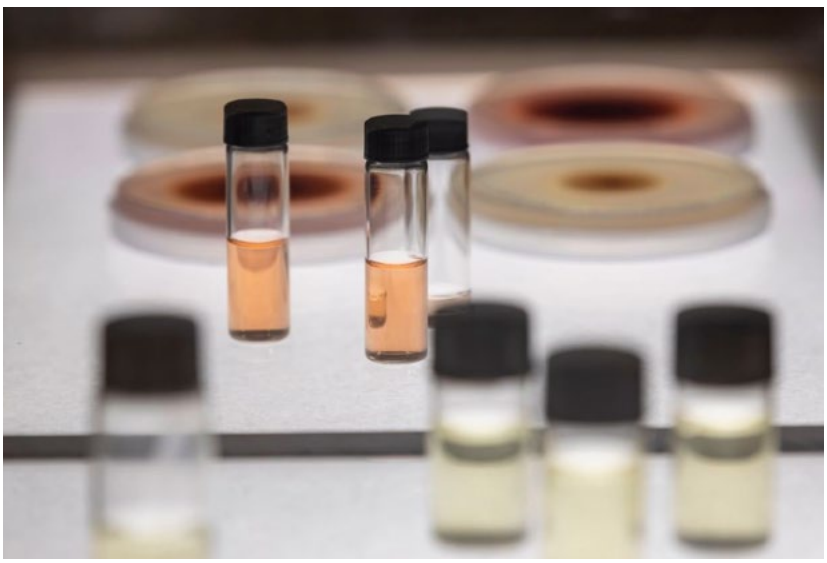


Figure 1.38 The BioColour exhibition (top). Bacterial dyed textiles (middle). Fungi growing in Petri dishes and colour samples in small glass flasks (bottom). Photo credits: Marko Junttila.

Evaluation

The role of the designer as a facilitator proved essential in bridging the gap between art/design and science. My personal knowledge of microbial colouring was crucial in fulfilling this facilitator role.

We had meaningful conversations about how biocolours change or fail to meet the functional aspects of conventional dyes, a topic that engaged several other researchers in the BioColour consortium.

The exhibition aimed to showcase biocolourants and encourage visitors to reflect on how they perceive colours. It served as a platform to provoke thought about the ethical concerns surrounding colour production. The exhibition highlighted less tangible values, allowing visitors to connect the origins of biocolours with application examples. Through activities such as the indigo dyeing demonstration, visitors were encouraged to reflect on colours, colour production systems, and their environmental impacts.

DIA 11: Search for structural colours

DIA 11

Time period: August 2021 to March 2022

Location: DIY Biolab, DSKD
Local nature in Aarhus and Kolding

Motivation: Testing if it is possible to work with locally sourced structural colours produced by bacteria

Summary

I contacted Danish researcher Torben Sølbeck Rasmussen, who had been part of the Vignolini Lab at Cambridge University, led by Professor Silvia Vignolini. The research group investigates photonic structures, including bacterial derived structural colours. He briefly explained their research on structural colours and their collaboration with the Dutch company Hoekmine, which focuses on upscaling bacterial derived structural colours (online interview, 24th August 2021).

Following this, I conducted an online interview with Dr. Colin Ingham (Hoekmine BV) and Laura Caton Alcubierre (industrial PhD candidate at Hoekmine BV). They shared insights into cultivating structural colour producing bacteria, and we discussed their application potential. While they did not go into detail, as much of the information was a business secret, they explained that the process requires specialised equipment, knowledge, and skills, but it is achievable. I sensed that they were exploring patenting their process, which understandably made them cautious about sharing specific details.

This led to another interview with Dr. Colin Ingham and Laura Caton Alcubierre, where we discussed the potential of applying bacterial derived structural colours to textiles. They explained that it would be possible but refrained from sharing details on how to approach this application. They had succeeded in applying structural colours to solid glass surfaces but had not yet developed methods for applying them to flexible materials (online interviews, 31st January and 2nd February 2022).

To explore this further, I collected bacteria samples from the seaside, as Flavobacteria, which produce structural colours, grow in seawater. I prepared growth media specific to Flavobacteria cultivation (Cytophaga Agar (CYT) and low-nutrient (LN) media prepared with Artificial Sea Water (ASW)), in sterile Petri dishes and then collected bacteria samples from the ocean. Figure 1.39 shows photos of the samples and the equipment used.

Figure 1.39 Sampling bacteria producing structural colourants from the Ocean.

I cultivated the samples at the DIY Biolab for four days at room temperature and observed the formation of structural coloured colonies in the Petri dishes, as shown in Figure 1.40. The structural colours became more pronounced after up to seven days of cultivation on the specialised media. Identifying the correct species was straightforward, as bacteria producing structural colours are visually identifiable due to their shimmering, reflective appearance.

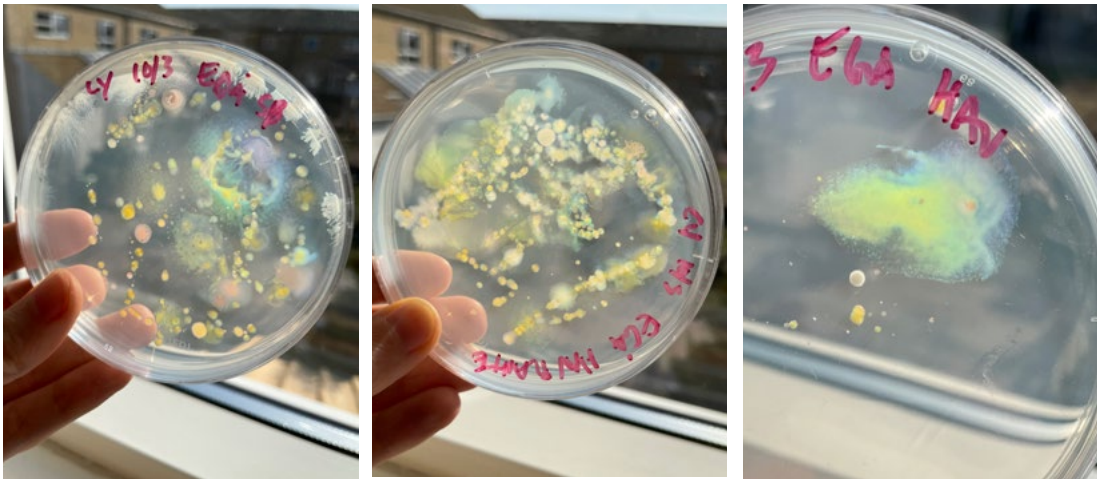


Figure 1.40 Finding and cultivating Flavobacteria.

I also researched how structural colours differ from pigments and dyes. Unlike pigments or dye molecules, structural colours are created by nanostructures that reflect light, producing a coloured surface. This phenomenon is illustrated in Figure 1.41. Two known bacterial species that form structural colours are Flavobacterium and Cellulophaga lytica (Betty et al., 2012; Johansen et al., 2018; Kientz et al., 2013).

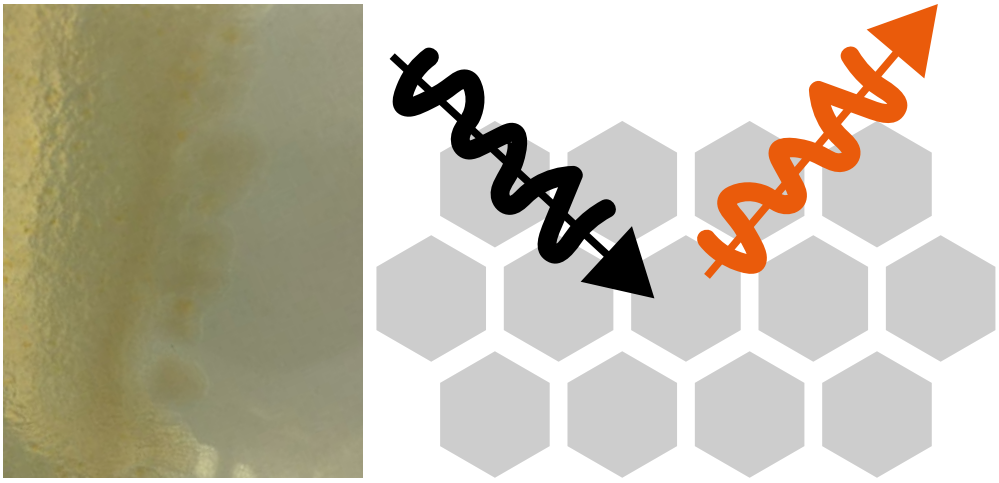


Figure 1.41 Structural colour formed by nanostructures reflecting light.

Evaluation

It is possible to find and cultivate bacteria that produce structural colours, but this requires a specialised growth medium. Transferring the structural colours from the growth media to materials such as textiles is challenging, though it is theoretically possible. An alternative approach could involve growing the bacteria directly on the textile.

Based on the interviews, the technology has potential but still faces significant challenges. Identifying the correct bacteria can be difficult, although structural colours are visually recognisable.

While I successfully cultivated bacteria that produced structural colours, I did not explore their application to textiles. I chose not to continue this research path, as cultivating the bacteria in a DIY biolab proved challenging. Additionally, the interviews indicated that applying structural colours to textiles is a complex process requiring advanced equipment and expertise in biofilm application, which were beyond the resources available to me.

This exploration was nonetheless valuable, as structural colours offer an interesting alternative to conventional colours, particularly because they do not fade in the same way.

DIA 12: Search for Green Elfcup

DIA 12

Time period: October 2021 to January 2022

Location: Forest in Djursland, Denmark

Motivation: Wanted to work with a locally sourced colour producing fungi

Summary

I went on a foraging trip in Ebeltoft, guided by the Danish fungi database (https://svampe.databasen.org). Using a map from the database, I was able to locate fungi by navigating to the exact coordinates where they had previously been spotted. Figure 1.42 shows a screenshot of the map. Although it still took several hours to find the fungi, starting the search in an area where it had last been observed significantly increased my chances of success.

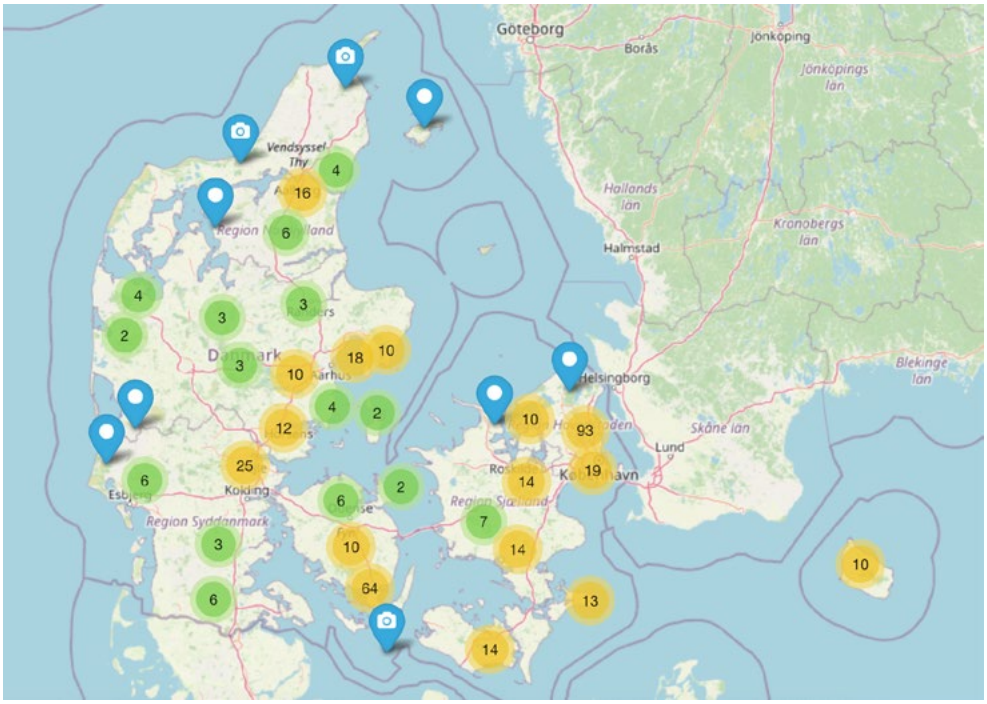


Figure 1.42 Map of mushrooms spotted in Denmark (https://svampe.databasen.org/en/).

Figure 1.43 Photos of other mushrooms found on the trip (top). Photo of the Green Elfcup found on trip (bottom).

After collecting samples of the Green Elfcup, I attempted to isolate and cultivate it in a natural science laboratory, as the spores would have contaminated the DIY Biolab. For this, I collaborated with Aarhus University.

I also consulted fungi expert and Jacob Blæsbjerg Hoof associate professor from DTU. Together, we examined the Green Elfcup samples I had tried to cultivate and isolate. He noted that it was difficult to determine from my samples whether the fungi had been successfully isolated. He suggested that spores should be visible under a microscope and could be compared visually to known spore structures. He

also mentioned that isolating the fungi should be possible with the right equipment, but purchasing already isolated fungi species might be a more practical solution.

Evaluation

Purchasing already isolated fungi could be a viable solution, as my experience showed that isolating fungi is significantly more challenging than working with bacteria. Additionally, the incubation time for fungi is much longer than for bacteria, meaning each attempt requires considerable time.

Finding the Green Elfcup was difficult due to its small size, as shown at the bottom of Figure 1.43. However, the search itself was an interesting and inspiring experience. During the trip, I discovered many other fascinating fungi, some of which are shown in the photos in Figure 1.43.

The foraging trip offered a different perspective, reframing the forest in a new way compared to simply walking through it. The search process heightened my awareness and made the experience more sensory and engaging.

Unlike bacteria, which are often invisible until grown on Petri dishes, fungi are more visually identifiable due to their fruiting bodies, which are often large enough to see. This visual aspect made the search for fungi a unique and rewarding experience.

DIA 13: Students in biolab

DIA 13

Time period: October 2021 to March 2022

Location: DIY Biolab, DSKD

Motivation: Introducing students to the DIY Biolab, while receiving feedback on the process

Summary

A group of three Design for Planet master's students explored how microbes grow on various textile surfaces, focusing on the differences between synthetic and natural fibres. Their experiments examined shirts made from either synthetic or natural fibres, aiming to test a hypothesis that a larger number of microbes would grow on synthetic fibres compared to natural fibres, particularly during physical activity. This hypothesis was based on previous studies exploring the relationship between textile odour and microbial growth (Callewaert et al., 2014).

The students began by swabbing the textile surfaces and transferring the samples to Petri dishes prepared with Nutrient Broth for bacterial growth. They then wore the shirts while engaging in activities to produce sweat. Afterward, they swabbed the textile surfaces again and transferred the samples to Petri dishes. The Petri dishes containing the microorganisms were placed in the DIY Biolab to grow over several days, as shown in Figure 1.45.

A similar project was conducted by another Design for Planet master's student, who explored microbial understanding and hygiene. She was curious about how we associate microorganisms with poor hygiene and how design could be used to challenge this narrative. She facilitated participatory workshops where participants explored microbes and their associations. Design students were invited to participate, as they were open to engaging in the workshops and interested in the subject of the microbiome.

The microorganisms used in the workshops were based on the participants' own microbes. Participants were asked to wear a white cotton T-shirt, and the microorganisms that grew on the worn textile surfaces were transferred to Petri dishes. This approach aimed to shift the narrative around microorganisms as undesirable. Examples of the microbial growth on textiles are shown in Figure 1.44. Through this process, the student explored how design could change behaviour, foster a more caring relationship with our microbiome, and spark discussions about the associations between clean and dirty clothes.

Figure 1.44 Master project exploring textile surfaces and hygiene.

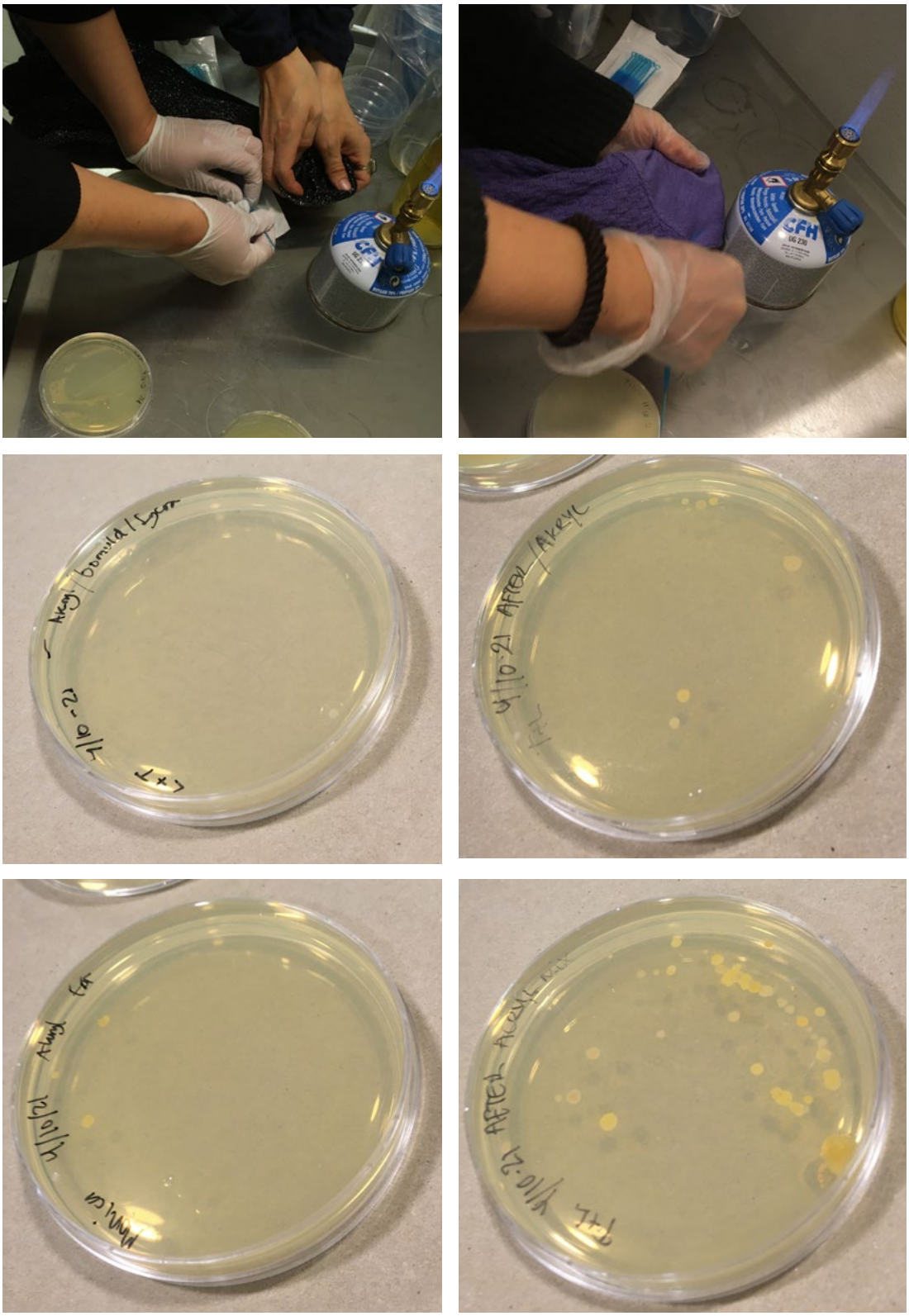


Figure 1.45 Student testing textile surfaces for microbial growth as part of the course material narratives/preferred future.

Evaluation

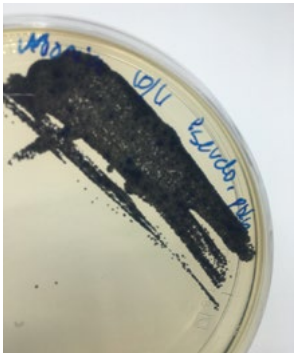
The students demonstrated a strong interest in exploring microorganisms through their projects. However, they needed guidance to understand the presence and role of microorganisms.

The three projects highlighted the potential of using microorganisms as a speculative design approach to provoke discussions. However, introducing students to the biolab required one-on-one or small group sessions, which was time-consuming. This experience inspired the idea of conducting workshops to introduce larger groups of students to the biolab and its possibilities.

It would have been valuable for the students to identify the microorganisms they had cultivated. However, the DIY Biolab lacked the necessary facilities to open the Petri dishes safely. A biosafety level 2 laboratory would have been required to isolate and screen the genetic material to determine which microorganisms were grown and whether they were safe to work with. Collaboration with an external laboratory could have provided this opportunity, but the time constraints of the students' projects made this unfeasible.

Despite these limitations, the projects successfully used microorganisms as a speculative tool to create discussions and challenge existing narratives about hygiene and the microbiome.

DIA 14: Grow indigoidine



DIA 14

Time period: November to December 2021

Location: Aarhus University, Department of Biochemical Engineering

Motivation: Expanding the existing colour range with a new pigment producing bacteria

Summary

The cultivation of indigoidine required specialised media, which was a custom mix gained from AU, differing from the standard media I had previously used. The pigment produced by indigoidine is subject to breakdown through oxidation, a process similar to that of indigo.

Figure 1.46 illustrates the setup used for cultivation. It includes small batches grown on Petri dishes, a microscopic image of the molecules after pigment production, and a close-up of the pigment in a Petri dish.

Evaluation

Due to COVID-19 restrictions, the natural science laboratories I was in contact with were only accessible to employees within their respective institutes to minimise risks. This limitation required me to seek alternative connections with facilities that had different setups and allowed access outside of normal working hours.

Despite these challenges, I successfully produced the pigment indigoidine, demonstrating that expanding the existing colour range is a viable possibility.

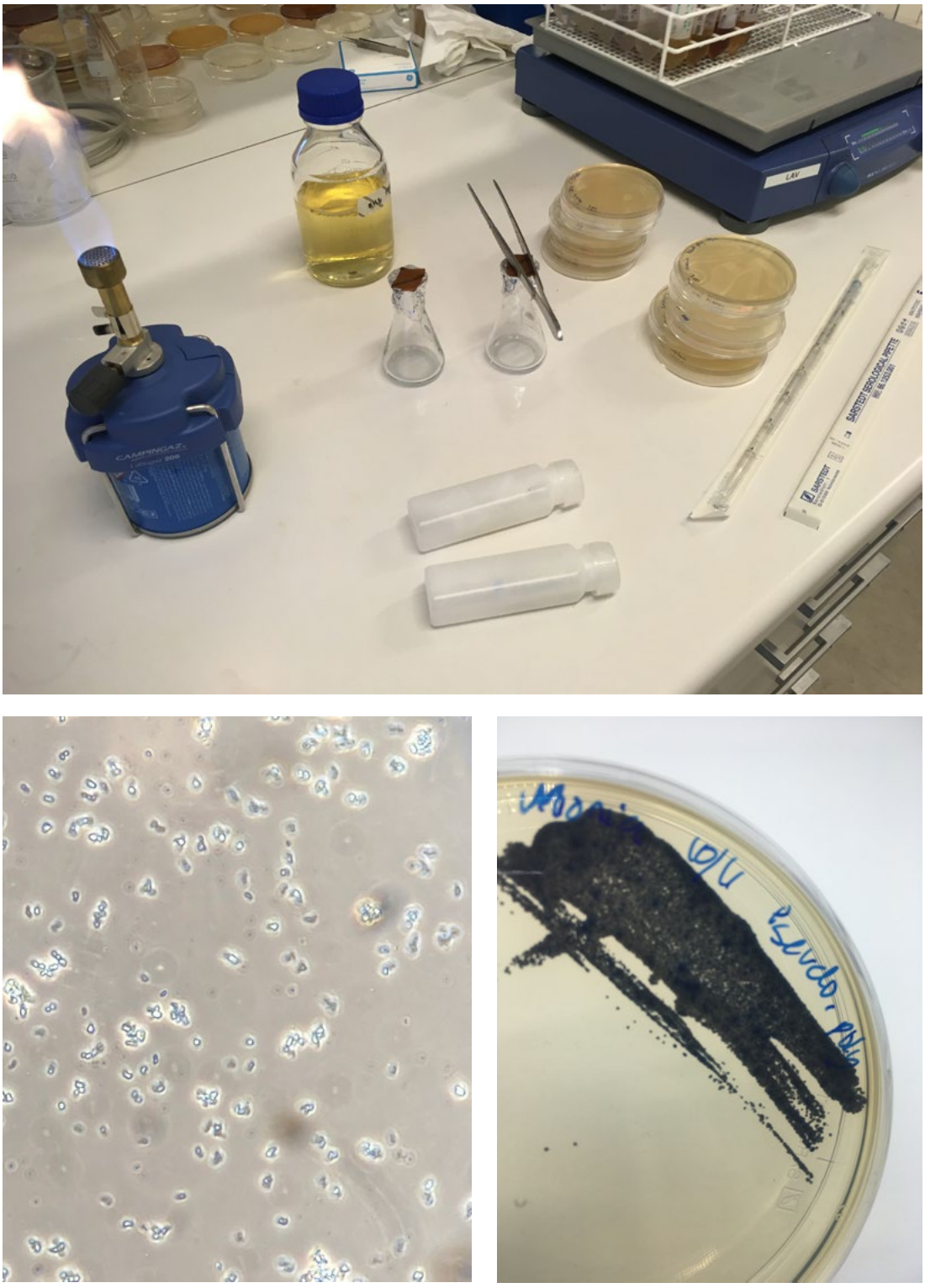


Figure 1.46 Cultivating indigoidine at AU.

DIA 15: Workshop 3rd year undergraduate students

DIA 15

Time period: January 2022

Location: Design School Kolding

Motivation: Developing a tool for exploring the sensuous qualities of textiles, which could potentially assist in exploring the different qualities and challenges of biomaterials

Summary

I conducted a workshop with approximately 30 third-year undergraduate students from industrial design, accessory design, and textile design, focusing on the sensuous qualities of textiles. During the workshop, I tested two tools I had developed, the sensorial wheel and the visual wheel, as shown in their initial versions in Figure 1.47.

The students began by selecting a material from the samples I provided and used it with the sensorial wheel. In groups, they explored the material by rating it based on contrasting values. Examples of completed wheels are shown in Figure 1.48. After completing the wheels, we gathered them on a table to discuss and reflect on the results of each group, as seen in Figure 1.48.

Next, the students used the visual wheel to find samples or photos that further explored the different qualities of their chosen material. Examples of this process are also shown in Figure 1.48.

The students found the tools easy to use, quick, and highly reflective. They described the tools as interesting and expressed a desire to explore them further. Many wanted to take the tools with them to use in their own projects, particularly for analysing the biomaterials they had developed.

The tools and their results are thoroughly described in a paper I co-authored and published at E&PDE 2022 (Hartvigsen & Hasling, 2022).

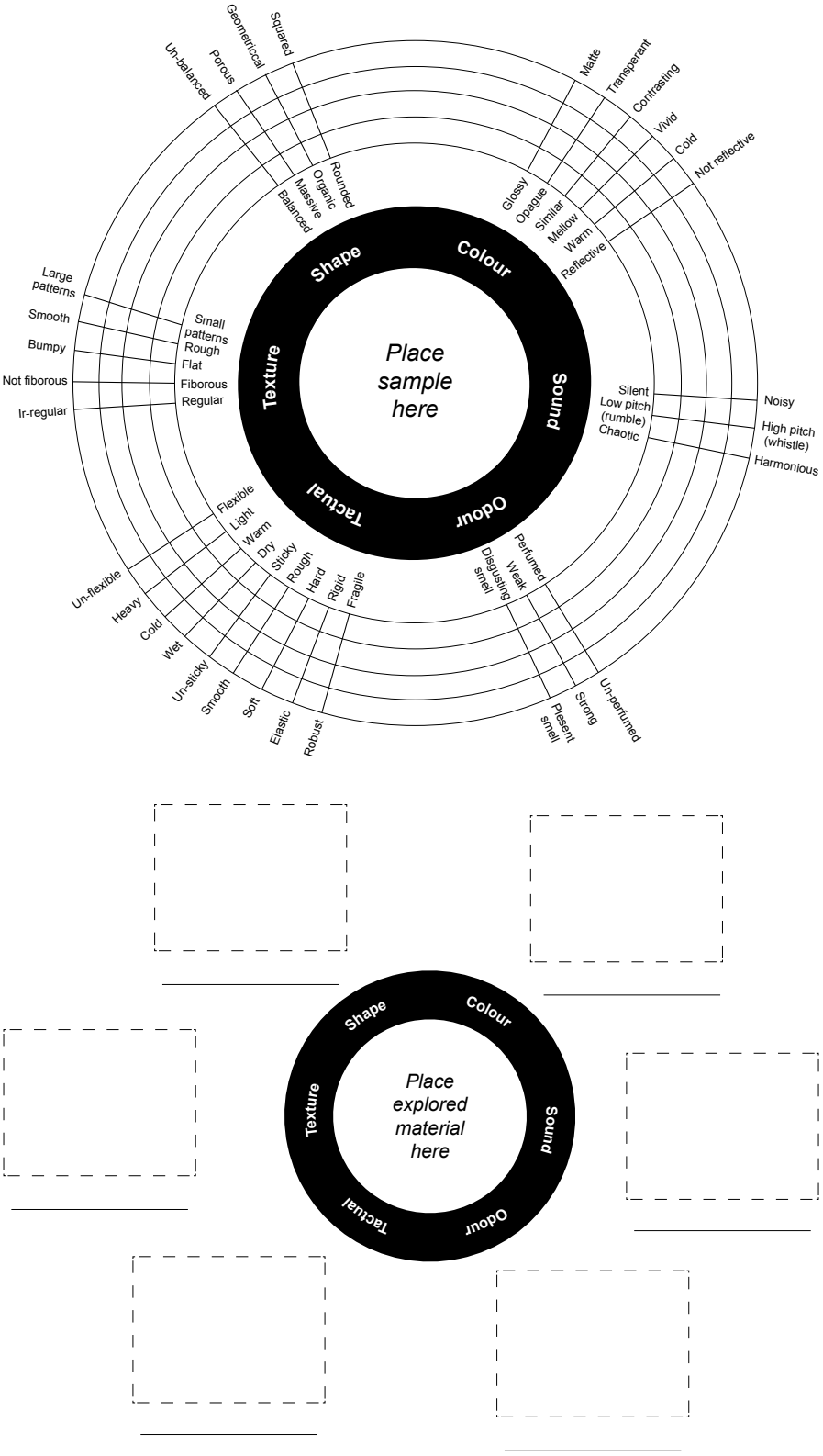


Figure 1.47 Initial templates of the Sensuous Tool.

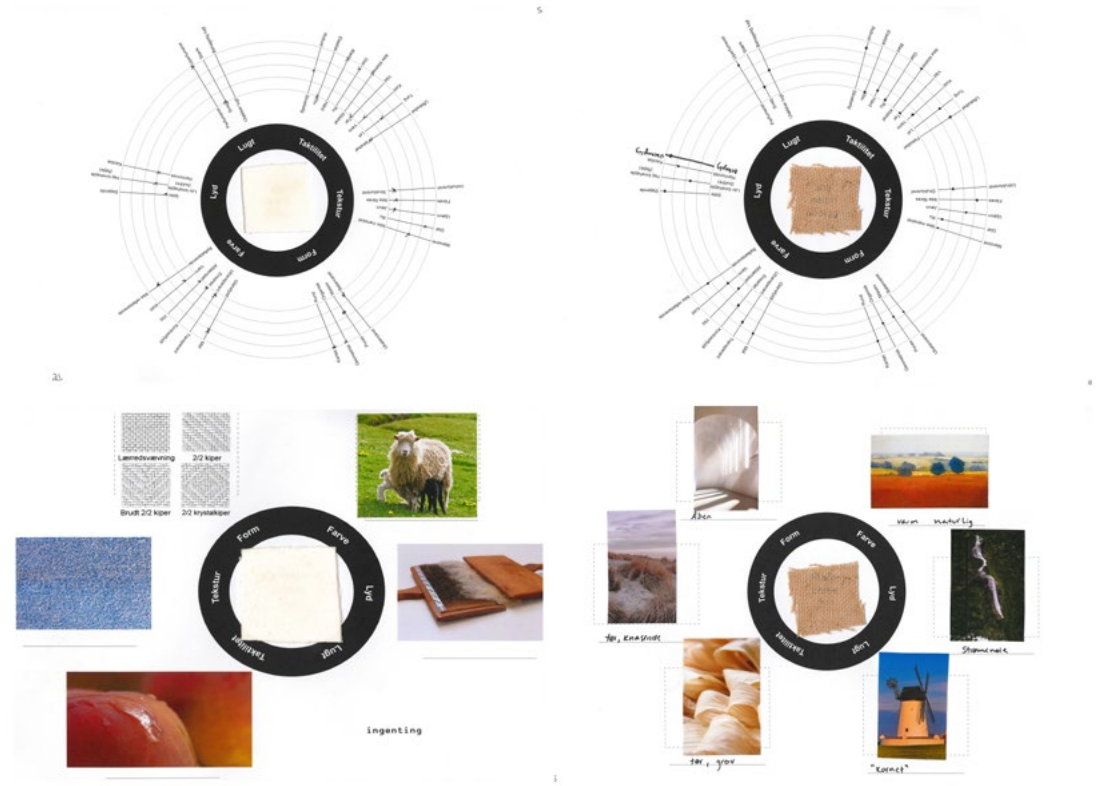


Figure 1.48 Workshop exploring sensuous qualities of textile materials.

Evaluation

The tools were effective in facilitating reflection on specific materials and helping students explore the sensuous qualities of their chosen materials. In a workshop setting, the tools also provided insights into material families by enabling comparisons of different results.

Some students raised questions about what they were comparing the materials to. To address this, I plan to further explore this aspect in **DIA 27** by introducing a reference material for comparison.

DIA 16: Bacterial cellulose

DIA 16

Time period: January to May 2022

Location: Aarhus University, Department of Biochemical Engineering

Motivation: Attempt to grow bacterial cellulose using a waste product

Summary

I established contact with researchers at Aarhus University's Department of Biotechnological Engineering, who allowed me to participate in a project where I could use one of their educational bioreactors. This provided an opportunity to test the possibilities and challenges of scaling up microbial production.

The project involved cultivating cellulose producing bacteria in both sterile and non-sterile environments, using various growth media, including waste stream crop residues such as brown juice. The process of producing and purifying bacterial cellulose is shown in Figure 1.49, Figure 1.50 and Figure 1.51.

Figure 1.49 Cellulose producing bacteria in sterile incubators.

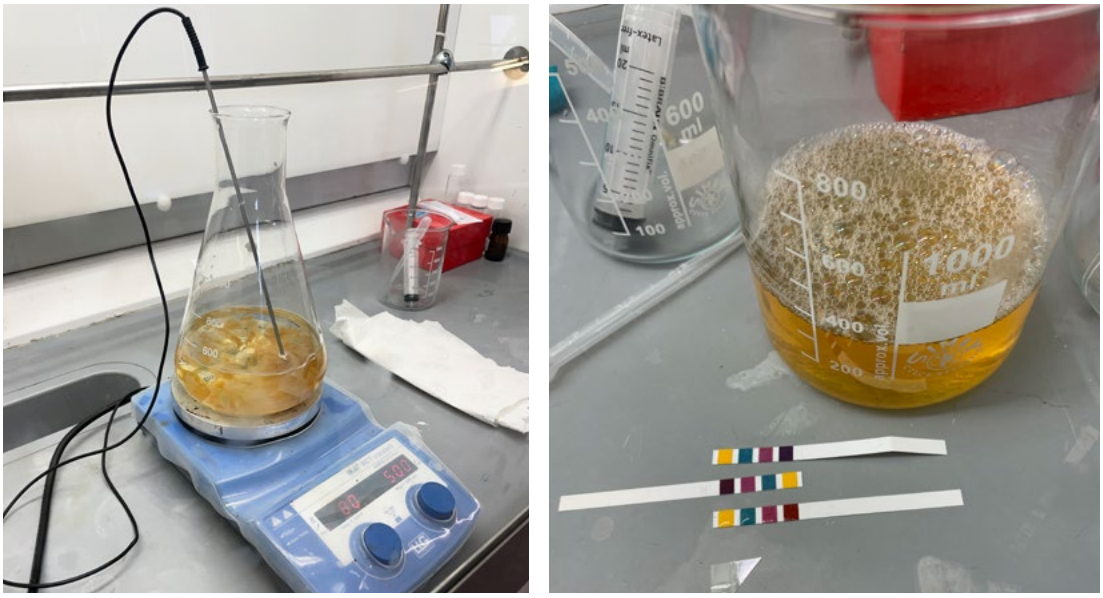


Figure 1.50 Purifying the bacterial cellulose.

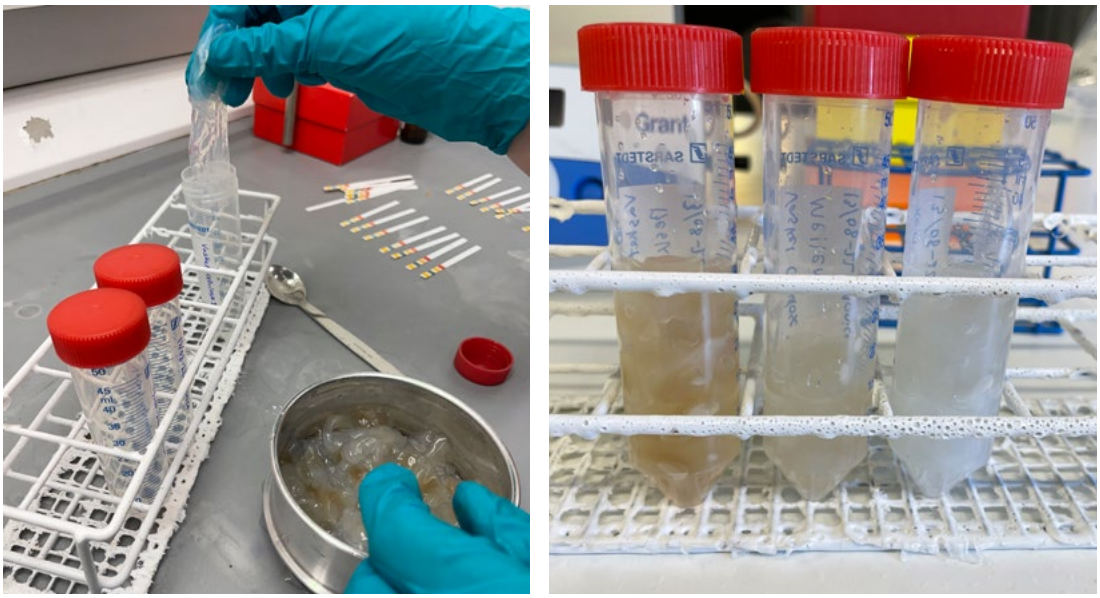


Figure 1.51 Purifying cellulose.

Evaluation

The researchers were open to allowing me access to the laboratory, as they already had team members with multidisciplinary backgrounds, including textile and design knowledge, such as Birgit Bonefeld.

Having previously collaborated with them, they were familiar with my skill set, which facilitated the process (e.g., **DIA 4**). I was granted permission to run an experiment using one of their 2L bioreactors.

The purification of cellulose required the use of hydrochloric acid (HCl) to remove cell debris. However, I was unable to purify the cellulose derived from brown juice sufficiently for use in further experiments.

This collaboration demonstrated that it is possible to work with a natural science laboratory through a mutually beneficial exchange. The researchers were interested in exploring applications for brown juice, which aligned with my research interests.

Ultimately, it was possible to grow cellulose using brown juice as a growth medium.

DIA 17: Kvadrat textiles with violacein

DIA 17

Time period: March to April 2022

Location: VIA Material Test Lab

Motivation: Professionally test the technical qualities of violacein coloured textiles from Kvadrat, creating a baseline for industrial application

Summary

I coloured Kvadrat textiles with violacein, at 90°C for one hour with 1:2 colour liquid to water ratio, as shown in Figure 1.52, and subsequently tested them for wash fastness, rub fastness, and light fastness at the Danish Technological Institute. Photos of the testing process are shown in Figure 1.53 and Table 1.1, Table 1.2, Table 1.3 and Table 1.4 for results.

Additionally, some of the textile samples were placed in a living room to observe how the colour faded over time. The results of that experiment are documented in **DIA 18**.

Figure 1.52 Kvadrat textiles coloured with violacein.

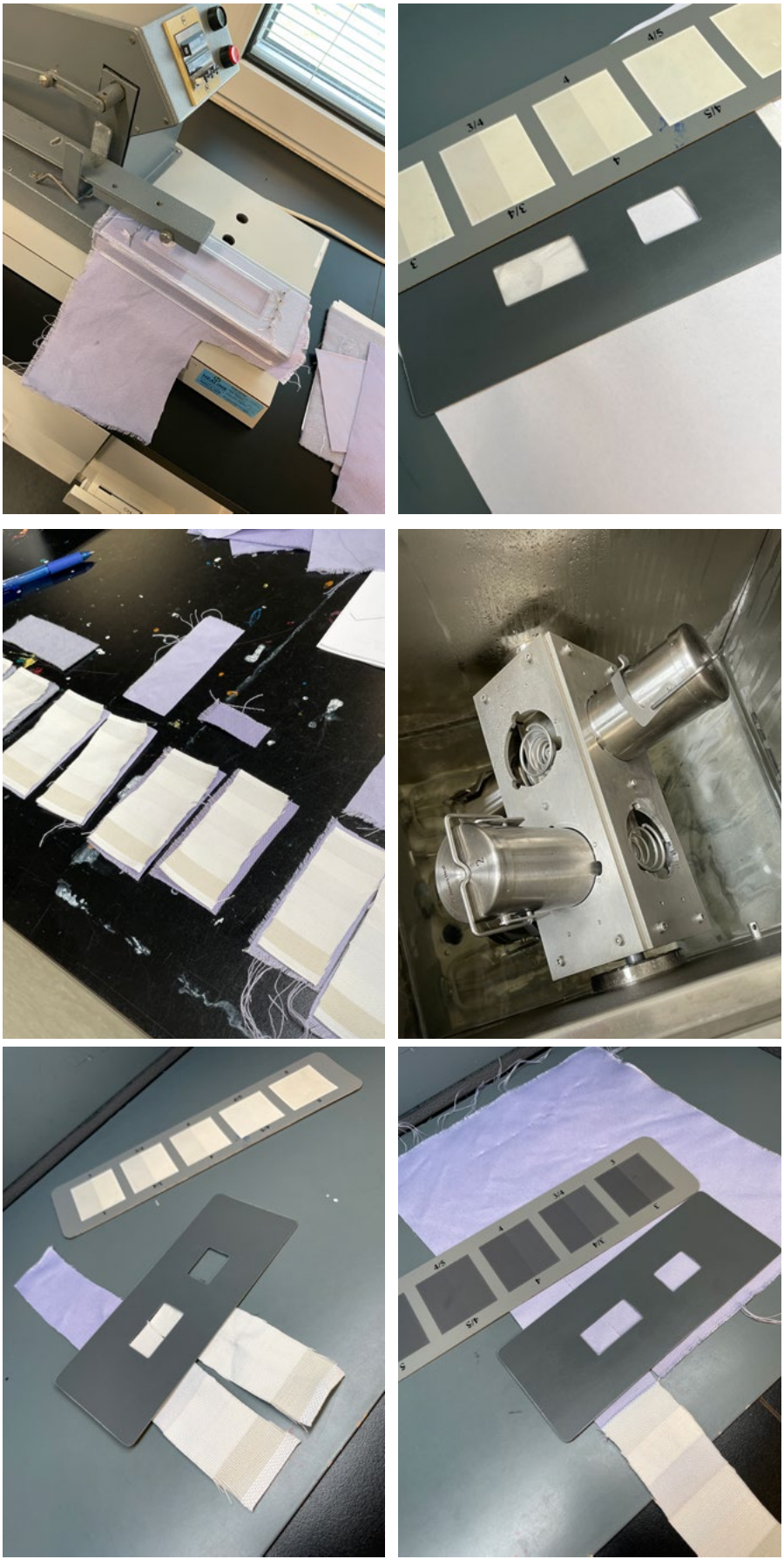


Figure 1.53 Textile testing of violacein coloured textiles.

Test / Fabric		Trevira CS	Polyester FR	Polyester	Wool
Colour wash fastness 30°C grader (ISO 105-C06: 2010)	*Acetate*	4-5	4-5	4-5	4-5
	Bleached cotton	4-5	4	4/4-5	4
	Polyamide	3-4	3	3	2-3
	Polyester	4-5	4-5	4-5	4-5
	Polyacrylic	4-5	4-5	4-5	4/4-5
	Wool	4	4	4	4
Colour change (ISO 105-A02:1993)		4-5	4-5	4	2-3

Table 1.1 Wash at 30°C ECE detergent, 150 ml wash flotté, Notes from 1 - 5, 5 is best. Wash fastness DS/EN ISO 105-C06:2010 (Danish Standards Foundation, 2010). Grey scale for assessing change in colour ISO 105-A02:1993 (Danish Standards Foundation, n.d.).

Test / Fabric		Trevira CS	Polyester FR	Polyester	Wool
Colour wash fastness 40°C grader (ISO 105-C06:2010)	*Acetate*	4-5	4-5	4-5	1-2
	Bleached cotton	4/4-5	4-5	4-5	2-3
	Polyamide	3-4	3/3-4	3-4	1
	Polyester	4-5	4-5	4-5	4
	Polyacrylic	4-5	4-5	4-5	4-5
	Wool	4-5	4-5	4-5	4
Colour change (ISO 105-A02:1993)		4-5	4-5/5	4-5	2

Table 1.2 Wash at 40°C ECE detergent, 150 ml wash flotté, Notes from 1 - 5, 5 is best. Wash fastness DS/EN ISO 105-C06:2010 (Danish Standards Foundation, 2010). Grey scale for assessing change in colour ISO 105-A02:1993 (Danish Standards Foundation, n.d.).

Test / Fabric		Trevira CS	Polyester FR	Polyester	Wool
Colour rub fastness (ISO 105-A03:2019)	*Dry*	3-4/4	3-4	4-5	3-4
	Wet	4	3-4	4-5	3

Table 1.3 Colour rub fastness DS/EN ISO 105-X16:2016 (Danish Standards Foundation, 2016). Notes from 1 - 5, 5 is best. Grey scale for assessing staining ISO 105-A03:2019 (Danish Standards Foundation, 2019).

Test / Fabric	Trevira CS	Polyester FR	Polyester
Colour light fastness (ISO 105 B02:2014)	1	1	1

Table 1.4 Kvadrat colour light fastness test at Danish Technological Institute. Notes from 1 - 8, 8 is best. Colour fastness to artificial light ISO 105 B02:2014 (Danish Standards Foundation, 2014).

Evaluation

I successfully applied bacterial colouring to Kvadrat textiles (Trevira CS, polyester FR, polyester, and wool textiles), as shown in Figure 1.52. The professional test results for violacein were as expected, with low scores for light fastness. However, the wash and rub fastness results were strong, indicating that the textiles could be used in settings where light fastness is not a critical factor.

The tests did not reveal any new information compared to existing knowledge about violacein. However, the results may differ slightly because I used a specific method to colour the textiles, which might not align with the methods used in other studies that tested violacein coloured textiles.

DIA 18: Fading in use

DIA 18

Time period: March to November 2022

Location: DIY Biolab, DSKD

Motivation: Exploring the current design possibilities and challenges of the bacterial colours I had available

Summary

Selected textile samples were placed in two different environments: a ‘normal’ room in a house and directly in sunlight. Weekly photographs were taken of the samples in the normal room to document how they faded over time. The samples exposed to direct sunlight were documented before and after exposure.

As the initial light fastness tests indicated that the colours faded, I aimed to understand in greater detail how the colours changed when exposed to daylight. This would provide insights into how the fading process unfolds during use. While it was clear that permanent fading occurred, I wanted to explore how this fading developed over time. To investigate this, I exposed selected textile samples, coloured using various techniques, to daylight in indirect sunlight for six months. Weekly photographs were taken in a photo box under consistent conditions, using the same camera settings and time of day to ensure comparability. Although exact replication of settings was not possible, I aimed to achieve as much consistency as possible.

For each textile sample, I selected four photographs to illustrate the fading process: 0 months (A), 2 months (B), 4 months (C), and 6 months (D). These images focus on the colour expression and its changes during the fading process. The changes in colour expression depended on the colour molecule, application technique, and textile fibre type. The purpose of this experiment was not to improve light fastness but to understand how colour expression changes with different application

techniques. Even if light fastness improves, the colour expression will still change over time, making this study relevant for understanding the aesthetic evolution of colours.

Yarn windings

For the study of yarn windings, I selected samples from the colouring technique described in **DIA 5**.

Figure 1.54: A yarn winding with polyester dyed with prodigiosin and wool dyed with carotenoids shows a noticeable fade in the bright pink colour, revealing the brown wool yarn. By two months (B), the pink fades to a more subtle tone, highlighting the brown. From two to six months (C, D), the colour expression remains visually similar.

Figure 1.55: A yarn winding with wool dyed with violacein, wool dyed with prodigiosin, and polyester dyed with prodigiosin shows the bright pink prodigiosin fading, making the blue violacein more prominent. By two months (B), the pink is almost gone, resulting in a more monotone expression. This remains unchanged from two to six months (C, D).

Figure 1.56: A yarn winding with wool dyed with carotenoids, wool dyed with violacein, and polyester dyed with violacein shows a subtle change. The blue colours become more prominent but fade to a paler blue over six months. The overall colour expression remains consistent throughout (A, B, C, D).

Figure 1.57: A yarn winding with polyester dyed with prodigiosin and polyester dyed with a mix of prodigiosin and violacein shows significant fading of the pink prodigiosin within the first two months (B). From two to four months (C), the pink and purple fade further, but the colour expression remains unchanged from four to six months (D).

The mélange effect caused by fading does not necessarily result in a ‘bad’ change in colour expression but rather a different one from the original.

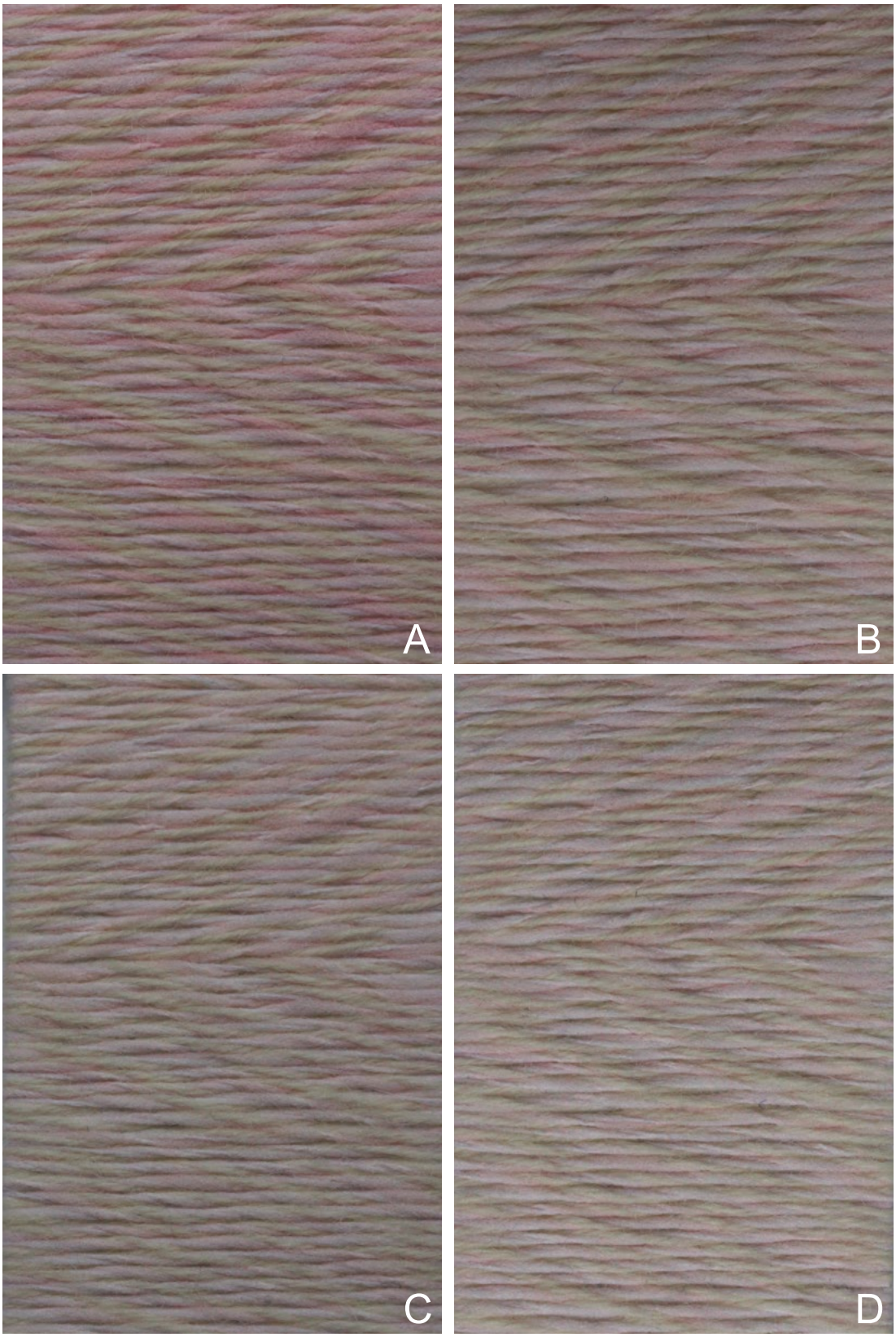


Figure 1.54 Yarn winding with prodigiosin dyed polyester and wool dyed with carotenoid.

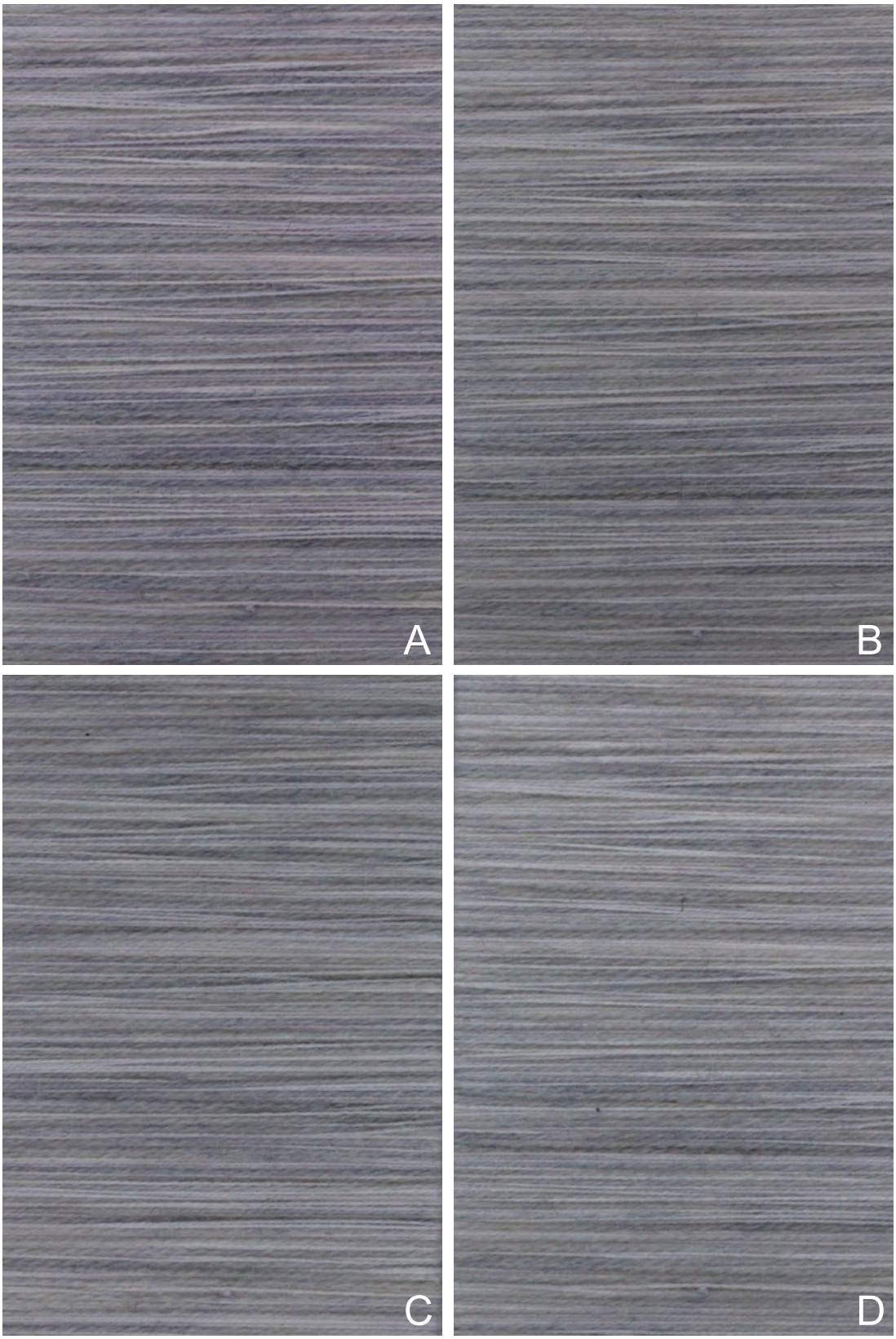


Figure 1.55 Yarn winding with wool dyed violacein, wool dyed prodigiosin and polyester dyed with prodigiosin.

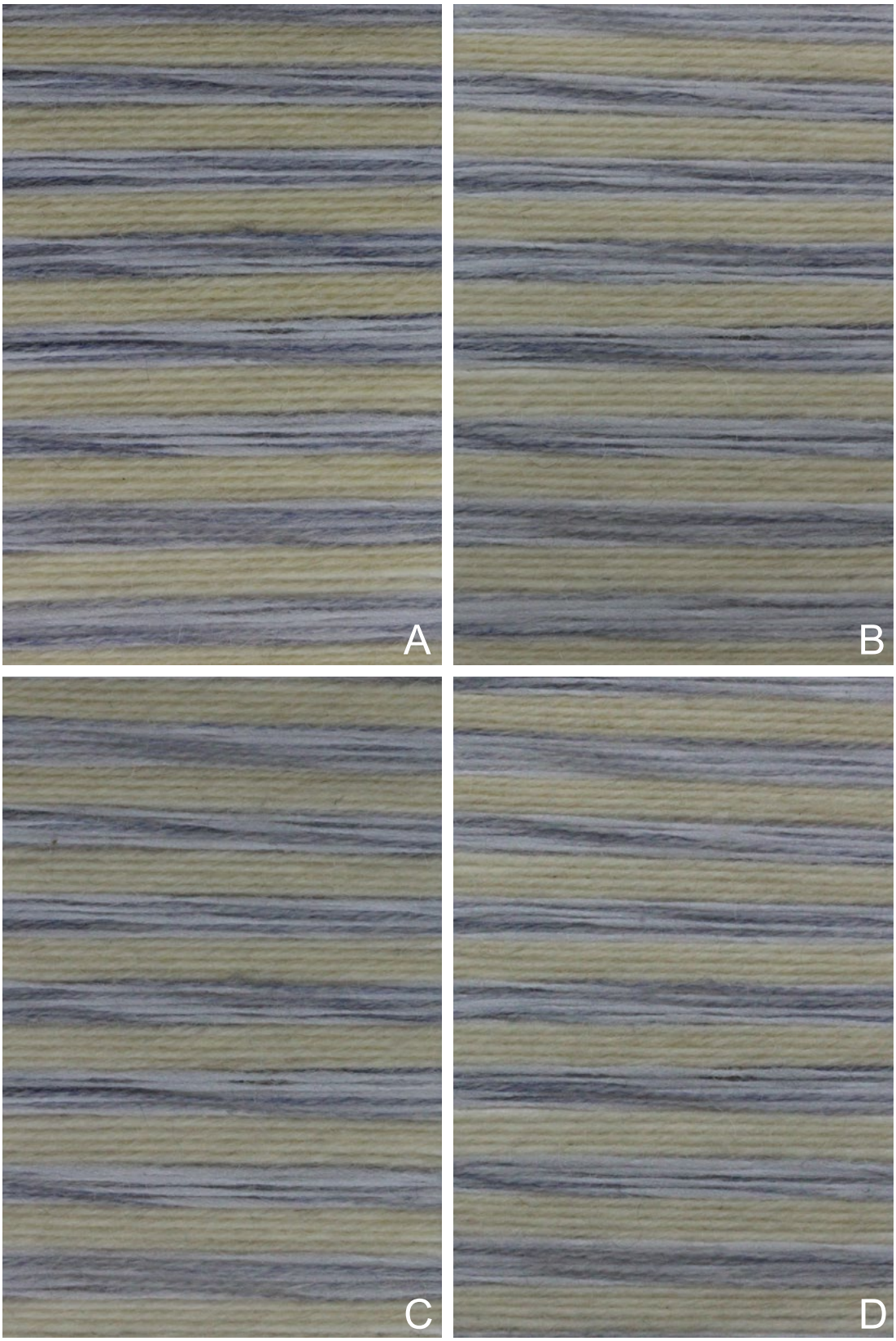


Figure 1.56 Yarn winding with wool dyed with carotenoid, wool dyed with violacein and polyester dyed with violacein.

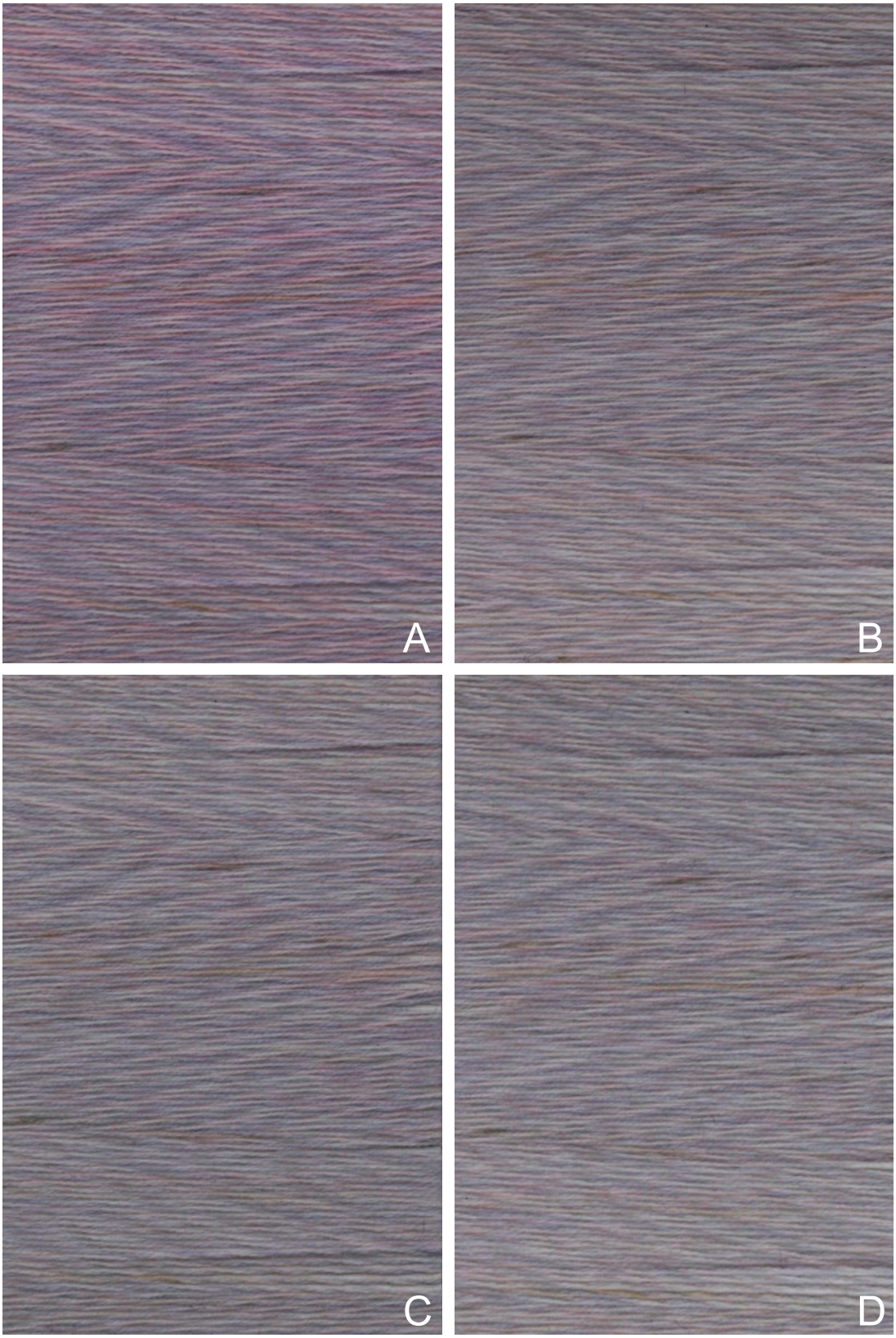


Figure 1.57 Yarn winding with polyester dyed prodigiosin and polyester dyed with a mix of prodigiosin and violacein.

Printed textiles

For printed textiles, I selected samples from the colouring technique described in **DIA 5**.

Figure 1.58: A printed polyester textile with violacein and Gum Arabic shows the most significant change in areas where the print paste is overlaid. By two months (B), the strong blue fades to a subtler hue. By four months (C), the difference between the overlaid and single-layered prints becomes less apparent. After six months (D), the colour expression remains the same, though slightly faded.

Figure 1.59: A polyester textile transfer-printed with violacein and carotenoids shows minimal change in colour expression over six months (A, B, C, D). The dark, highly saturated colours allow more pigment to fade without noticeable changes to the human eye. A slight reduction in saturation is observed in the yellow pigment.

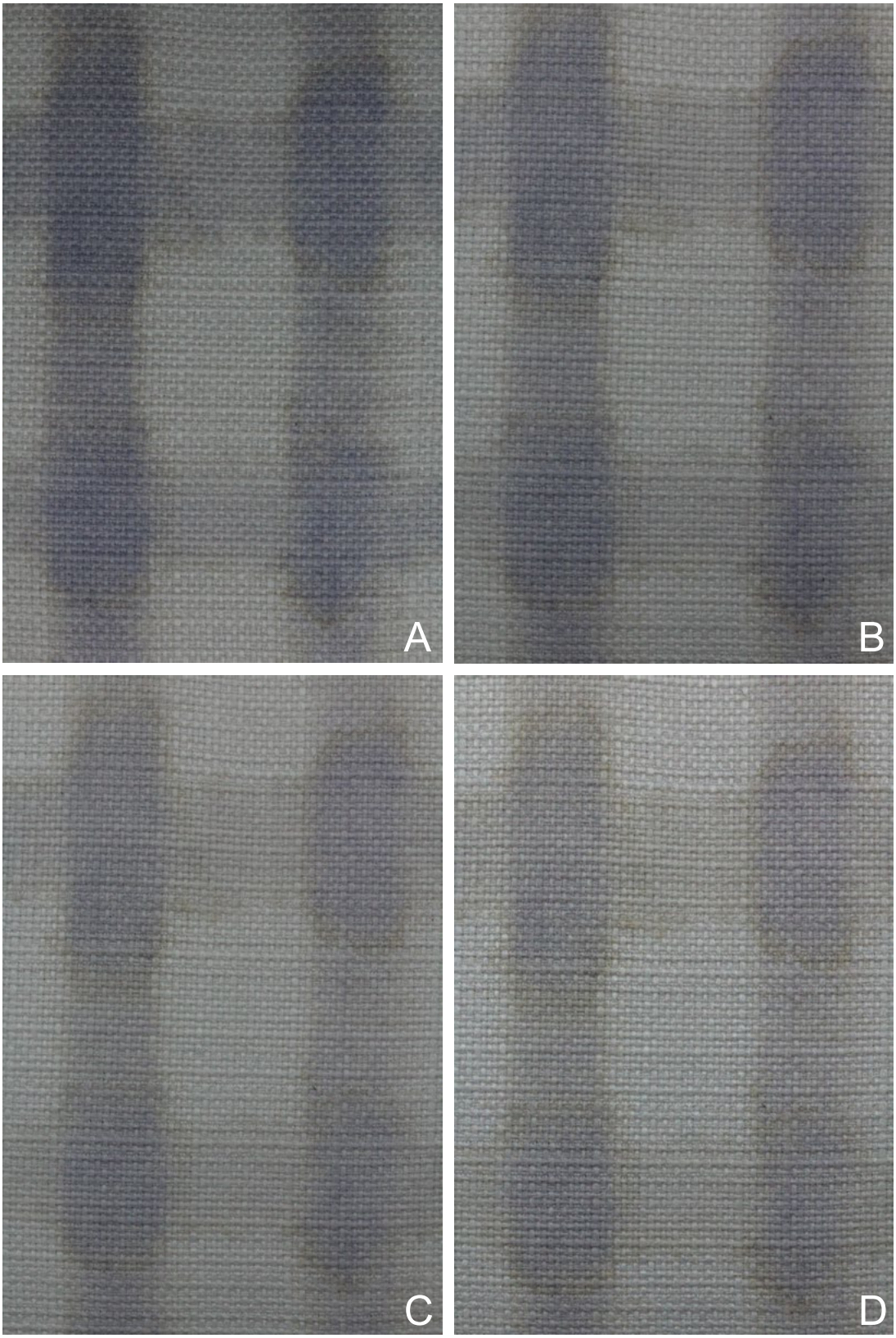


Figure 1.58 Textile polyester printed with print paste made from Gum Arabic and liquid bacteria colour.

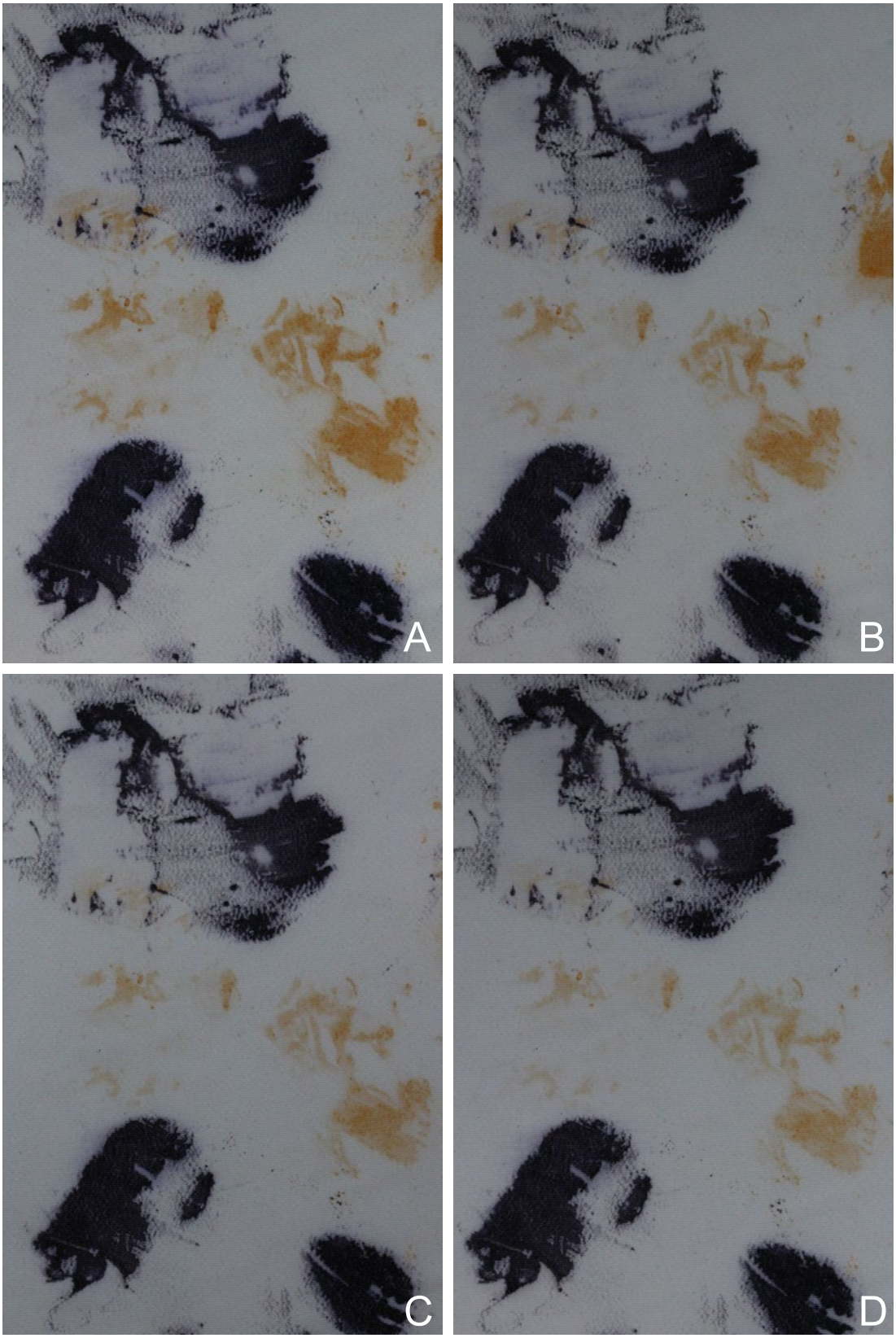


Figure 1.59 Polyester textile transfer printed with violacein and carotenoid.

Textiles dyed during cultivation

For textiles dyed during cultivation, I selected samples from the colouring technique described in **DIA 5**.

Figure 1.60: A polyester textile dyed with prodigiosin and violacein shows the pink prodigiosin fading to a subtle red and the purple violacein fading to blue by two months (B). From two to six months (B to D), the colour expression remains consistent, with slight fading.

Figure 1.61: A wool textile dyed with prodigiosin shows drastic fading over six months (A to D), with the colour almost disappearing. The most significant change occurs between two and four months (B to C).

Figure 1.62: A wool textile dyed with violacein shows fading in less saturated areas, while highly saturated areas retain their colour. Overall, the surface loses some brightness gradually over six months (A, B, C, D).

Figure 1.63: A cotton textile dyed with violacein shows minimal changes over six months (A, B, C, D). The brightness decreases slightly, but the patterned expression remains intact.

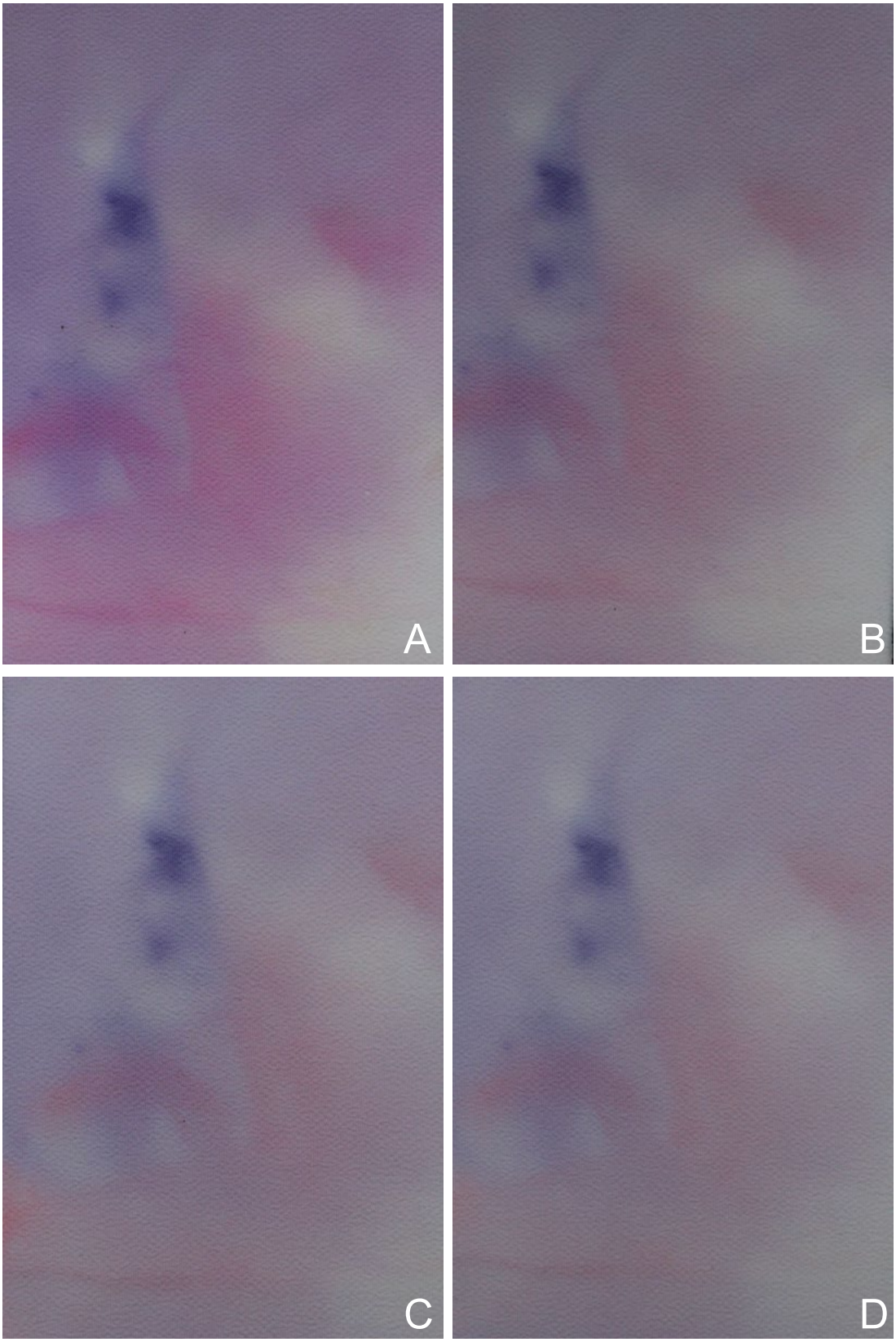


Figure 1.60 Polyester dyed with Shibori technique and prodigiosin and violacein.

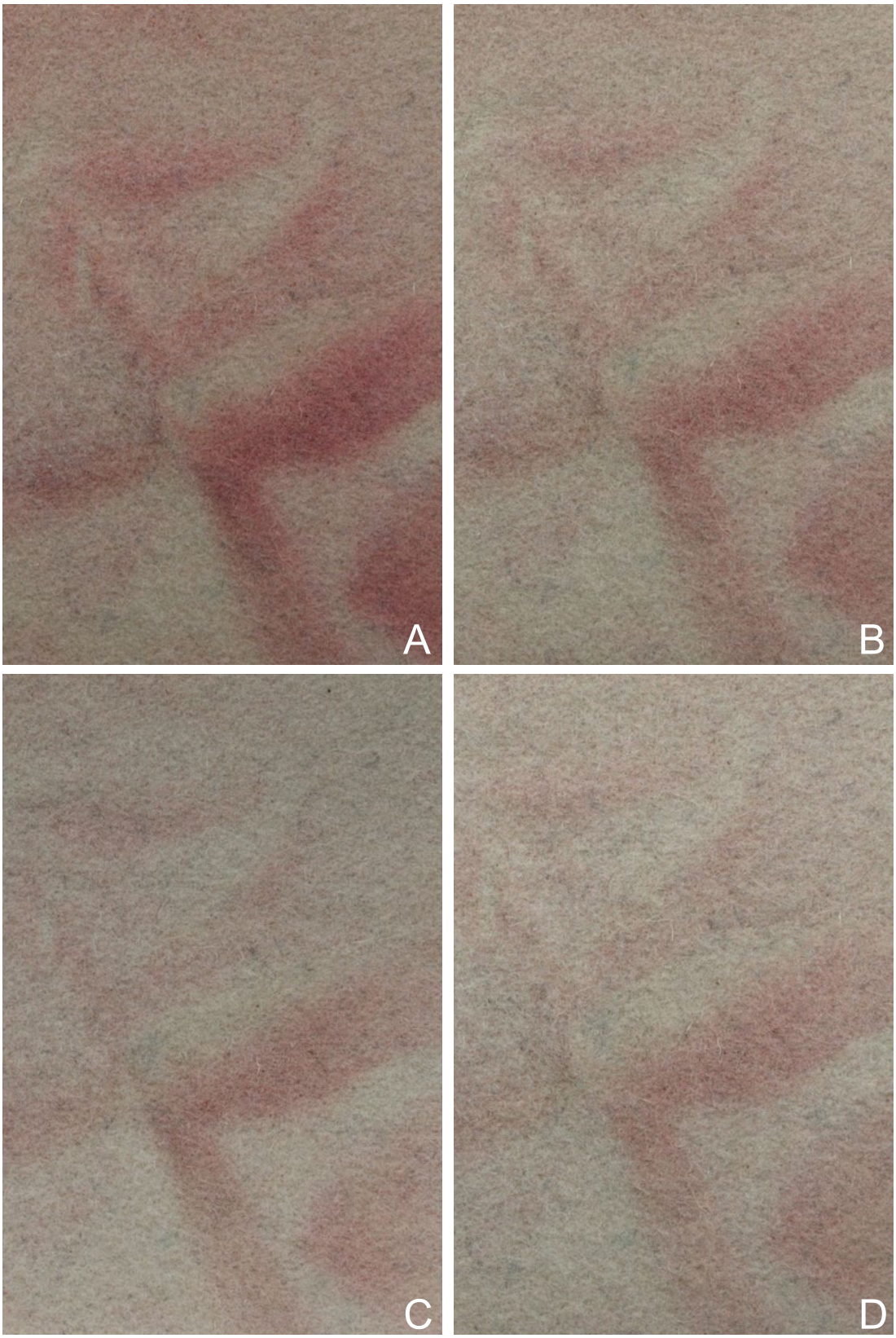


Figure 1.61 Wool textile dyed with prodigiosin.

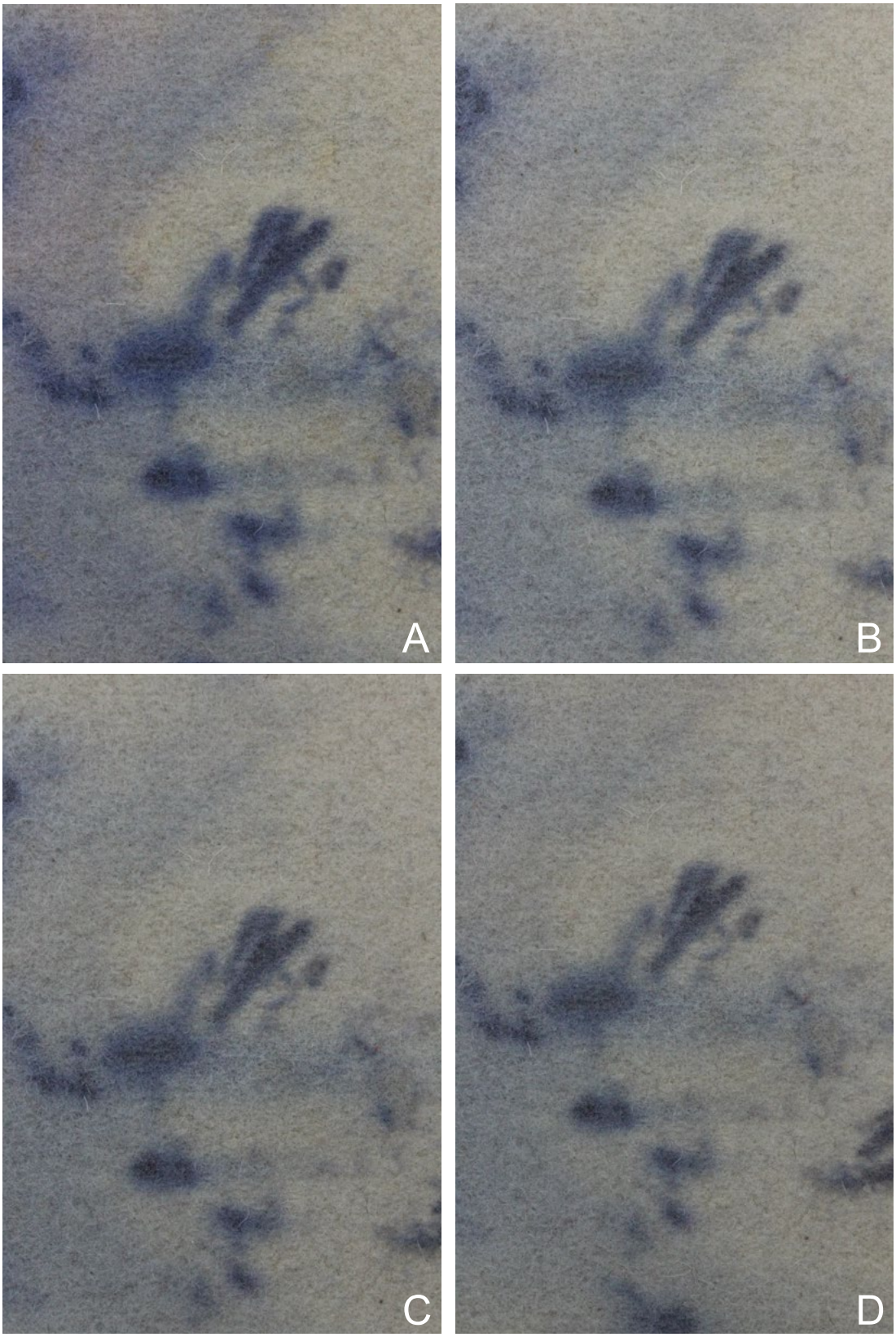


Figure 1.62 Wool textile dyed with violacein.

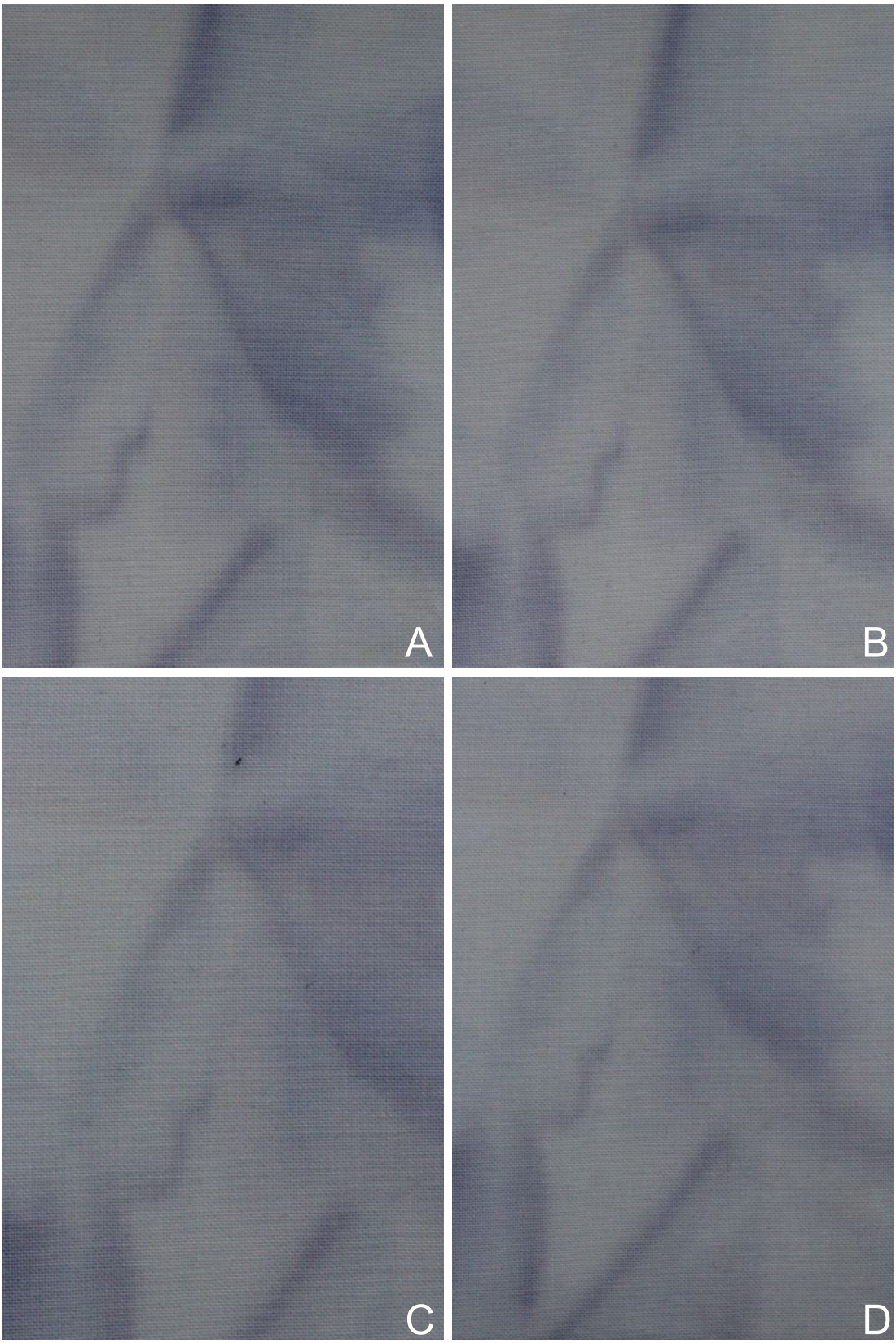


Figure 1.63 Cotton textile dyed with violacein.

Conventional dyed textiles

For conventional dyed textiles, I used the technique described in **DIA 5**. Kvadrat textiles made from polyester, wool, or wool-polyamide blends were dyed with violacein, chosen for its broad application range and relatively high light fastness.

Figure 1.64, Figure 1.65 and Figure 1.66: Polyester samples show varying degrees of fading depending on fibre type and fabric construction.

Figure 1.64: A drastic change occurs by two months (B), with the blue fading to grey. By four months (C), the colour appears entirely grey.

Figure 1.65: The sample retains its brightness over six months, with the most significant fade occurring by two months (B).

Figure 1.66: A noticeable fade occurs by two months (B), but the colour does not turn grey as in Figure 1.64. From two to six months (B to D), the brightness fades slightly, but the colour expression remains consistent.

Figure 1.67 and Figure 1.686: Wool samples show noticeable fading.

Figure 1.67: The blue fades to a greyer tone by two months (B) and appears grey by four months (C).

Figure 1.68: Similar to Figure 1.67, but the fading continues from four months (C) to six months (D).

Figure 1.69, Figure 1.70 and Figure 1.71: Wool-polyamide blends show fading in all samples.

Figure 1.69: The violacein almost disappears by six months (D).

Figure 1.70 and Figure 1.71: Both samples retain a blue tone after six months (D), though in a more faded version compared to the unexposed sample (A).

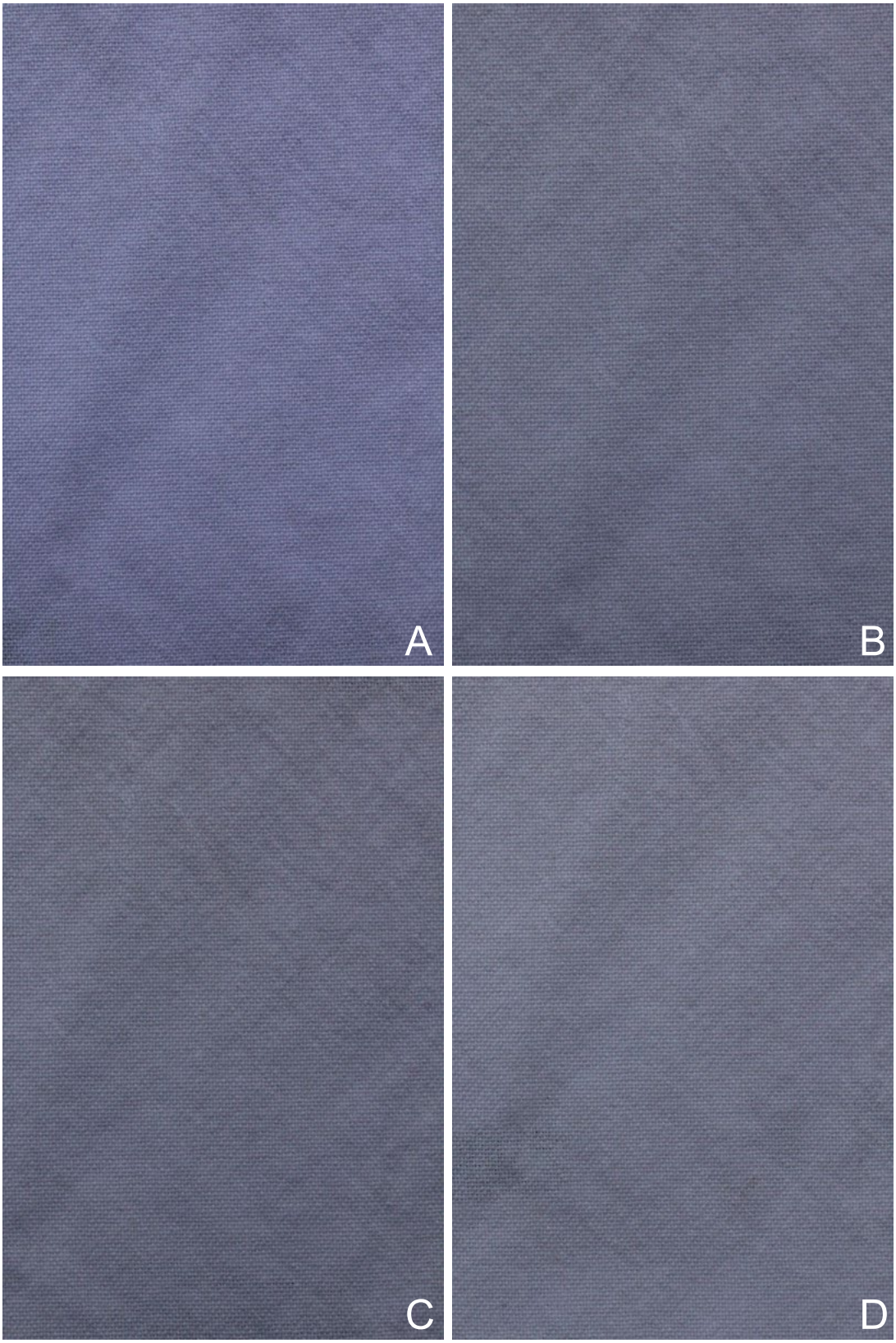


Figure 1.64 100% polyester.

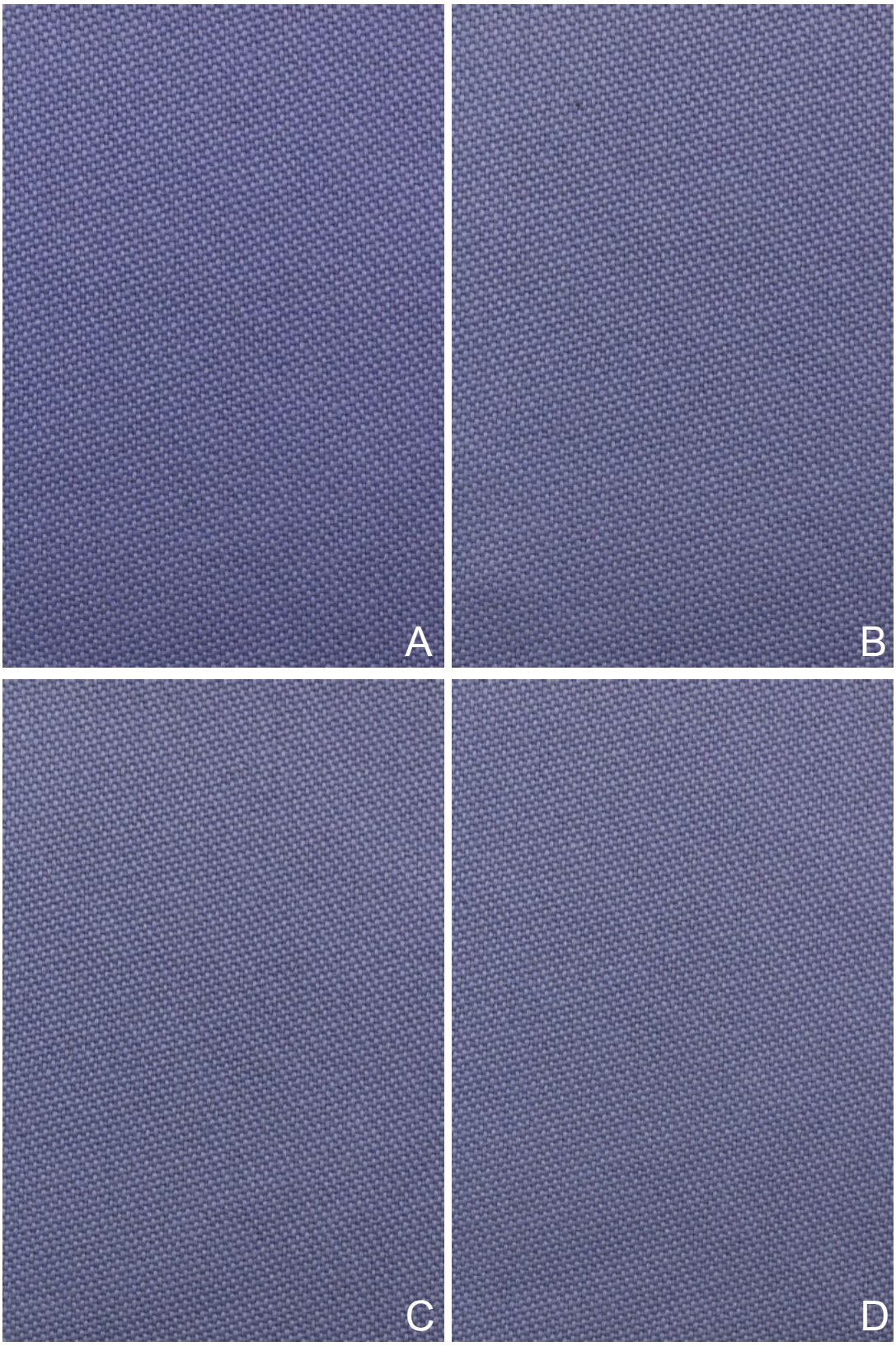


Figure 1.65 100% polyester.

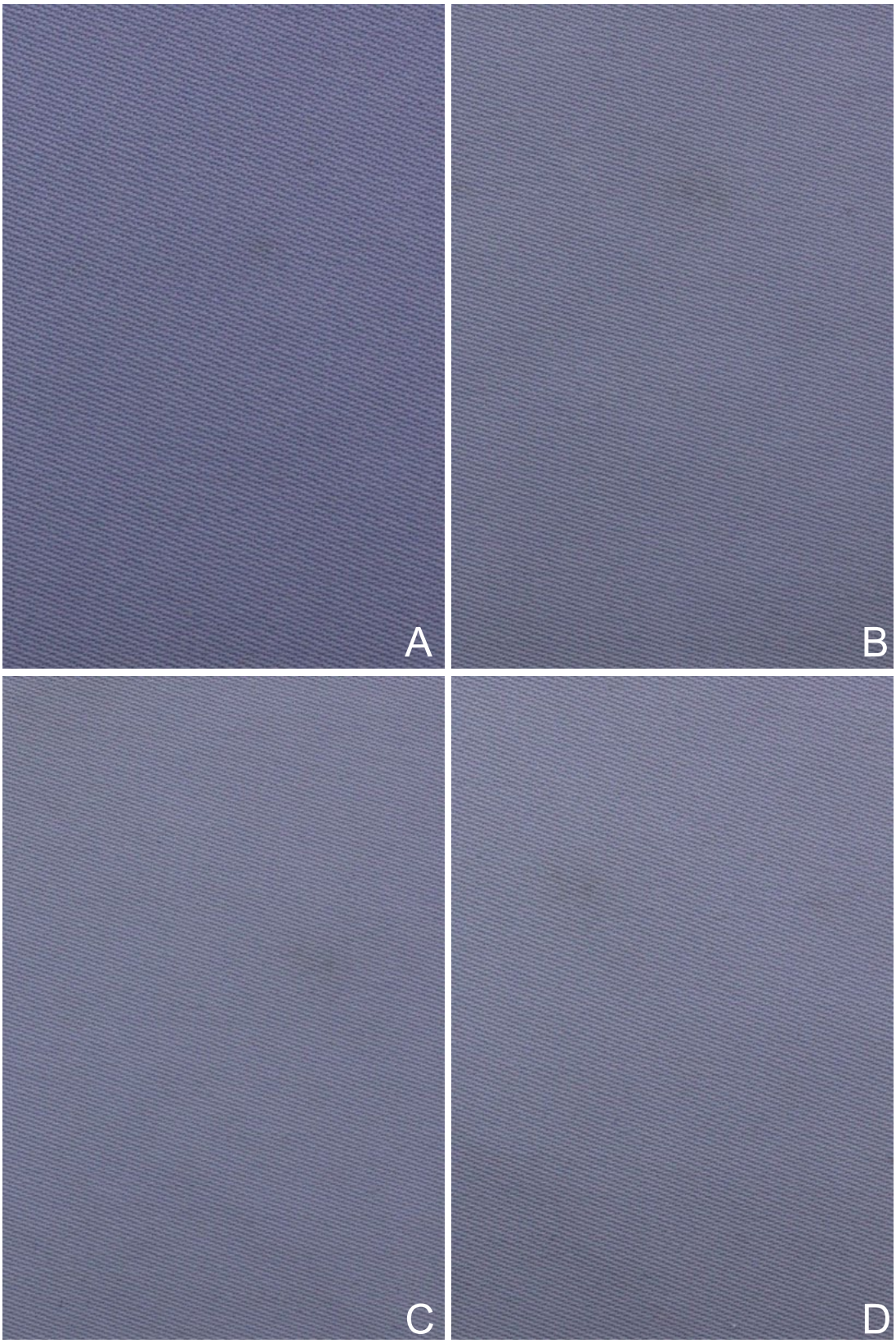


Figure 1.66 100% polyester.

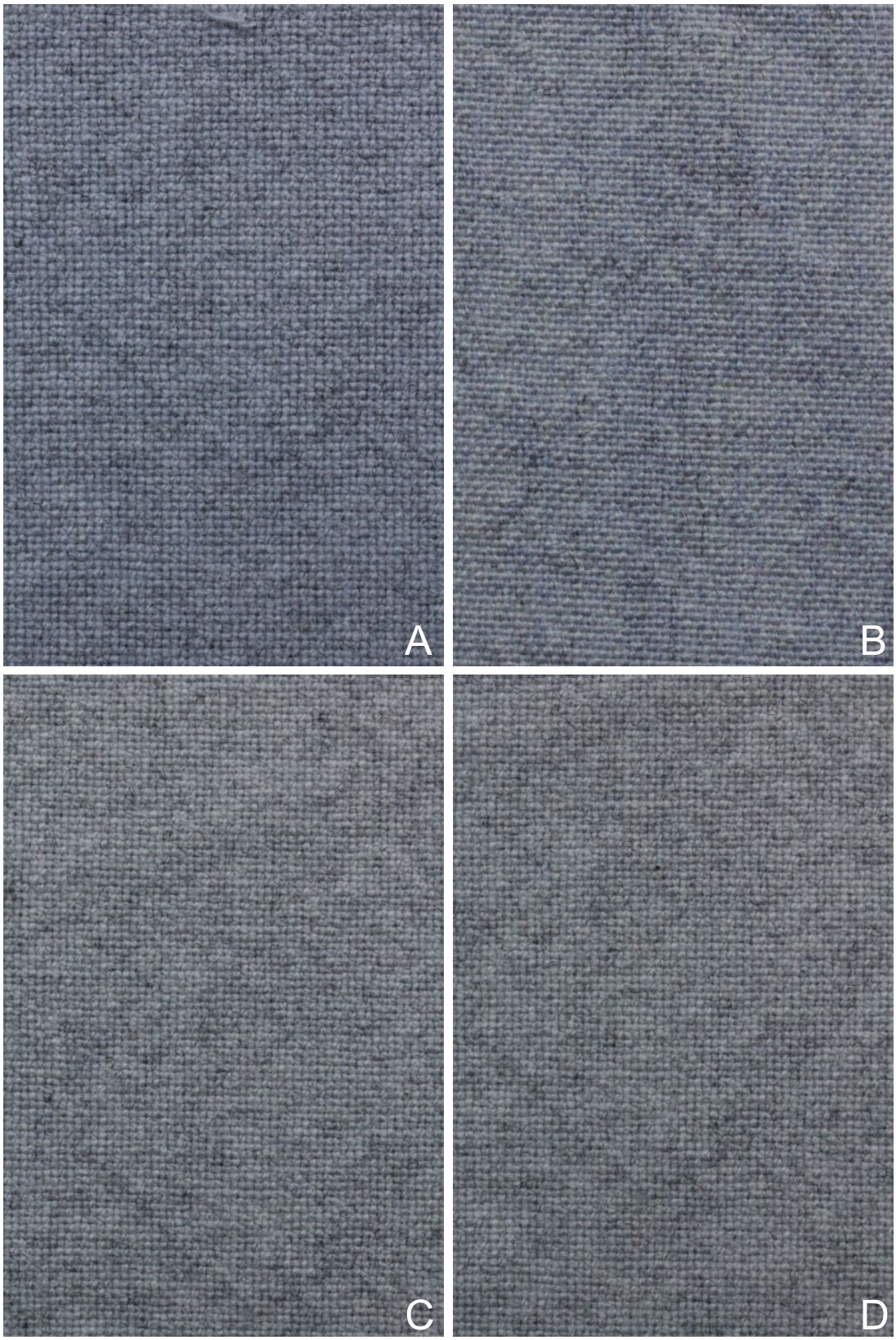


Figure 1.67 100% new wool.

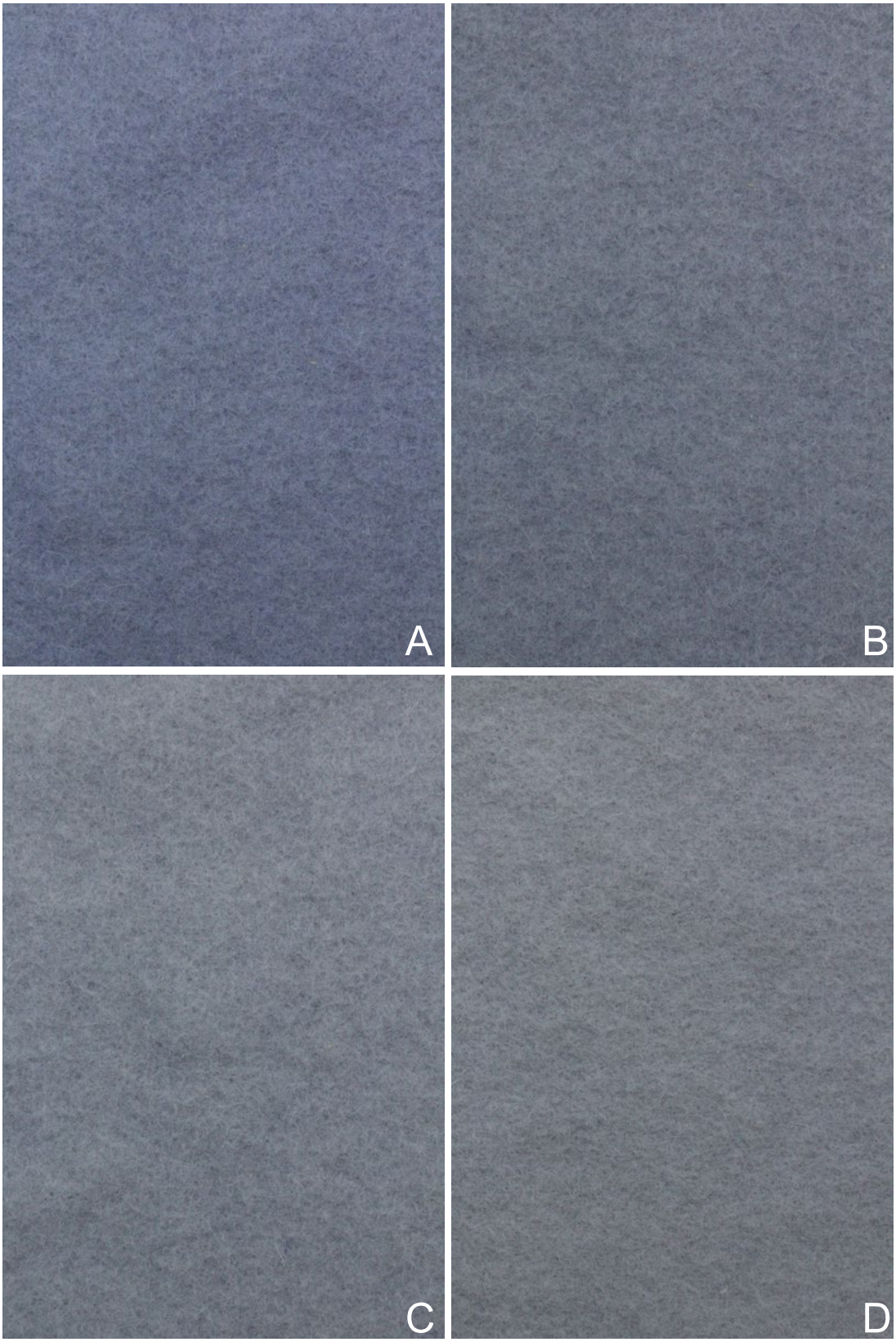


Figure 1.68 100% new wool.

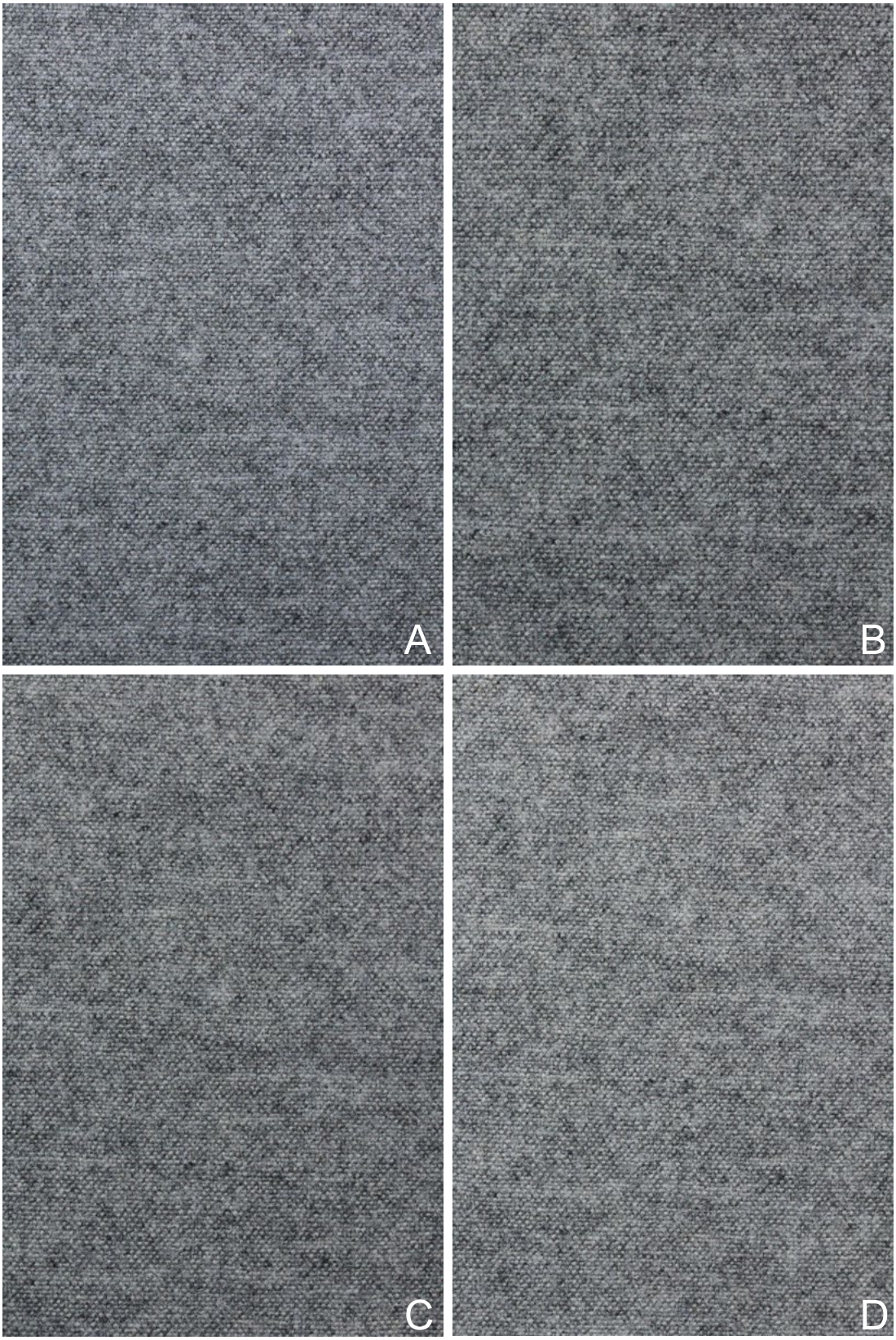


Figure 1.69 97% new wool (worsted), 3% polyamide.

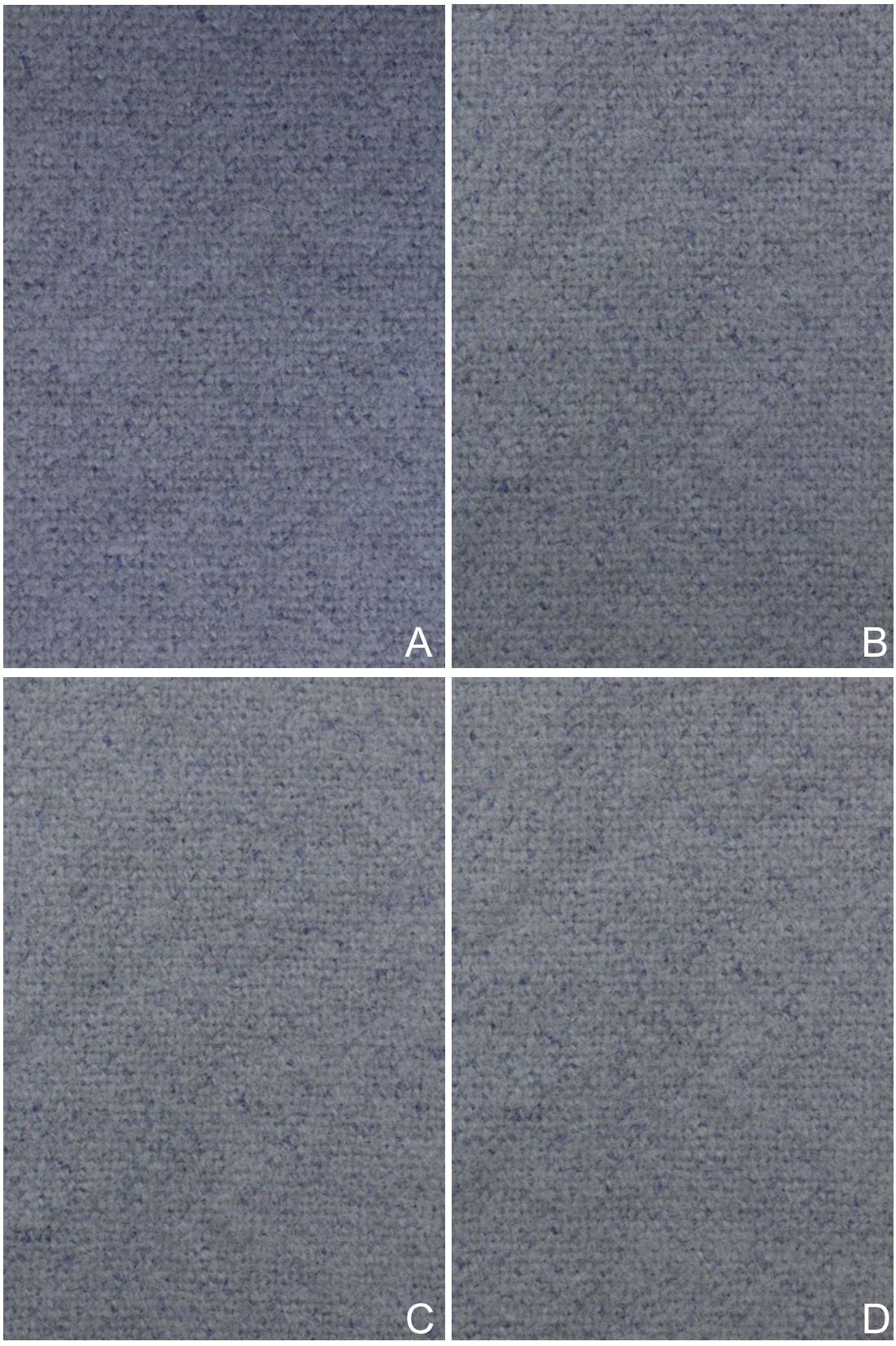


Figure 1.70 90% new wool 10% polyamide.

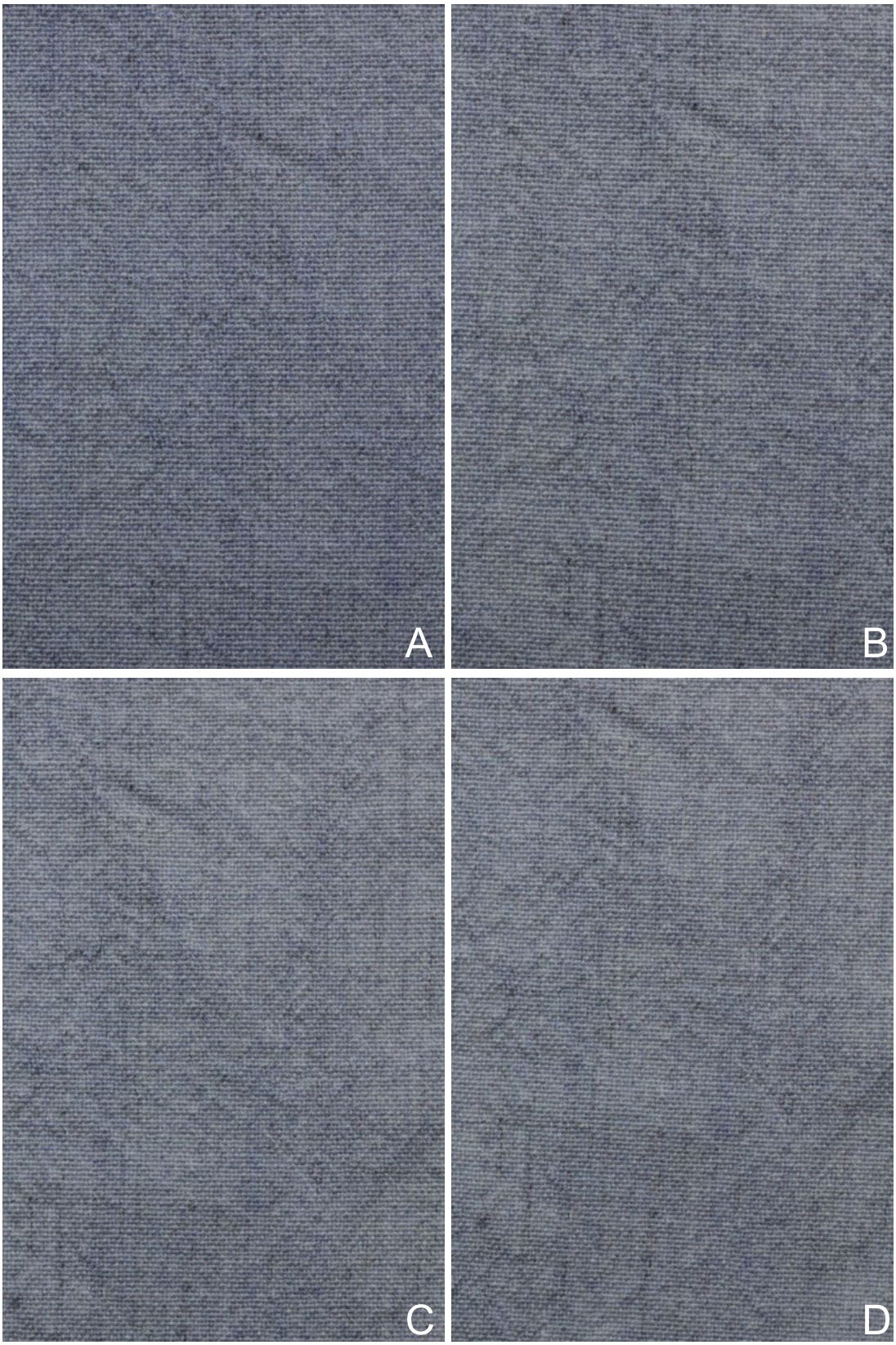


Figure 1.71 90% new wool (worsted), 10% polyamide.

Evaluation

For printed or textured surfaces, the fading is less noticeable and could be used as an aesthetic parameter in design.

Violacein, the most lightfast colourant, was applied to Kvadrat textiles. The results show that polyester fibres differ in their response to the same application method, with fabric construction and polymer composition influencing the colour hue.

DIA 19: Violacein production at DTU

DIA 19

Time period: April to August 2022

Location: Technical University of Denmark (DTU), Department of Biotechnology and Biomedicine

Motivation: Create a larger amount of violacein to enable future experiments

Summary

I stayed at DTU to upscale violacein production for pigment extraction. While the process was time-consuming, it was not a true upscale of the production process but rather an increase in the quantity of the product (violacein). The researchers at DTU guided me and helped develop a protocol for the process.

Figure 1.72 shows photos of the process, which was largely the same as the small-scale method but involved significantly more Petri dishes (approximately 200). Figure 1.73 illustrates the steps of harvesting, isolating, and drying the pigment. This involved dissolving the cellulose with a solvent, separating it in a centrifuge, and pouring out the liquid containing the cellulose. The final step was drying the remaining pigment through evaporation. Figure 1.74 provides a close-up of the evaporation process and the final dried product.

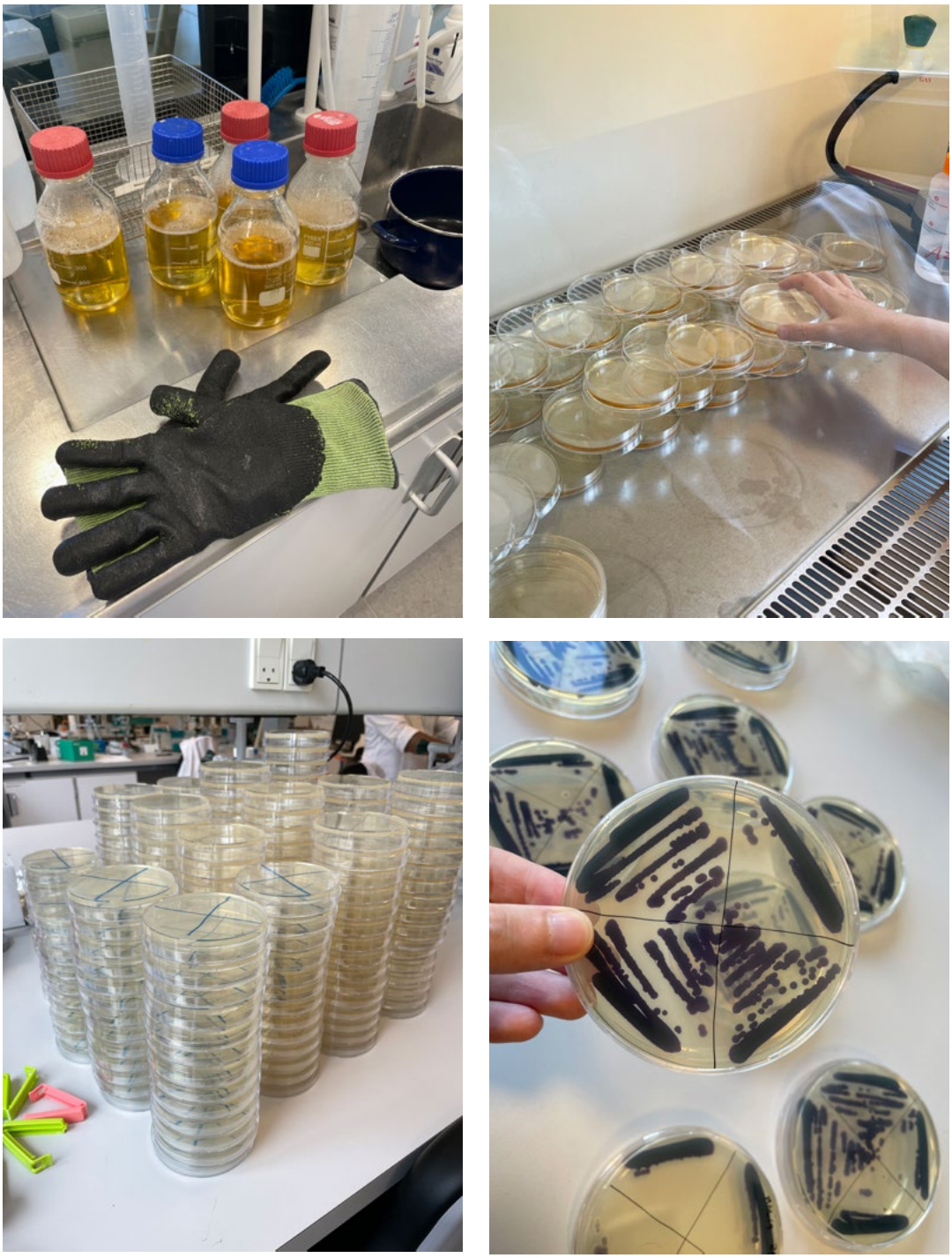


Figure 1.72 Upscaling violacein production at DTU.

Figure 1.73 Isolating violacein pigment.

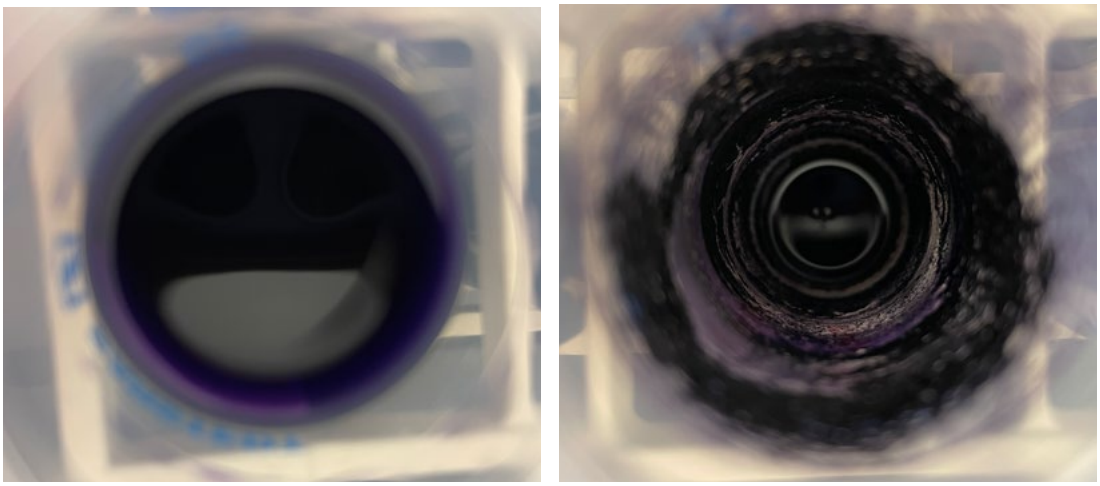


Figure 1.74 Zooming in on solvent evaporation.

I also visited Chromologics, facilitated by the group leader at DTU, who was a former colleague of the CEO. During the visit, Sara, their senior research scientist, gave me a tour of their laboratory and production site.

Evaluation

Finding a facility to conduct larger-scale production was challenging, and I ultimately carried out the work at DTU. The researchers at DTU had no prior experience collaborating with designers, but my background enabled me to work independently.

The process was highly time-consuming and labour-intensive. It was not a proper upscale of the production process but rather a repeated application of the small-scale method using many Petri dishes. However, I succeeded in obtaining the dry pigment needed for further experiments, which was the primary goal. Approximately 5g of dried violacein pigment was extracted in total.

Although I did not have the time to set up a bioreactor, which could have been a more effective method for upscaling, the process allowed me to produce dried grams of pigment for subsequent experiments.

On an industrial scale, bacterial colour production is already being actively pursued, and textile companies have shown interest in these developments. However, these companies often lack extensive knowledge of textile colouring, which presents an opportunity for potential collaboration.

DIA 20: ECO-printing at Crafthub residency

DIA 20

Time period: May 2022

Location: Clasheen, Ireland

Motivation: Get inspired by eco-printing

Summary

I spent a week eco-printing with Nicola Brown at Clasheen, Ireland. On her farm, she introduced me to felting and eco-printing, using vegetation from the surrounding lands. Nicola has eucalyptus trees planted in her garden specifically for eco-printing purposes.

We used a “dirty pot” plant dyeing method for the eco-printing process. Figure 1.75 shows photos of the process and the resulting prints.

Evaluation

The local scale of production and the regenerative practices Nicola employed were inspiring, leading me to consider whether similar approaches could be applied to bacterial colouring.

The colours produced through eco-printing are generally less vibrant, with green and brown tones dominating. While this limits the design potential, the process is feasible on a local scale.

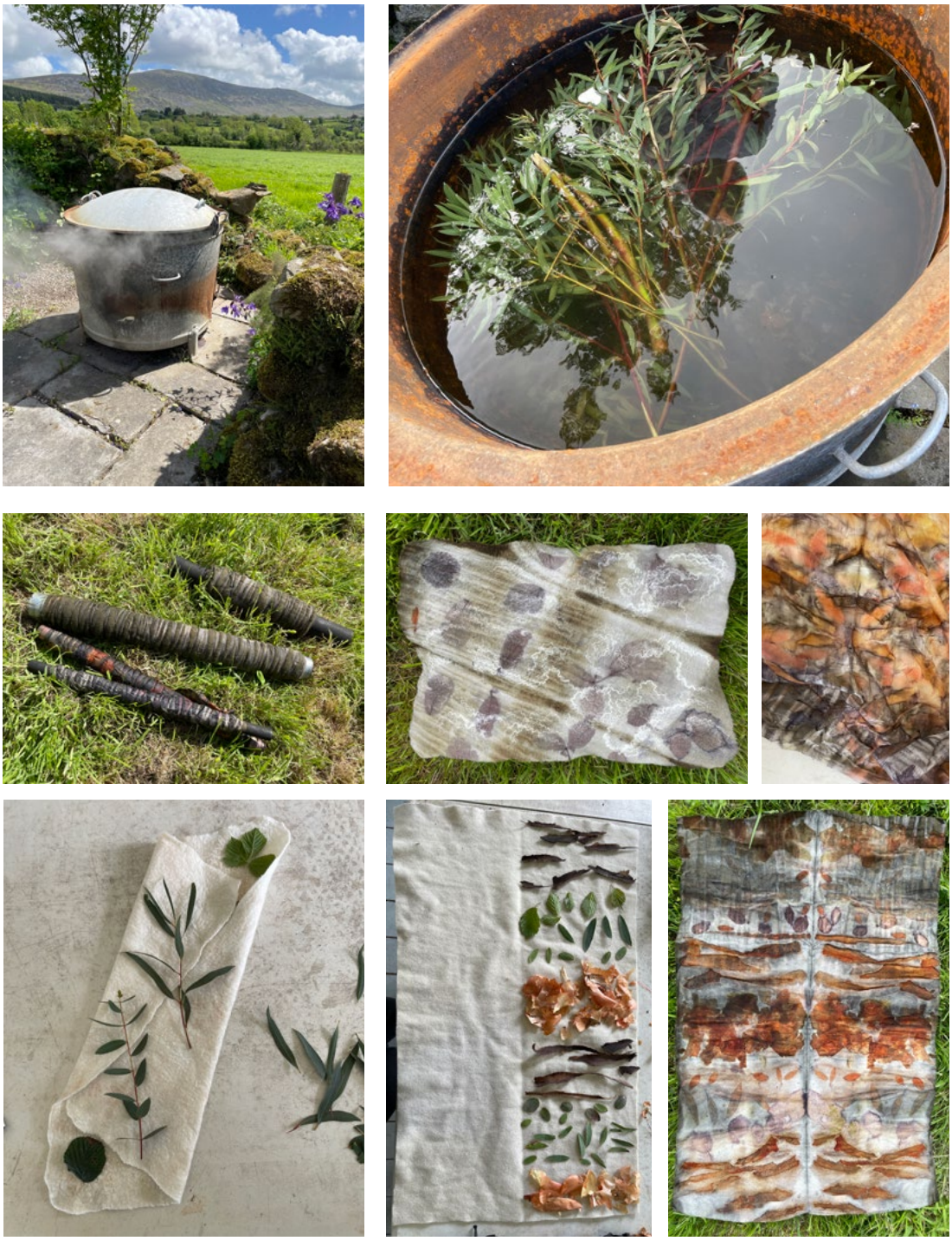


Figure 1.75 Eco-printing textiles.

DIA 21: Isolation and cultivation of the fungi xylindein

DIA 21

Time period: June to September 2022

Location: Aarhus University, Department of Biochemical Engineering

Motivation: Isolate and cultivate xylindein for pigment production

Summary

I attempted to isolate the Green Elfcup fungus from a tree stump I found in the forest. As shown in Figure 1.76 , I took pieces of the Green Elfcup from the tree stump and cultivated them in multiple Petri dishes. However, all the samples became contaminated with bacteria or other fungi from the tree stump.

Due to the long incubation time required (40 days), I decided to use a pre-isolated Green Elfcup fungus instead. As shown in Figure 1.77, I carved a piece from the purchased pre-isolated Green Elfcup and placed it into flasks for shake flask incubation.

After 40 days of shake flask incubation, some green pigment was produced, as seen in Figure 1.78.

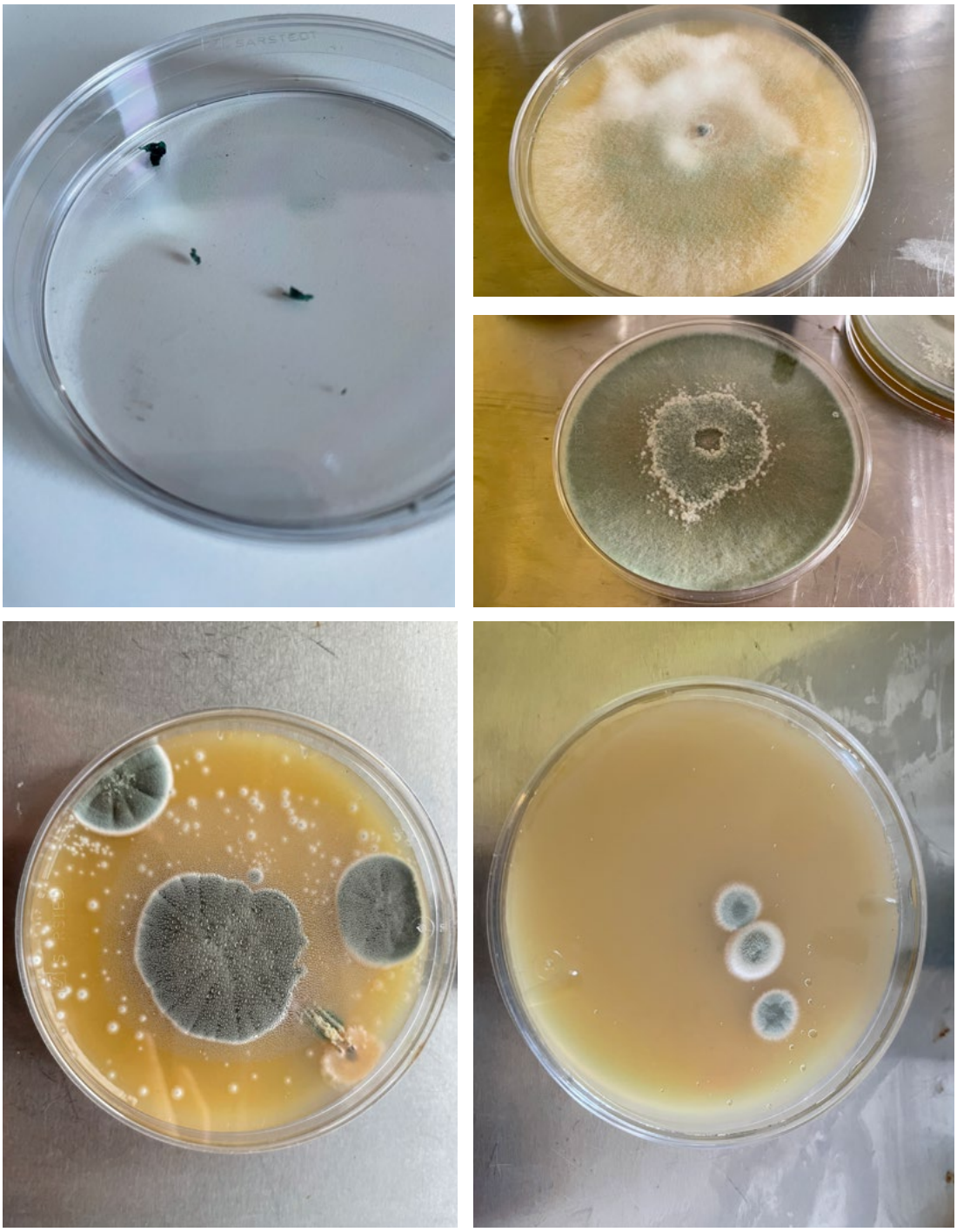


Figure 1.76 Contaminated Petri dishes.

Figure 1.77 Cultivating already isolated fungi.

Figure 1.78 Cultivated Green Elfcup.

Evaluation

Isolating this fungus proved significantly more challenging compared to bacteria, with contamination being a constant issue. Combined with the long cultivation time of approximately 40 days, isolating the fungus was too demanding for this project.

Purchasing pre-isolated fungi was a practical solution for this project, but it detracted from the narrative of sourcing the fungus locally, isolating it, cultivating it, and using it to colour local products.

Despite these challenges, it was possible to grow pigment for textile application from the fungus using the laboratory equipment available. However, further work is needed to refine the process and extract the pigment. Methods described in **DIA 9** could be applied to improve the process.

DIA 22: PHA cultivation and extraction

DIA 22

Time period: June to November 2022

Location: DIY Biolab, DSKD

Motivation: Producing PHA from bacteria

Summary

In Figure 1.79, the process of cultivating PHA-producing bacteria on Petri dishes is shown. The bacteria were received in a glass tube, which was broken to spread the bacteria onto multiple Petri dishes for cultivation. The PHA-producing bacteria were grown using a standardised bacterial medium (Nutrient Broth).

In Figure 1.80, the process of cultivating PHA in shake flasks is illustrated. Some of the cultivated PHA-producing bacteria from the Petri dishes were transferred into shake flasks containing liquid media to achieve a potentially larger yield.

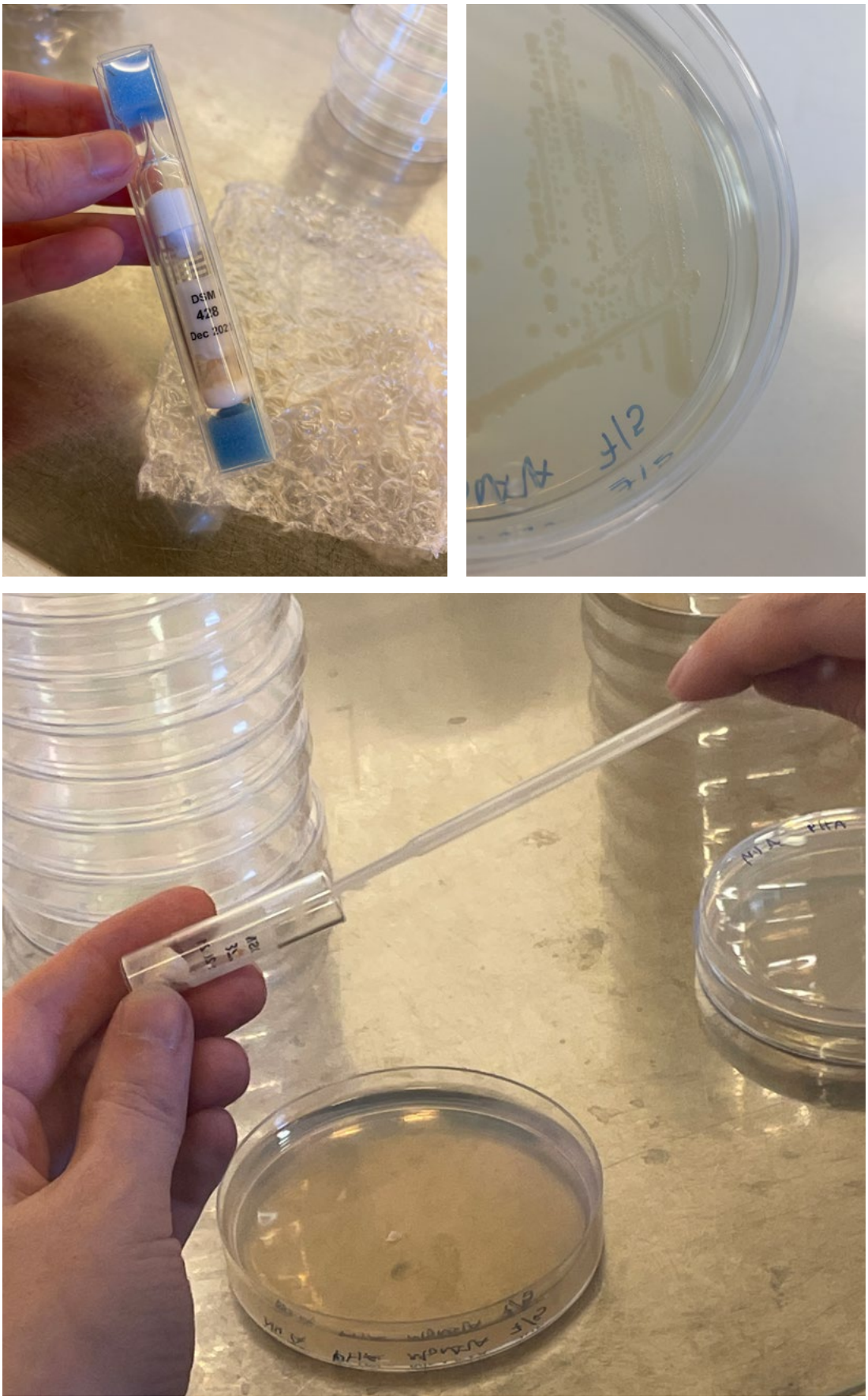


Figure 1.79 Cultivating PHA producing bacteria on Petri dishes.

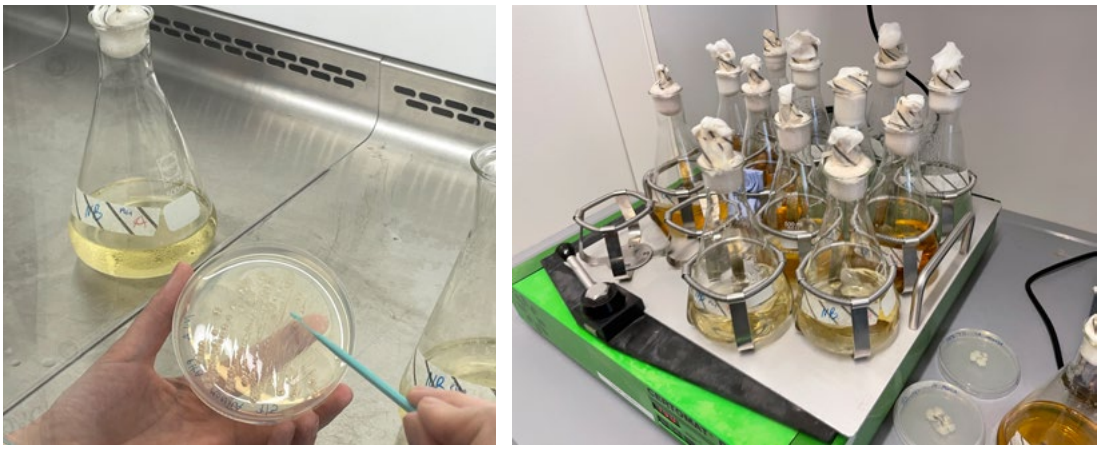


Figure 1.80 Cultivating PHA from Petri dishes in shake flasks.

The contents of the cultivated shake flasks were then transferred into falcon tubes, where acetone was added, and the mixture was centrifuged. The liquid was carefully extracted, leaving behind the solids, which contained the extracted PHA. This process is shown in Figure 1.81.

Finally, the contents of the falcon tubes were dried to remove any excess acetone. The remaining dried PHA is shown in Figure 1.82.

Figure 1.81 Extraction of PHA.

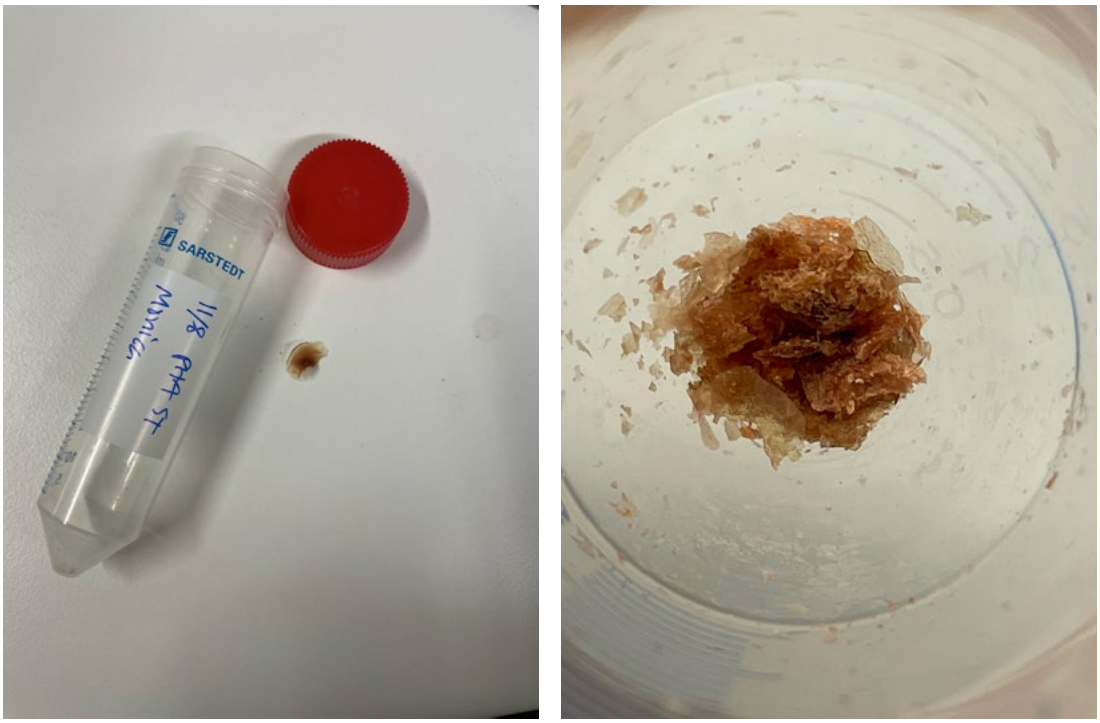


Figure 1.82 Result of Isolating and drying PHA.

Evaluation

The PHA produced by the bacteria is not visible, making it challenging to confirm whether PHA has been successfully produced. Further testing is required to verify its production.

The approach used to purify and isolate the PHA proved difficult. The resulting PHA contained many impurities, which made it brittle and brown. This highlights the need for refining the purification process to improve the quality of the extracted PHA.

DIA 23: Bacterial colouring workshops

DIA 23

Time period: August to September 2022

Location: Design School Kolding

Motivation: Introducing a large amount of students to the DIY Biolab

Summary
After establishing the DIY Biolab, I noticed that students did not independently start cultivating microorganisms. However, I was aware of their interest, as several students had previously engaged in fungi cultivation and growing mycelium composite materials before the biolab was set up.

To educate students about bacterial colouring and encourage their participation, I developed a bacterial colouring workshop. I applied for and received funding to hire an assistant to help conduct and prepare the workshop. The workshop format was inspired by methods used at Waag and CSM for teaching bacterial colouring, as described in **DIA 2**.

Given the limited equipment available—similar to what I had used in my own experiments—I kept this in mind while planning the workshop. Additionally, implementing the workshop in a school with no prior foundation for bacterial colouring presented a unique challenge compared to the experiences of the experts I interviewed. To address this, I included a mix of theory and practice to create a shared foundation for the students to learn from.

The bacterial colouring workshops consisted of three parts, which built on each other, as shown in Figure 1.83. Photos of the workshop in progress can be seen in Figure 1.84, Figure 1.85 and Figure 1.86.

To accommodate more students, I moved the equipment from the DIY Biolab to a temporary larger location, allowing me to induct more participants simultaneously. Figure 1.87 illustrates how the knowledge from the workshops was shared.

We presented insights from the workshops at the EKSIG conference, “From Abstractness to Concreteness - Experiential Knowledge and the Role of Prototypes in Design Research”, organised by the special interest group exploring experiential knowledge from the Design Research Society. The conference was held at Politecnico di Milano in June 2023 (Hartvigsen et al., 2023).

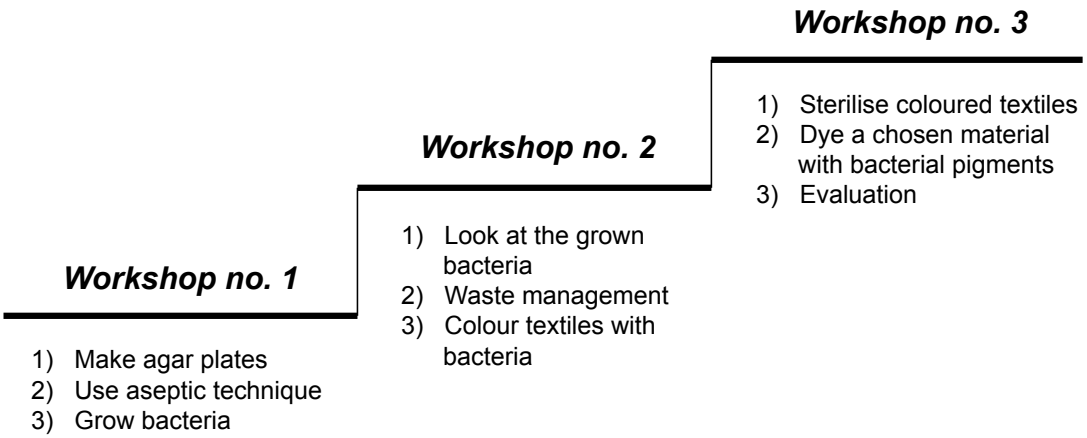


Figure 1.83 The 3 parts of the workshop, spread over three weeks.

After the workshops, 12 students completed an evaluation form, answering the following questions:

- How would you evaluate the workshops?
  1 = boring and useless, 5 = interesting and inspiring.
- How would you describe the experience of participating in the workshops?
- Was there one of the workshops that were your favourite?
- What was hard/difficult? And what was easy? E.g., waste management, media preparation, sterilizing.
- What about the design that came out of it? Do you have any thoughts about that?
- Is there anything you would like to have had more or less of?
- Do you have any suggestions to improve the workshops?
- Have you gained new knowledge, methods or ways of thinking from the workshop?

- Could you imagine working in the biodesign field (growing materials) in the future?
- Would you like to participate in similar workshops i.e. growing kombucha or mycelium?

Figure 1.84 Workshop 1 introducing design students to bacteria cultivation.

Figure 1.85 Workshop 2 introducing bacterial inoculation.

Figure 1.86 Workshop 3 using bacterial colour for conventional dyeing and evaluation the three workshops.

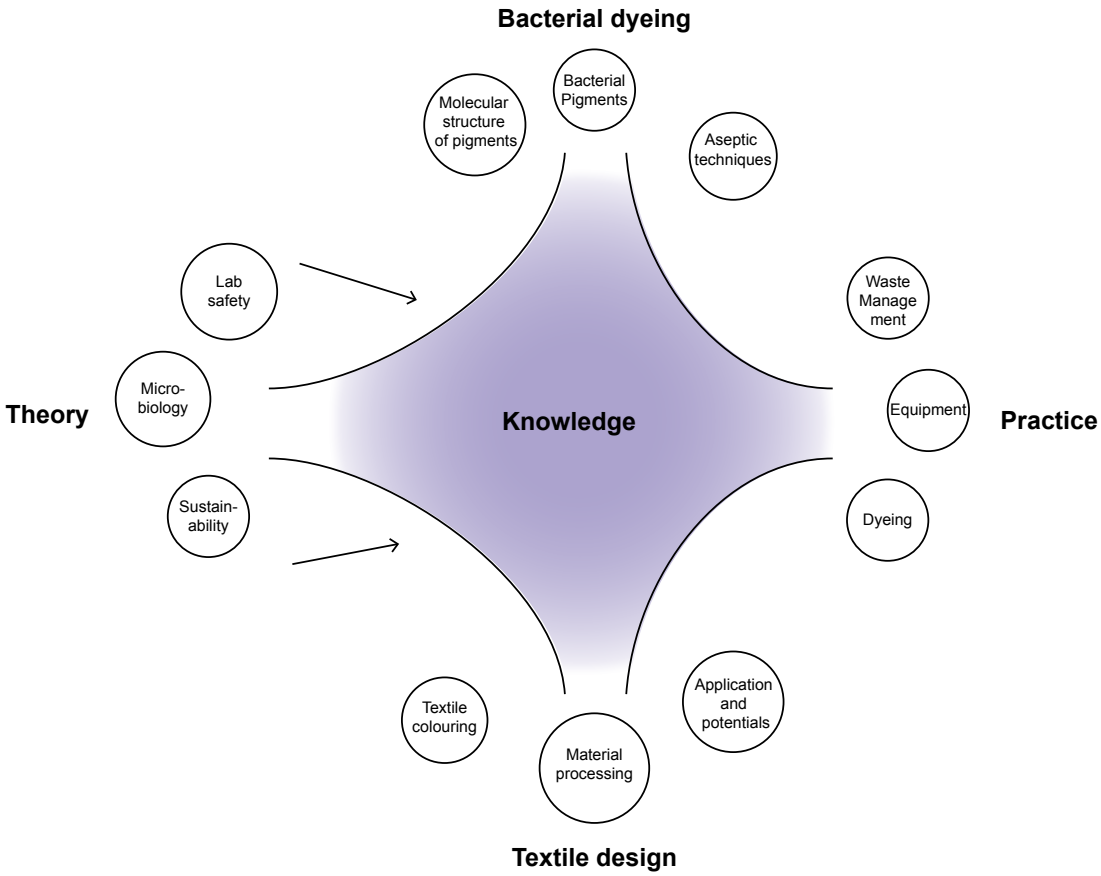


Figure 1.87 Diagram showing how the knowledge was provided for the bacterial dyeing workshops.

Evaluation

The workshop generated significant interest, leading me to conduct two separate sets of workshops, with many more students expressing interest. This demonstrates a strong enthusiasm for bacterial colouring among design students at DSKD.

The students who attended the workshops, and fillet the evaluation form, reported that they enjoyed the experience, found it fun, and learned a lot. They expressed curiosity to explore more.

The workshops provided students with both laboratory knowledge and experiential knowledge. By integrating design elements into the workshop, I made the content more approachable and relatable for the students. Overall, the workshops proved to be an effective method for introducing bacterial colouring to students at DSKD.

A total of 14 students participated including seven textile design students, three fashion design students, three industrial design students, and one communication design student.

DIA 24: Workshop at Klimafolkemødet

DIA 24

Time period: September 2022

Location: Klimafolkemødet Middelfart

Motivation: Making the attendees at the workshop connect with the hidden organisms in the soil

Summary

Louise Permiin and I conducted a speculative drawing workshop at Klimafolkemødet 2022 (translated as “People’s Climate Meeting”). The workshop invited attendees to draw the hidden organisms they imagined living in the soil and to conclude the session by giving their drawings back to the soil, reflecting on this symbolic action.

Before the workshop, we explored ways to connect with nature through a practical, hands-on approach, focusing on the soil as a natural element. This exploration inspired us to develop a more sensuous approach to engaging with the living species in the soil. We aimed to transform our initial curiosity into a workshop that combined speculative thinking with practical elements, fostering a connection with the surrounding nature.

Together, we designed a workshop where visitors speculated on the organisms living in the soil through a drawing exercise. The workshop took place in a tent with round tables and chairs, and we were allocated one hour on 2nd September, from 17:00 to 18:00.

We prepared soil pigments, A3 drawing paper, and pencils. To inspire participants, we created posters showcasing different soil types and possible organisms living in the soil, helping to create an engaging atmosphere. As the workshop was open, visitors could stop by, participate, and leave as they wished.

In total, nine visitors participated, representing a variety of backgrounds and ages: three design students, an anthropologist, an IT technician, two pensioners, a child, and his mother. Participants were asked to draw the organisms they imagined lived in the soil and reflect on the nature around them. They were given ten minutes to draw and speculate. During this time, Louise and I walked around the tables, discussing the drawings and the participants' reflections.

Participants with non-design backgrounds were initially hesitant to start, but conversations about soil organisms and inspiration from the posters helped them engage. Some participants focused on a single species, while others drew as many organisms as they could imagine.

The IT technician shared how the drawing exercise helped him connect with the nature he encounters daily. The design students described the workshop as a "ritual" that brought attention to the soil and encouraged reflection on unfamiliar species. One student noted that designers are often taught to ask questions and explore the unknown, and this exercise provided a valuable opportunity to shift perspective—looking below the soil rather than focusing on what is above it.

The workshop fostered dialogue about the organisms present in the soil. It also highlighted how drawing and engaging multiple senses can enable freer expression and facilitate both verbal (intangible) and physical (tangible) interactions.

After speculating on the organisms, participants were asked to bury or "give back" their drawings to the soil and reflect on this act. This process sparked further discussions about their thoughts on giving back to nature.

We left the remains of the workshop outside the tent as a small exhibition to observe how other visitors at Klimafolkemødet would respond. Several visitors inquired about the workshop and the containers, leading to conversations about soil and organisms. This visual communication tool extended the workshop's impact beyond the initial attendees.

Notes from Middelfart

Participants:
Three second-year Planet students, one IT technician, an anthropologist from the University of Copenhagen, a young boy with his mother, and two elderly women.

Students:
One student chose to write a love letter to mycelium. She appreciated how the workshop evolved from a memory to an awareness of the earth, culminating in letter-writing and a ritual.
Another student found the workshop to be a meaningful exercise that fostered focus on the unknown. She valued the opportunity to take time to reflect on something specific.
The third student remarked that, as designers, they excel at asking questions and exploring the unknown. She was captivated by the shift in perspective—wondering more about what lies above the soil rather than what is within it. She noted that we are accustomed to looking upwards but rarely downwards. Designers, she argued, are adept at uncovering the invisible, offering a unique approach to the world.

IT Technician:
He described his daily cycling commute and the speed at which he passes through nature. He reflected on the connection between this experience and his work. During the workshop, he became aware of microorganisms and wrote them a message, expressing regret for having overlooked their importance for so long. He acknowledged their vital role in soil health and permaculture. He appreciated the creative aspect of the workshop, which allowed him to convey his theoretical knowledge in a new way.

Anthropologist:
She expressed interest in tactile approaches to exploring life within the soil. She was particularly intrigued by the idea of recording the sounds of the earth and mentioned some students and a course that focused on this topic. (No further details were noted.)

Young Boy and His Mother:
After being encouraged to enter the tent, the boy was asked to imagine a place in nature that he found exciting or comforting. He looked at a poster and, after observing the sand, exclaimed, “The desert!” He described darkling beetles in the desert and a snake eating them, as well as a sandstorm. This metaphor resonated with the desert environment. He also created a charcoal drawing.

Elderly Women
The women were initially present for the next presentation but were encouraged to participate. Despite initial resistance—”We can’t draw” and “We don’t know what lives in the soil”—they eventually engaged. They proved capable of drawing and

demonstrated knowledge of various soil-dwelling organisms. They appreciated the concept of the workshop and expressed that it was effective.

General Observations:
The workshop facilitated meaningful conversations around the tables, with participants showing enthusiasm and openness to the ideas presented.
It successfully fostered dialogue about the organisms living in the soil. The act of drawing seemed to encourage freer conversation, as participants engaged multiple senses to focus on the same issue.
The subsequent exhibition attracted attention, with several people stopping to ask about it. It served as a conversation starter and a visual communication tool.

Reflections:
The workshop was well-received but held at an inconvenient time—just before dinner, during a transitional period at the festival, which resulted in fewer participants.
Despite the low turnout, the participants were engaged and brought positive energy, supported by Monica (and Louise).
It may be worth reaching out to individuals who saw the exhibition in Kolding to gather their feedback.

Additional Notes from Middelfart:

Two Elderly Women:
Initially hesitant, saying, “We can’t draw” and “We don’t know what lives in the soil”.
With encouragement, they began drawing and demonstrated knowledge of various soil organisms.
They understood the purpose of the workshop and felt it was effective.

General Feedback:
The workshop encouraged dialogue about soil-dwelling organisms.
Drawing seemed to facilitate freer conversation, as participants engaged multiple senses to address the same topic.
The exhibition that followed attracted attention, sparking curiosity and conversations.

Suggestions:
Consider reaching out to individuals who viewed the exhibition in Kolding to gather their impressions.

Photos from the workshop can be seen in Figure 1.88.

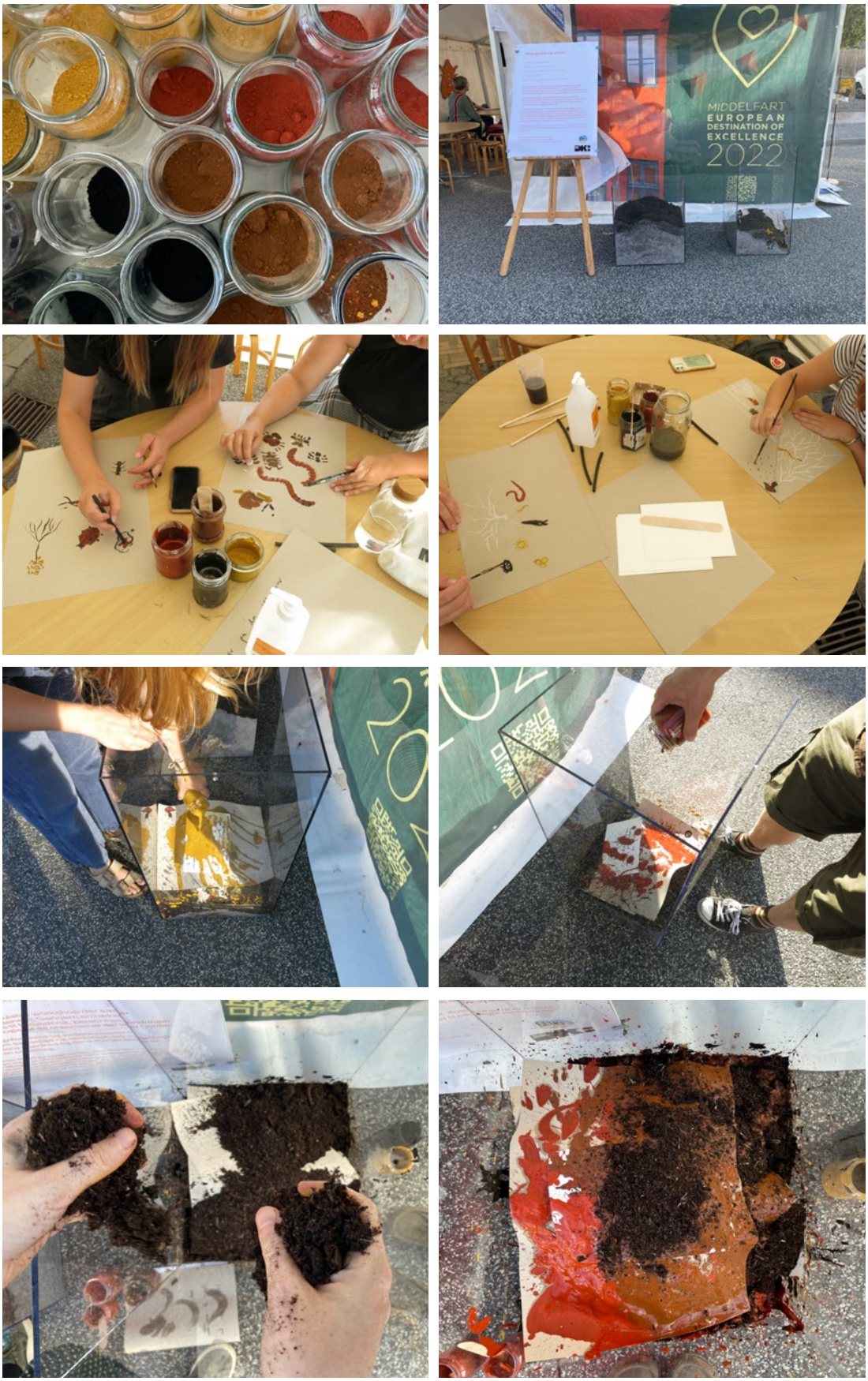


Figure 1.88 Workshop exploring inhabitants in our soil. Photo credit: Louise Permiin.

Evaluation

Some attendees hesitated at the start of the workshop, likely due to the abstract nature of the task. However, the hands-on activity of drawing helped them engage, and sitting in groups allowed them to inspire one another.

The workshop successfully prompted thoughtful reflections from the participants, achieving its intended purpose. It served as a way to reconnect with nature, even if the workshop or exhibition itself may not directly change how we design or interact with nature. Instead, the experience might inspire designers to reflect on the resources they use and the ecosystems they are part of.

Training one aspect of design practice, such as a speculative approach using the senses, can influence other forms of design practice. For example, product creation can be shaped by the thoughts we carry and our connection to nature, influencing the approaches we choose and the materials we use.

DIA 25: DSKD exhibition

DIA 25

Time period: 2nd of September to 18th of October 2022

Location: Design School Kolding

Motivation: Extending the intent of the workshop to more students

Summary

After observing how the transparent containers and posters effectively communicated the workshop's purpose at Klimafolkemødet, we decided to bring the workshop materials back to Design School Kolding (DSKD). We created an exhibition in the school's canteen, displaying posters that described our research project and explorations, alongside the soil and drawings of the imagined soil inhabitants in two transparent containers. This setup is shown in Figure 1.89.
Our aim was to transfer the questions raised during the drawing workshop at Klimafolkemødet to the design students at DSKD. We hoped to spark discussions among the students about the organisms living in the soil and encourage conversations about design practices and how we use the resources around us.

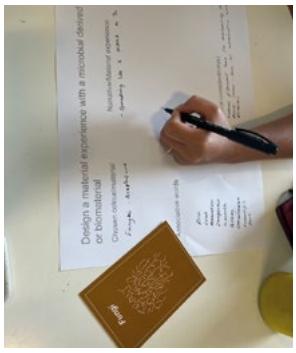
To complete our speculative collaboration, we returned the exhibition materials to the soil by composting them. Since the school has a small gardening area, we used this space to replenish the soil with the materials from our exhibition, as shown in Figure 1.89.

Evaluation

The students engaged with the exhibition and responded positively to it. Transforming the results of the workshop into a gallery-style exhibition extended the reach of the workshop's intent. It encouraged awareness of the organisms hidden in the soil and prompted reflection on their presence and significance.

Figure 1.89 Exhibition after the workshop and giving our explorations back to the soil. Photo credit: Louise Permiin.

DIA 26: BioCard workshop



DIA 26

Time period: September 2022

Location: Design School Kolding

Motivation: Creating a tool for introducing biomaterials

Summary

As part of teaching the first-year course Material Narratives to approximately 30 first-year postgraduate Design for Planet students, I engaged them in an workshop exploring biomaterials produced by microorganisms. For this, I used a tool I developed called BioCards (the full tool can be found in Appendix 4).

The BioCards tool provides inspiration by introducing one aspect of the biomaterials world per card. By drawing cards at random, each group is encouraged to reflect on and relate to a potentially unfamiliar microorganism.

Each group was given a random BioCard featuring a biomaterial, along with a paper containing reflective tasks. The goal was for the students to create a material experience based on the biomaterial described on their card.

Once the exercise was completed, the groups presented their material experiences to one another, followed by an open discussion about the materials and the exercise. Photos from the workshop are shown in Figure 1.90.

Figure 1.90 Workshop exploring cultivated colours or materials.

Evaluation

The students expressed a desire for more information about the biomaterials before creating their material experiences or more time to research the materials independently. However, they were generally interested in the introduction to the different biomaterials.

The material experiences presented by the students ranged from speculative to realistic.

Reflecting on and discussing biomaterials proved challenging for the students, as they had no prior knowledge of the subject. However, the words they associated with the biomaterials were particularly interesting and provided valuable insights.

DIA 27: Workshop postgraduate Planet students

DIA 27

Time period: October 2022

Location: Design School Kolding

Motivation: Making the Sensuous Tool better, and helping the students evaluate materials

Summary

Based on feedback from the first workshop with the sensorial wheels in **DIA 15**, I added a reference material to the wheel templates. The updated templates are shown in Figure 1.91. I then conducted a workshop with approximately 30 first-year postgraduate Design for Planet students as part of the first-year course Material Narratives, focusing on exploring the qualities of textiles.

The students worked in groups and were asked to select two textile materials: one for evaluation and another as a reference. Using the wheels, they evaluated the qualities of their chosen materials. After completing their evaluations, the filled-out wheels were placed next to each other to provide a direct visual comparison of the values assigned to the materials. This setup supported group reflections and discussions. Photos of the completed wheels and the workshop process can be seen in Figure 1.92.

The final version of the tool is included in Appendix 4

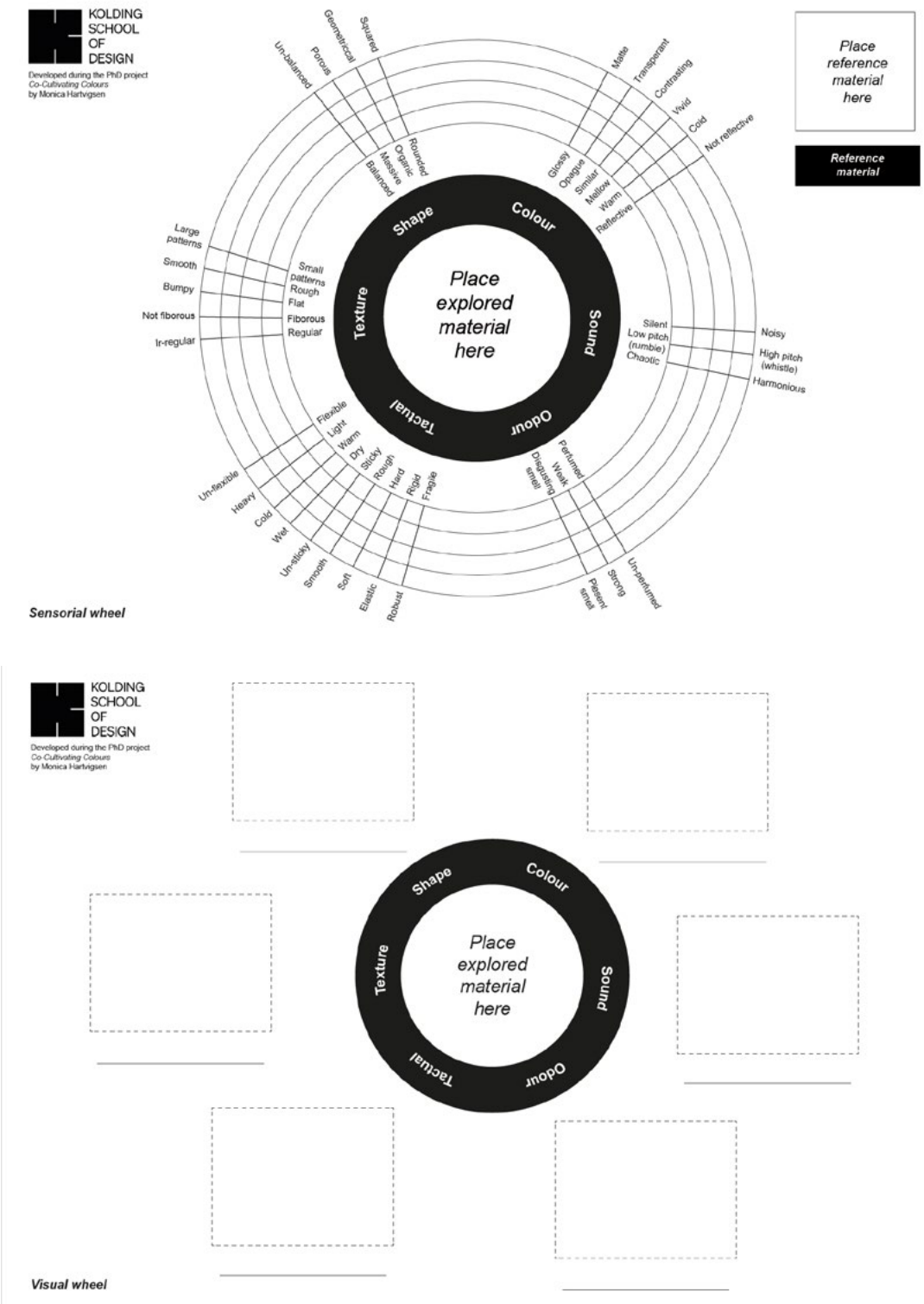
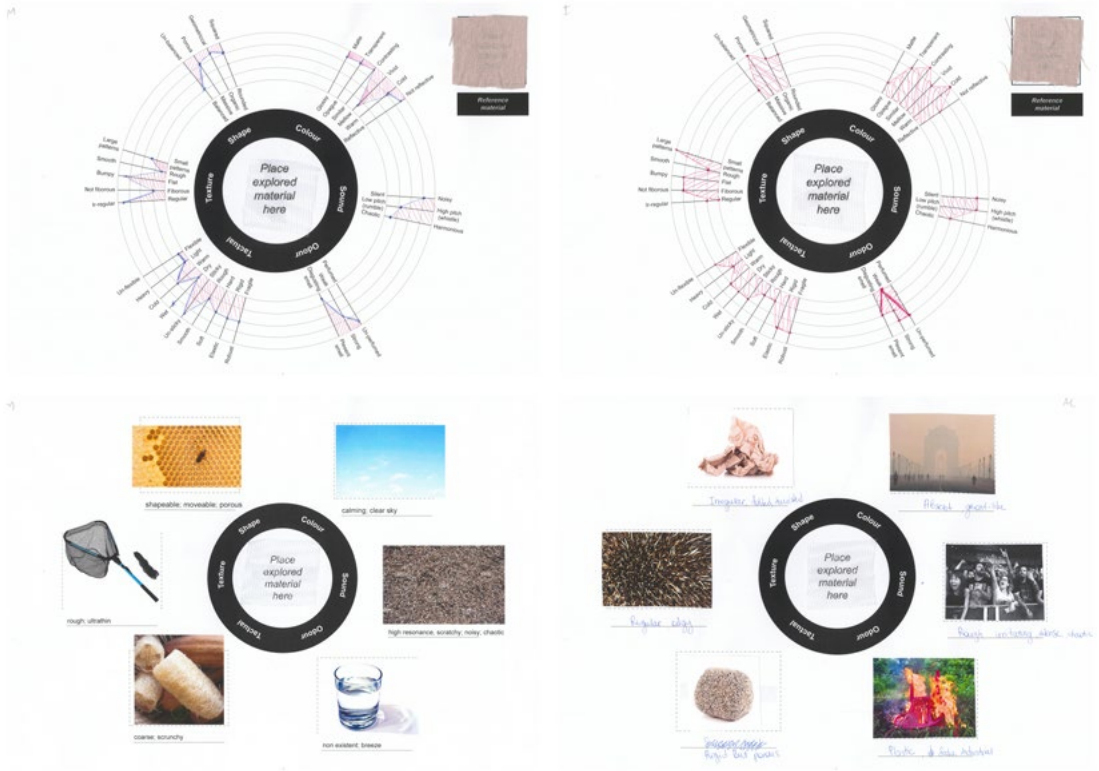


Figure 1.91 Templates for the sensorial wheel (top) and the visual wheel (bottom).



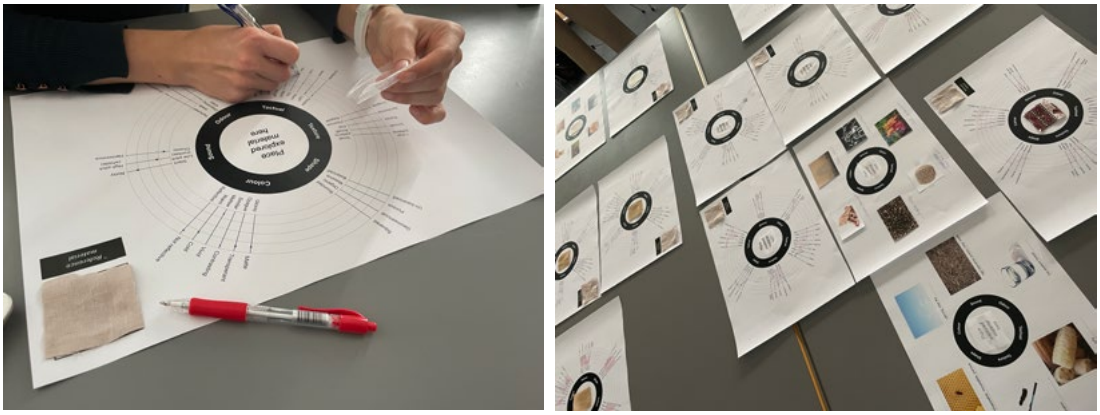


Figure 1.92 Filled out examples of the sensorial wheel and the visual wheel from the workshop.

Evaluation

The students found the tool useful for reflecting on the qualities of a material and recognised its potential. They described it as easy to use, quick to fill out, and interesting to engage with. Some students were so inspired by the tool that they used the template in their own projects outside of the workshop, applying it to biomaterials they had developed.

The addition of the reference material proved effective in guiding the comparison and evaluation of the materials, enhancing the overall utility of the tool.

DIA 28: Visit Borås

DIA 28

Time period: October 2022

Location: The Swedish School of Textiles, Borås

Motivation: Learning more about the potential of using advanced dying techniques, to potentially increase lightfastness of bacterial dyed textiles

Summary

I visited Borås to meet the Vincent N. group and explore their supercritical CO_2 dyeing machine. During the visit, I also attended a meeting with Kvadrat at the “Textilmässe” in Borås. At the event, I gained insights into other advanced industrial dyeing technologies, such as Imogo’s spray dyeing demonstration. Photos from the visit are shown in Figure 1.93 .

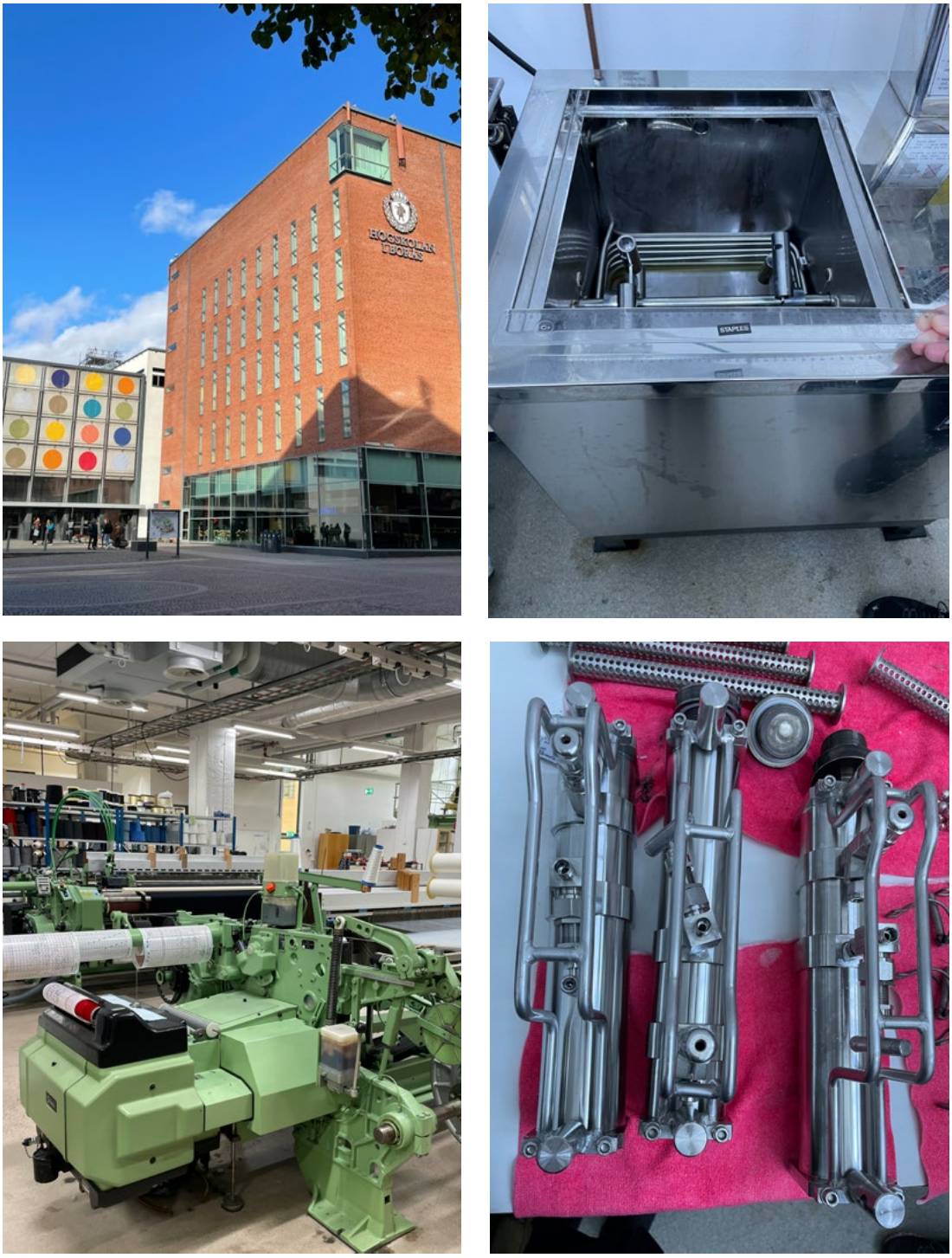


Figure 1.93 Vincent N. Group building (Top left), their industrial machine hall (Bottom left) and their supercritical CO_2 dyeing machine and equipment (Top right and bottom right).

Evaluation

Kvadrat expressed more interest in fibre spinning rather than CO_2 dyeing.

While testing advanced dyeing technologies could be intriguing, most of these methods require a larger quantity of pigment, which presents a challenge.

DIA 29: Chromologics Red

DIA 29

Time period: October 2022

Location: Aarhus University, Department for Biochemical Engineering

Motivation: Testing an established fungi pigment, and its application possibilities on textiles

Summary

Chromologics provided me with a sample of their Chromologics Red pigment, produced from fungi. I tested the pigment on wool, cotton, polyester, and silk textiles to observe its visual effect. As the focus of this experiment was not on technical properties, no mordants were used.

The textiles were weighted and 2% wof (weight of fabric) of pigment was added to 800 ml water. A heating plate was used to boil the water and textiles to see if the pigment could colour the textiles. After 1 hour of boiling the textiles were washed with water and dried.

Figure 1.94 shows an in-progress photo of the colouring process, and the results can be seen in Figure 1.95.

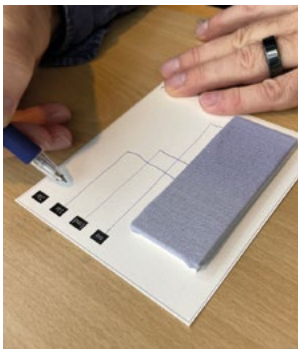
Figure 1.94 Colouring different textiles with Chromologics Red.

Figure 1.95 Result of dying different wool textiles with Chromologics Red.

Evaluation

The textiles displayed a beautiful range of colours, with many vibrant and visually interesting variations.

DIA 30: Biocolour speculative workshop



DIA 30

Time period: November 2022

Location: Design School Kolding

Motivation: Using a speculative and sensuous approach to get insights on bacteria coloured textiles from SMEs

Summary

Building on the speculative and sensuous approach Louise and I used to explore organisms in the soil (see **DIA 8**), we were inspired to apply a similar method to engage small to medium-sized enterprises (SMEs) in a dialogue about the current colouring ecosystem. Insights from this workshop were presented at the PLATE conference in May 2024 at Aalto University in Helsinki (Hartvigsen & Permiin, 2023).

The workshop participants included three representatives from smaller Danish companies within the textile sector and one representative from a Danish university college. An overview of the participants is provided in Table 1.5:

Participants	Company	Product(s)
Participant 1	VIA University College	Design education
Participant 2	Amoode	Women's Clothing
Participant 3	Margit K	Scarfs
Participant 4	TinyCozyStore DK	Textiles for bath interior

Table 1.5 Overview of participants

Including the university college participant was relevant, as the school educates textile designers in close collaboration with the Danish textile and lifestyle sector.

In the preliminary part of the workshop, participants were asked to map the current lifetime system of a coloured product from their company. This involved describing

the materials or resources used to create the product, the colouring method applied, and what happened to the product at the end of its use.

In the next part of the workshop, participants were asked to reflect on their tolerance for colour fading in their products over time. Using a faded biocolour sample, they indicated how much colour fade they could accept within specific timeframes: Now, 1 month, 1 year, and 2 years. This exercise was supported by a visual scale, and Figure 1.96 (middle left) shows a participant filling out the scale by drawing lines from the time spans to the level of fade they found acceptable

Figure 1.96 Workshop for SMC's about biocolours and acceptance of fading.

The final part of the workshop invited participants to imagine a future world where only biobased colours exist, meaning all colours would fade over time. To guide this speculative exercise, we prepared a timeline spanning from 2022 to 2052, which is displayed in Figure 1.97.

Figure 1.97 Workshop for SMC's about biocolours and acceptance of fading and future scenarios.

After the workshop, Louise and I reflected on our experiences as facilitators and discussed how the participants engaged with the activities. We noted that there is a need for support and education when collaborating with SMEs, as the participants

arrived with little to no prior knowledge about biocolours. Providing knowledge to the industry is essential to enable them to work with and accept biocolours.

Evaluation

The SMEs expressed interest in biocolours but expected better light fastness results than what is currently achievable. They are not yet ready to accept the level of fade that biocolours currently exhibit and anticipate a technical solution to improve light fastness. Despite this, the workshop was effective in gathering insights and fostering dialogue, as the participants provided honest input about their expectations and industry knowledge.

The current status of bacterial colour fastness is still far from meeting the requirements of the SMEs, and they did not see it as a viable option in the near future. However, they did not express any concerns about the fact that the colours were produced by bacteria.

The workshop highlighted the importance of working with the industry and providing education about biocolours. Building knowledge and fostering collaboration with SMEs is crucial to changing how biocolours are perceived and used.

DIA 31: Fibre spinning

DIA 31

Time period: November 2022 to February 2023

Location: Aarhus University, Department for Biochemical Engineering

Motivation: Wanting to test if it is possible to fibre spin violacein

Summary

I had an in-person discussion with Birgit Bonefeld, who has experience in fibre spinning. During our meeting, I was able to see a fibre spinning machine, and she provided me with relevant literature to read. We also discussed potential mordants for violacein in relation to fibre spinning, aiming to improve its stability.

I conducted a wet-spinning test using violacein pigment and dissolved cellulose (with ionic liquids). To enhance light stability, I incorporated beta-cyclodextrin. The cellulose and pigment were melted together using heat, and after cooling, one sample was exposed to indirect sunlight for three weeks (in January). The process and results are shown in Figure 1.98.

The results were later presented in an online meeting with Kvadrat. A close-up of the results, as presented to Kvadrat, is shown in Figure 1.99.

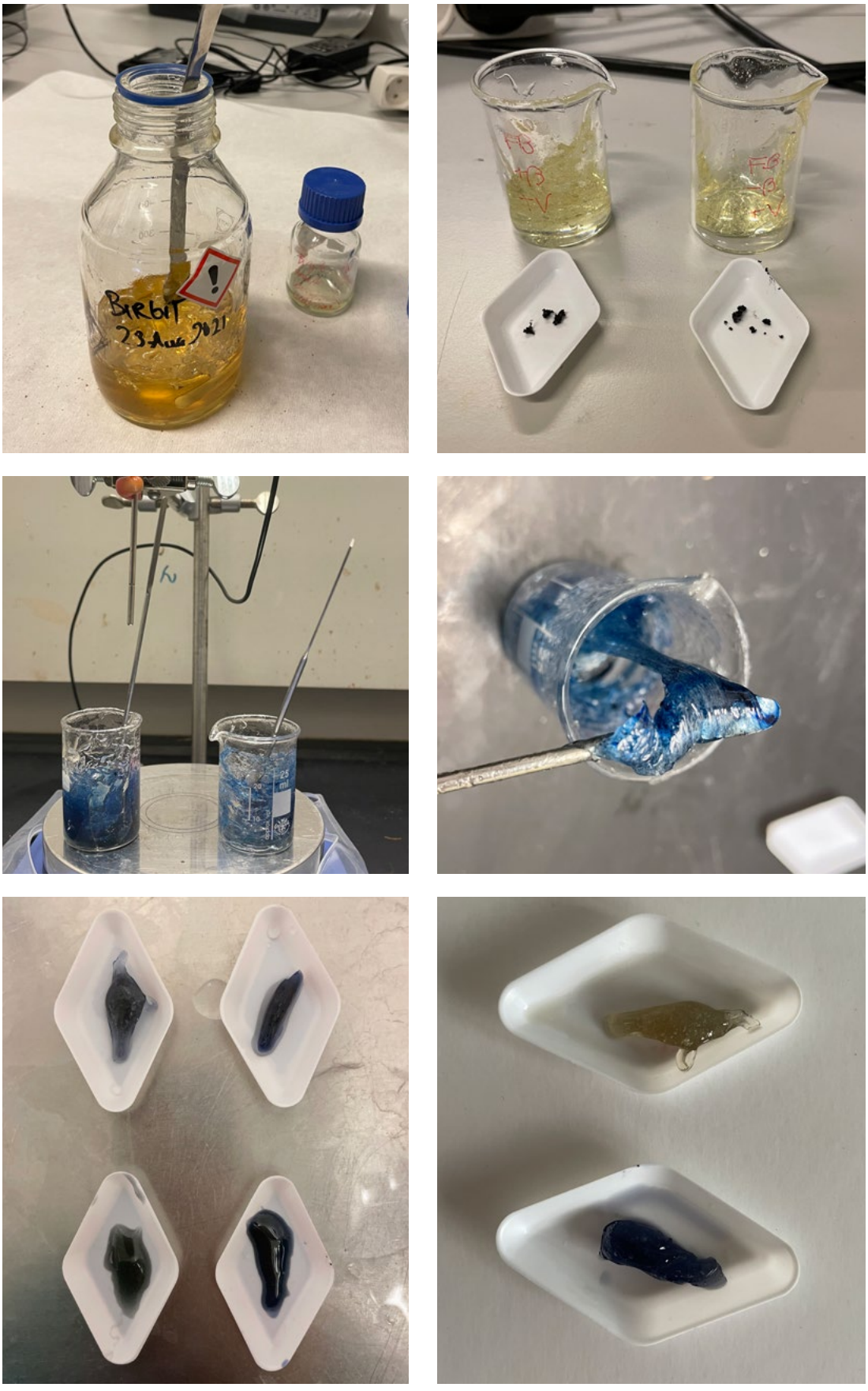


Figure 1.98 Colouring regenerated cellulose with violacein.

Figure 1.99 Closeup of the result of fibre spun violacein.

Evaluation

It is possible to conduct small-scale fibre spinning tests using small syringes before scaling up the process. The test demonstrated that fibre spinning with violacein is feasible. However, the lightfastness did not improve sufficiently to warrant further testing.

Kvadrat found the experiment interesting but saw greater potential in melt-spinning, as this initial test did not significantly enhance lightfastness. Their primary interest lies in polyester melt-spinning and cellulose fibre spinning, with less enthusiasm for other bio-based polymer fibres.

DIA 32: Advisor Bio-Fablab Vejle

DIA 32

Time period: November 2022

Location: BioTechLab, Fablab, Spinderihallerne, Vejle

Motivation: Expanding biolab network and learning from other DIY setups

Summary

I was invited to join the advisory board for establishing a Bio-Fablab at FabLab Spinderihallerne in Vejle. As part of this role, I participated in a series of meetings, both online and on-site, where I provided advice on experiments and explorations involving microbial organisms. My contributions supported the setup of the Bio-Fablab and guided its experimental and exploratory activities. Photos from the FabLab can be seen in Figure 1.100.

Evaluation

Being part of the advisory board facilitated the sharing of networks and knowledge among its members. The Bio-Fablab also adopted workshops as a method for inducting participants, which aligns with similar approaches I have used.

The engagement of others in biolabs that incorporate microbial organisms highlights the growing interest in this concept within Denmark.

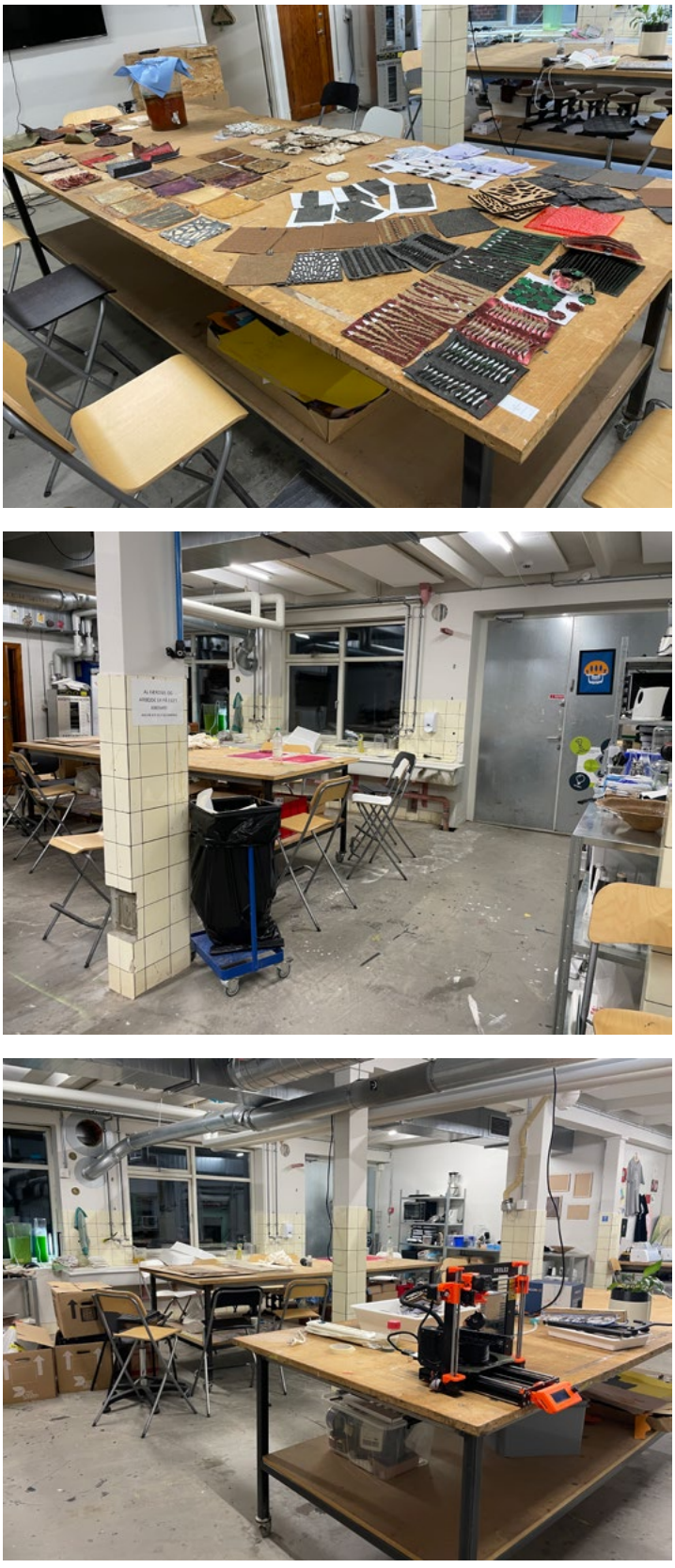
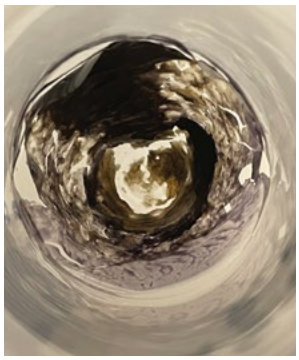


Figure 1.100 Photos of Fablab Vejle.

DIA 33: PHA colouring process



DIA 33

Time period: December 2022

Location: Aarhus University, Department for Biochemical Engineering

Motivation: Testing the possibilities of colouring bacteria produced PHA with bacteria produced pigment, to make an entirely bacteria produced material

Summary

The bacterial PHA remnants from **DIA 22** were coloured with violacein pigment using heat in a water bath. The coloured PHA was then isolated using a centrifuge and left to dry. The process is shown in Figure 1.101, and the result is displayed in Figure 1.102.

Evaluation

It was possible to successfully colour PHA, produced by bacteria, with violacein, which is also a bacterial pigment.

Figure 1.101 Colouring PHA with violacein.

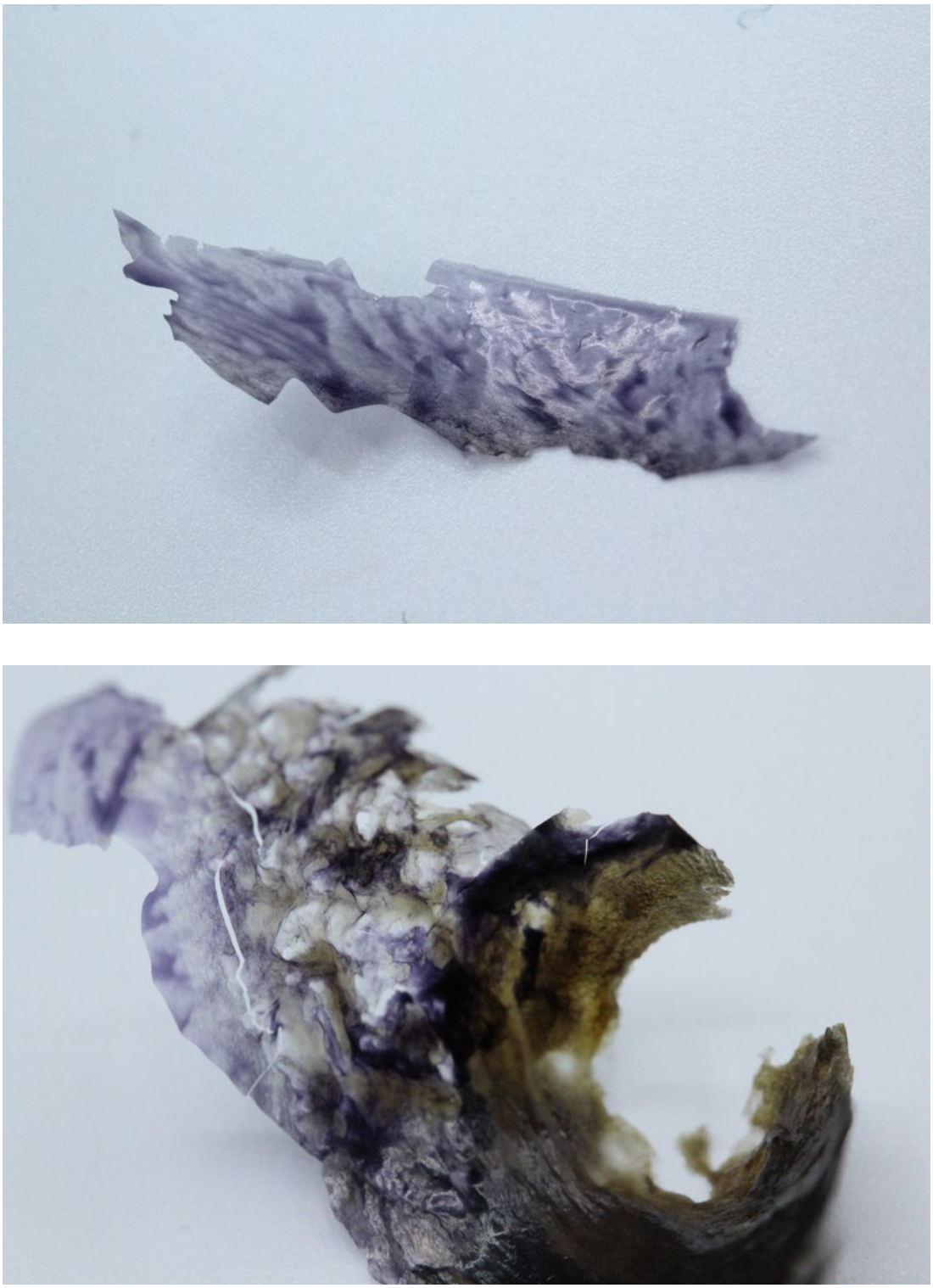


Figure 1.102 PHA coloured violacein.

DIA 34: Green entrepreneur exhibition at DTM

DIA 34

Time period: December 2022 to April 2023

Location: Danish Technical Museum

Motivation: Gaining insights into visitors immediate reactions and thoughts on bacteria coloured textiles

Summary

An interview was conducted by the curators, and a video was recorded at Aarhus University, where I was cultivating bacteria at the time. This was followed by a dialogue about the exhibition and decisions on which samples should be showcased and how bacterial colours should be communicated.

The exhibition “GRØNT IVÆRKSÆTTERI” (translated as Green Entrepreneurs) ran from April 2023 to December 2023. It was part of the larger exhibition “OPFINDELSER – skabertrang og drømme” (translated as Inventions – Creative Urges and Dreams). The exhibition featured three green entrepreneurs at a time, showcasing their work with technologies and products aimed at contributing to a more environmentally friendly planet. In total, nine exhibitors participated, divided into groups of three.

I exhibited alongside Brickcycling, which develops bricks made from recycled bricks and tiles, and Grey Water Solution, which produces systems for recycling household water (Danmarks Tekniske Museum, n.d.). While the exhibition focused on showcasing the technology behind the inventions, I included bacteria dyed textile samples to demonstrate different colouring techniques and the colour mixing potential, illustrated with a colour wheel. My part of the exhibition is shown in Figure 1.103.

At the exhibition's opening, I engaged with visitors, conducting semi-structured interviews of the process of bacterial dyeing and gathering their impressions of the bacteria coloured textiles. Taking notes and audio recording my initial thoughts after the interviews.
The interviews included the following questions:

- What is your opinion on the colour hues presented in this exhibition?
- Would you use products coloured with bacteria colourants?
- Would it be a problem if the colour faded on textiles products?
- Which products could you imagine using bacteria colourants for?
- What is your opinion on the colour hues presented in this exhibition?

Figure 1.103 The exhibition about me and my work with microbial colours in the Danish Technical Museum.

Evaluation

The curators were particularly interested in highlighting the scientific aspects of bacterial pigments, including their environmental benefits, production processes, and the resulting textile samples.

Overall, the visitors were intrigued and curious about the potential of bacterial dyeing. They were especially drawn to the colour wheel, which demonstrated how

some bacterial pigments could be mixed. Many visitors were already aware of the environmental challenges posed by the textile industry, which added relevance to the discussion.

I estimate that the majority of visitors were over 50 years old. Several of them drew comparisons between bacterial dyeing and plant dyeing, with some sharing their own experiences of working with plant dyes. They were surprised by the boldness of the colours produced by bacterial pigments, which they contrasted with their memories of plant dyes as being dull and faded. Some visitors remarked that the vibrant colours of the bacteria dyed textiles resembled synthetic colours.

One visitor commented on the blue-coloured bacterial samples, noting their similarity to denim and raising the question of whether bacterial pigments could be used for such applications. This visitor also expressed concern about lightfastness, as they were aware of lightfastness issues with plant based dyes.

A Finnish consumer study by Yli-Heikkilä et al. (2020) explored consumer associations with synthetic and biocolours, including considerations of the colours' origins. The study found that consumers often associated synthetic colours with the chemical industry, toxicity, and artificiality, while also recognising their intensity and brightness. In contrast, natural colours were associated with ecological benefits, naturalness, and safety for wear, with a preference for plant based sources over insects. However, the study also revealed that consumers were critical of bacterial colour sources for clothing, associating bacteria with poor hygiene and disease, despite their widespread use in food production.

Interestingly, the visitors at the Danish Technical Museum did not express concerns about hygiene or the use of bacteria for textile colouring. This may be attributed to the museum's history of showcasing innovations involving microorganisms, such as Emil Christian Hansen's 1870s cultivation process for Carlsberg beer yeast (Saccharomyces Carlsbergensis). It is likely that the visitors were already familiar with the potential applications of microorganisms and, therefore, more open to the idea of bacterial coloured textiles.

DIA 35: Pre- and post-treatments of violacein coloured textiles

DIA 35

Time period: January 2023

Location: Aarhus University, Department for Biochemical Engineering

Motivation: Finding a mordant for improving lightfastness of violacein

Summary

I pre-treated and post-treated wool, polyester, and cotton textile samples coloured with violacein at 90°C for one hour with 1:10 colour liquid to water ratio, using alum or chitosan at 10% and 20% concentrations. The process is shown in Figure 1.104.

The treated samples were then placed in indirect sunlight for six weeks (in March and April) alongside a blue wool scale to assess light fastness. The results are displayed in Figure 1.105, Figure 1.106 and Figure 1.107, with textiles before exposure shown on the left and after exposure on the right. The blue wool scale is included for comparison.

Evaluation

None of the mordant treatments significantly improved the light fastness of the violacein coloured textiles.

Figure 1.104 Pre- and post-treatments for textiles coloured with violacein.

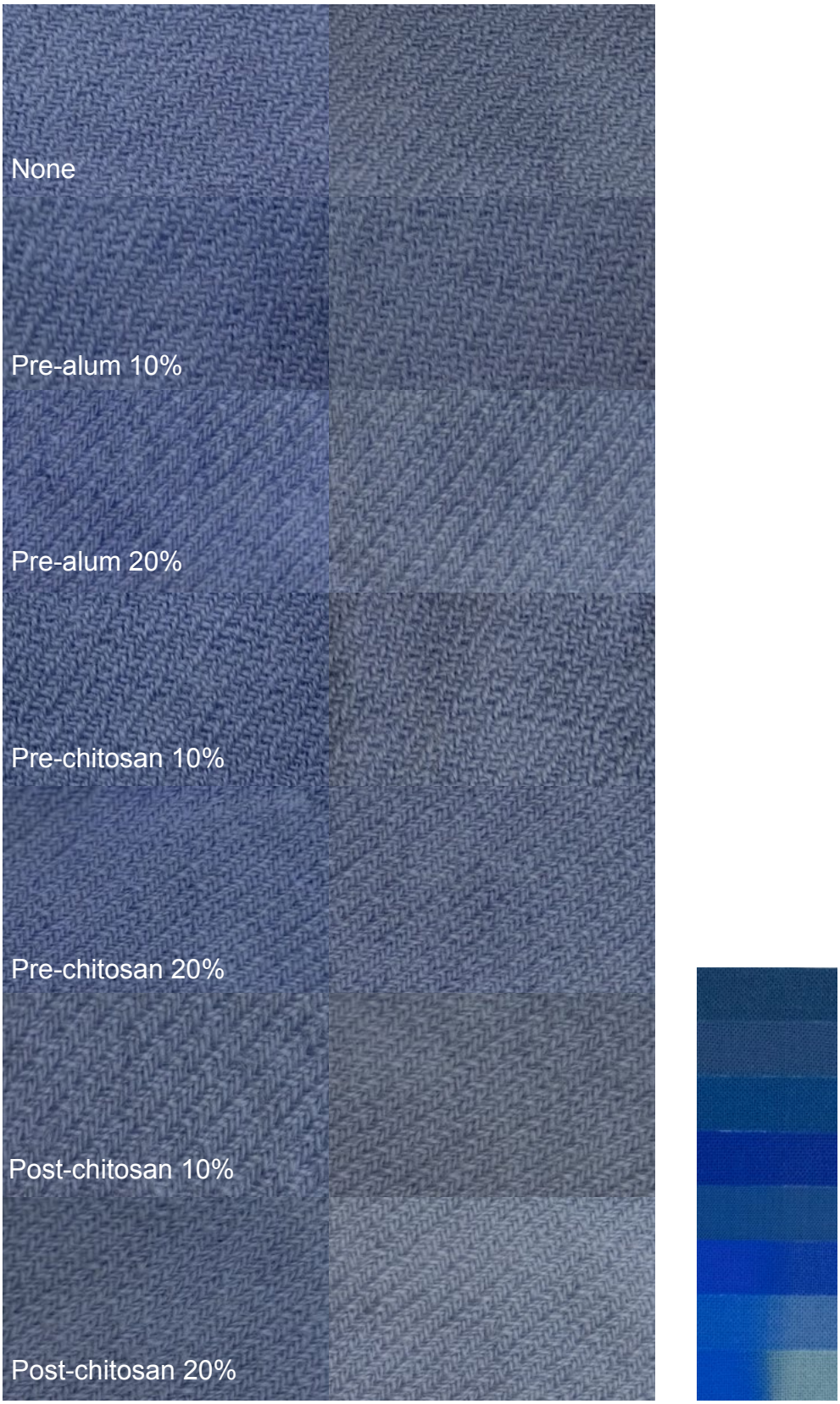


Figure 1.105 Wool coloured with violacein and treated with alum or chitosan tested for colour lightfastness.

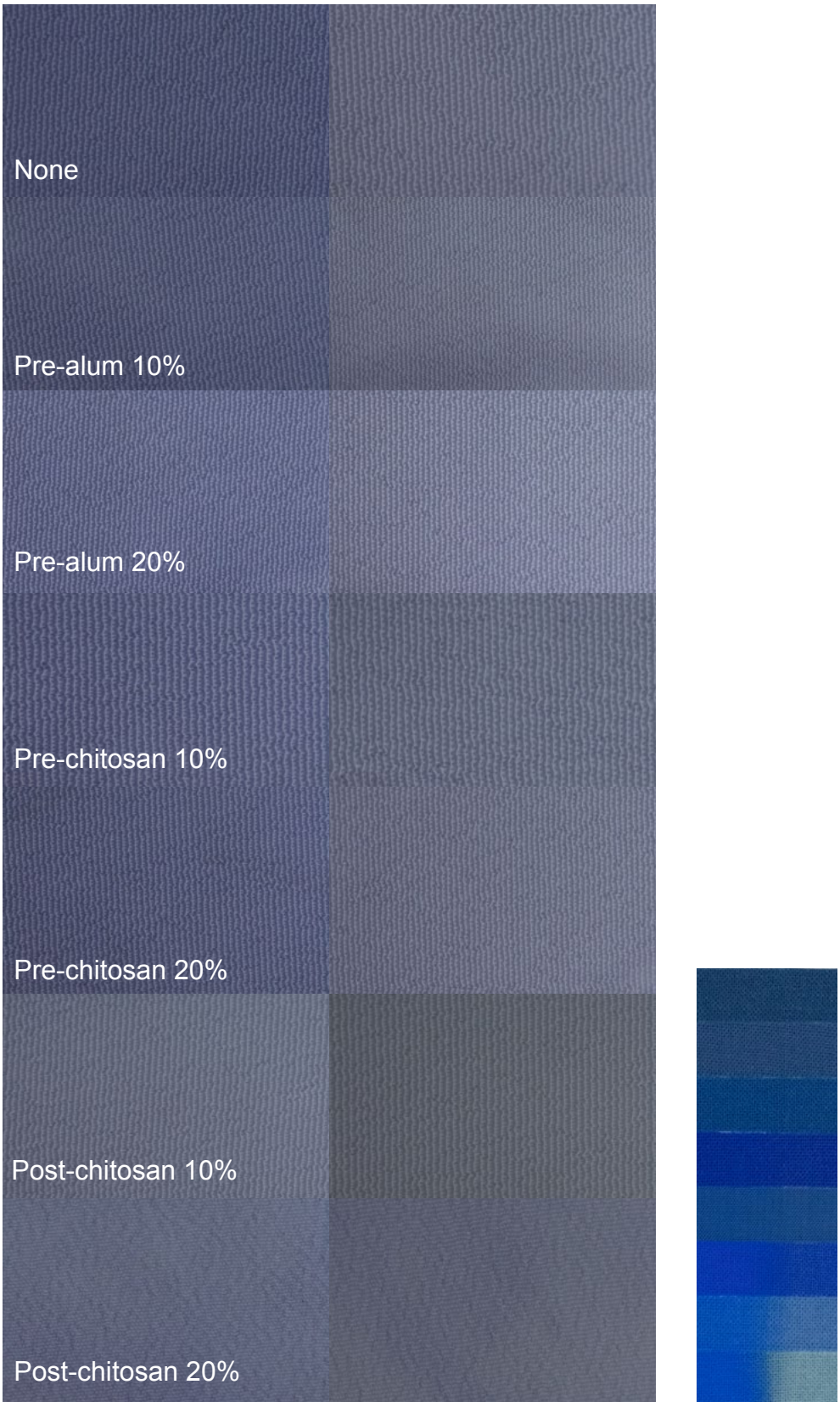


Figure 1.106 Polyester coloured with violacein and treated with alum or chitosan tested for colour lightfastness.

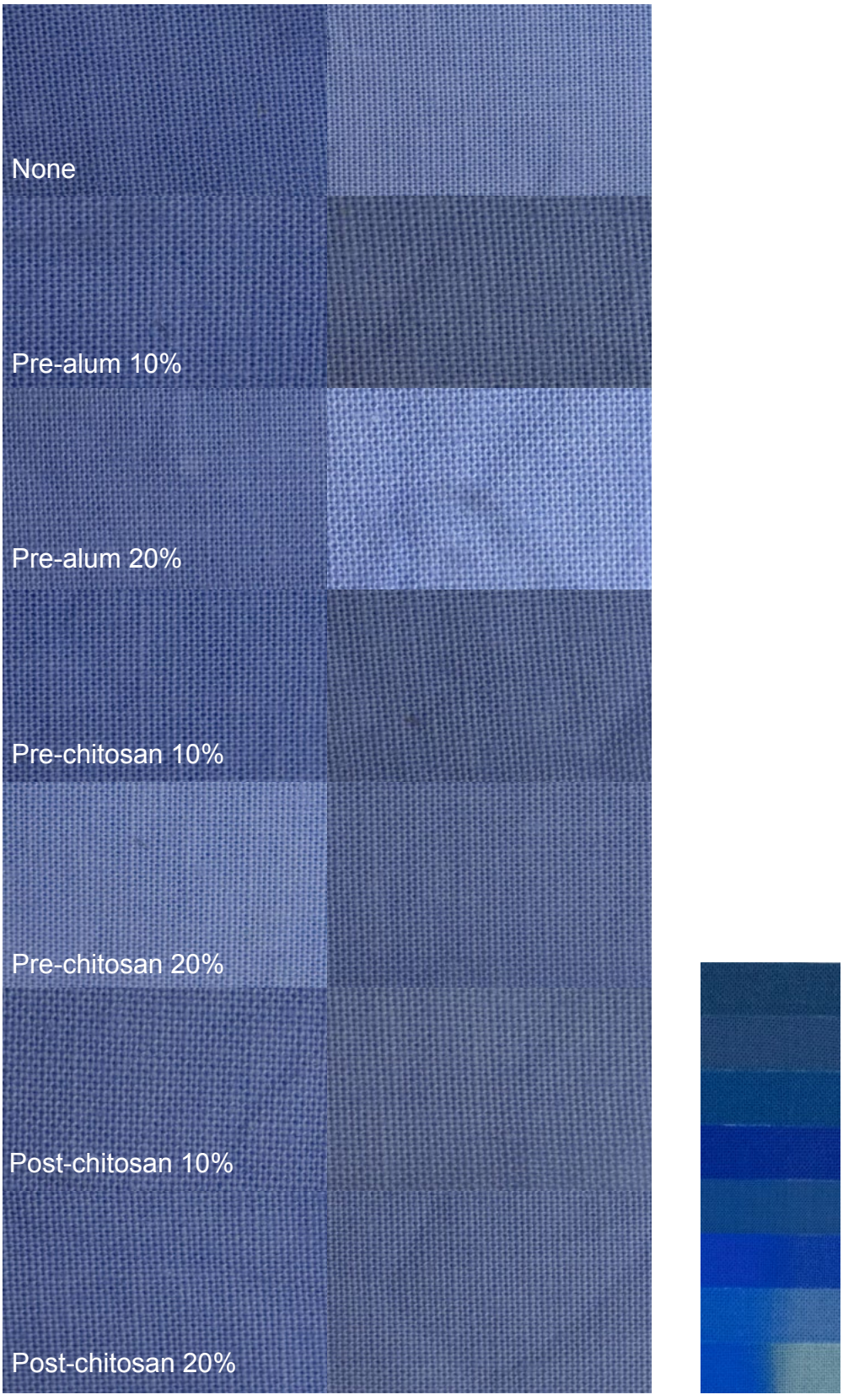


Figure 1.107 Cotton coloured with violacein and treated with alum or chitosan tested for colour lightfastness.

DIA 36: Sensory wheels workshop 3rd year undergraduate students

DIA 36

Time period: February 2023

Location: Design School Kolding

Motivation: Further improvement of the sensorial wheel, the visual wheel and initial testing of the impact wheel.

Summary

As in the previous workshop, the students selected one textile material to explore and another as a reference. In this session, I also introduced a third wheel, the impact wheel. This wheel guided reflections on how the chosen material might react or change when exposed to various factors, always in comparison to the reference material. The template for the impact wheel is shown in Figure 1.108.

This session was conducted with approximately 30 third-year undergraduate students from textile design, accessory design, and industrial design as part of the third-year course Material Strategies.

The results of using the wheels to explore textiles are displayed in Figure 1.109, while photos from the discussion segment of the workshop are shown in Figure 1.110.

Additionally, I wanted to investigate whether the wheels could also be used to explore the sensuous qualities of biomaterials. Since the design students in the course were actively engaged in material making and tinkering, they had biomaterials they had developed themselves. In this workshop, the students also selected biomaterials to explore using the wheels, as shown in Figure 1.111.

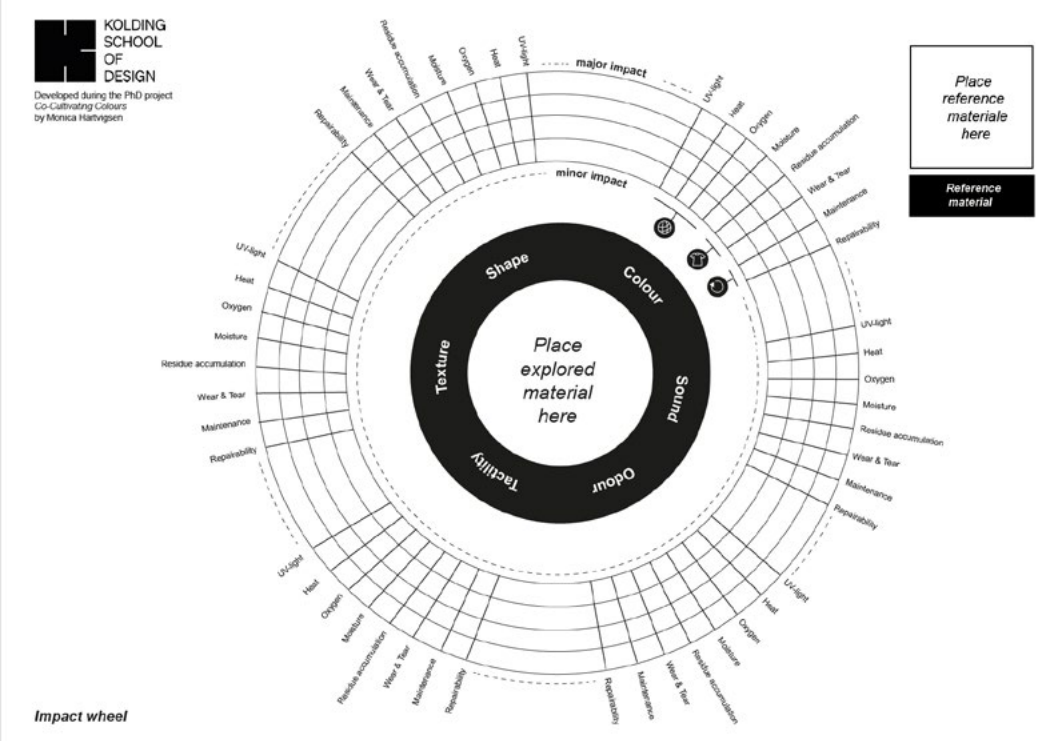


Figure 1.108 Template of the impact wheel.

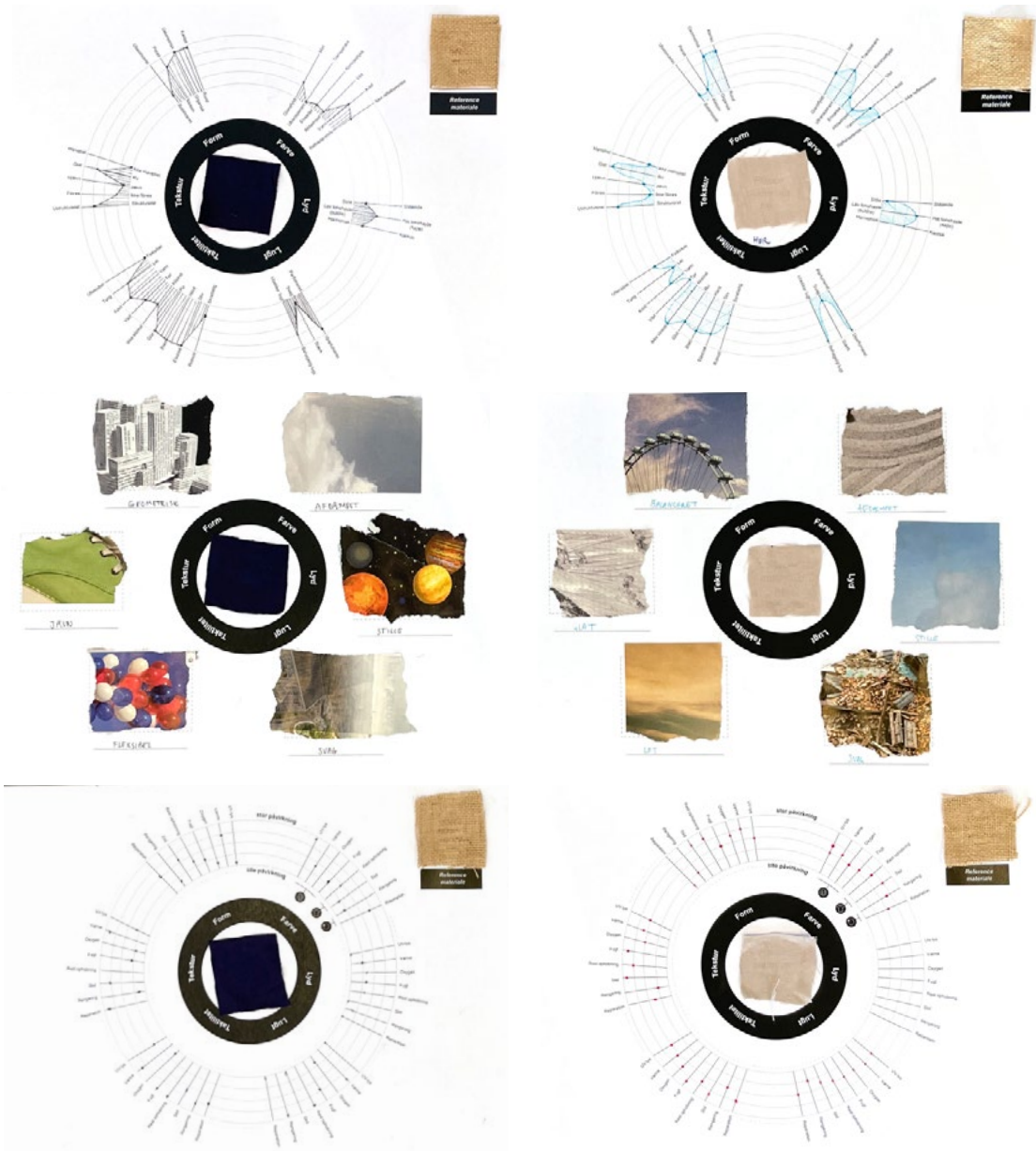


Figure 1.109 Wheels filled out by students with textiles as reference material.

Figure 1.110 Workshop material - exploring sensuous qualities of textiles.

Figure 1.111 Students exploring sensuous qualities of biomaterials.

Evaluation

The use of the sensorial wheel proved highly effective, as group discussions at the tables allowed students to gain a deeper understanding of the sensuous qualities of their chosen materials. The collaborative nature of the exercise was evident, with industrial design students often seeking input from textile design students, given the textile focus of the materials being explored.

The visual wheel was equally successful, with some groups completing it digitally and others using analogue methods. Both approaches worked as intended, and the choice of method could be left to the students' preferences, allowing for flexibility in how they engaged with the tool.

The impact wheel presented more challenges, as some concepts, such as residue accumulation, were difficult for students to grasp. However, it effectively initiated reflections on the use phase of the materials. This wheel required a deeper understanding of the materials and additional time for research, making it more suitable for later stages of material exploration rather than as an introductory tool like the other two wheels.

Accessory design students expressed that they lacked sufficient knowledge about textiles to fully utilise the tools, which limited their engagement. Despite this, the wheels proved versatile, as they could be used for both subjective discussions and objective evaluations, with different perspectives yielding varying results.

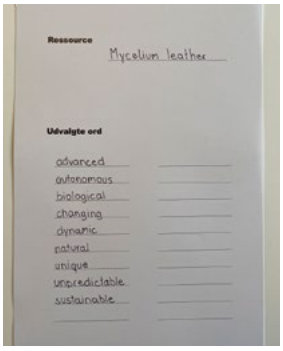
The exercise required relatively low input—providing only material samples and paper templates—but generated high output in terms of student discussions, exploration, and reflection on materials. The tools worked well as starting points, with students reporting that they gained valuable insights. Additionally, the wheels were seen as potentially useful for facilitating discussions with non-designers.

While the impact wheel was effective in sparking reflection, it demanded more knowledge and time, making it better suited for later stages of exploration. In contrast, the sensorial wheel and the visual wheel functioned well as introductory tools.

Students noted that when filling out the wheels, they did not always feel the need to take a firm stance and sometimes aligned their responses with others in the group. This behaviour could be linked to expectations about whether the wheels should be completed subjectively or objectively.

The tools were applicable for biomaterials, but comparing similar materials proved challenging, as the results became too generalised. The wheels were more effective when contrasting biomaterials, and some students even swapped biomaterial samples to work with more contrasting materials rather than two similar ones.

DIA 37: Bio Cards and vocabulary exercise



DIA 37

Time period: February 2023

Location: Design School Kolding

Motivation: Wanting a better tool for introducing biomaterials to design students

Summary

Building on the experience of the first workshop with the Bio Cards in **DIA 26**, I developed a simpler vocabulary exercise. In this activity, students were asked to fill out which words they would use to describe the resource they selected, as shown in Figure 1.112. After completing the exercise, they presented the resource along with the words they had chosen to describe it. The Bio Cards used in the workshop can be found in Appendix 4.

This workshop was conducted as part of the third-year undergraduate course Material Strategies with approximately 15 students from textile design, accessory design, and industrial design working with Material Driven Design.

Evaluation

The workshop provided concrete insights into the associations design students have with each biomaterial, which were generally positive.

Additionally, it offered the students a brief introduction to specific biomaterials, some of which they may not have been aware of. This exposure has the potential to inspire their future work.

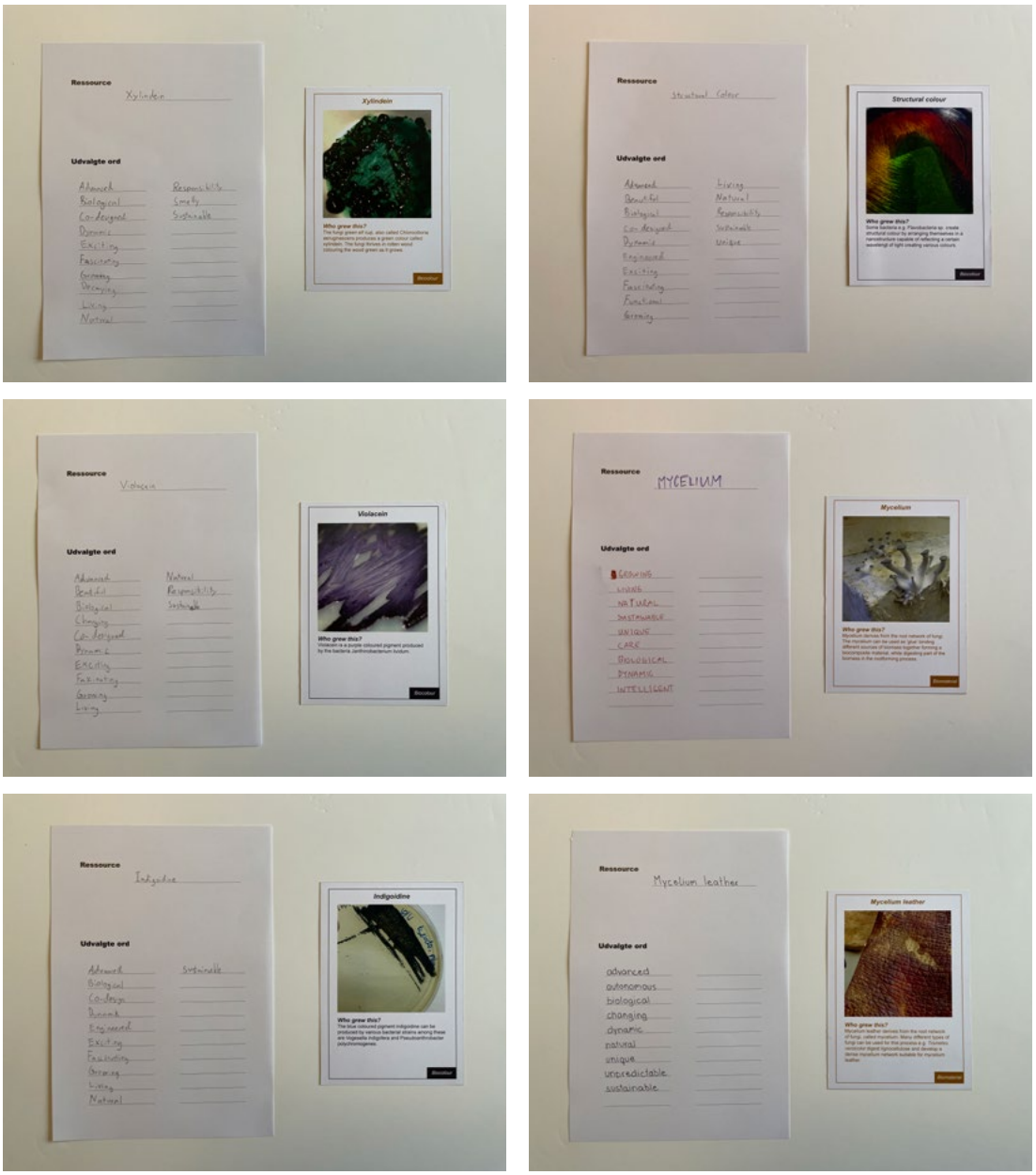


Figure 1.112 Cultivated colour or material word associations.

DIA 38: Project lead textile at Chromologics

DIA 38

Time period: March to May 2023

Location: Chromologics, Lyngby

Motivation: Getting Inside knowledge of the industrial applications of micro-organism producing pigment, and the challenges it presents

Summary

From March to August 2023, I was granted a leave of absence from my PhD studies to work as Project Textile Lead for the Danish company Chromologics. Chromologics specialises in developing red pigments produced by fungi. The company was founded in 2017 as a spin-off from a PhD project at DTU conducted by Gerit Tolborg (Tolborg, 2018). As of 2023, Chromologics employs approximately 20 people with diverse backgrounds, ranging from microbiologists to business developers. The company has raised 97 million DKK in funding (Chromologics - Crunchbase Company Profile & Funding, n.d.) and is in the process of preparing its product for market launch.

In my role, I explored the potential of fungi based colours for textile applications. This included testing a variety of mordants to improve the initial light fastness of the pigments.

- Pigment amount have been between 0.5% and 6% wof.
- The textile qualities which have been tested: wool, polyamide, cotton, viscose and linen.
- The mordants which have been tested: alums (15% wof, including high/ low PH), irons (1-2% wof), titanium (6% wof), tin (3% wof) and copper (4-8% wof).

- The biomordants which have been tested: symplocos leaves (50% wof), chitosan (15% wof), tannin (10% wof) and tannin acid (30% wof).

Figure 1.113 shows Chromologics' fermentation platforms and the laboratory where I worked. Figure 1.114 displays in-progress photos and examples of the coloured textiles.

Figure 1.113 Chromologics fermentation platforms and laboratory.

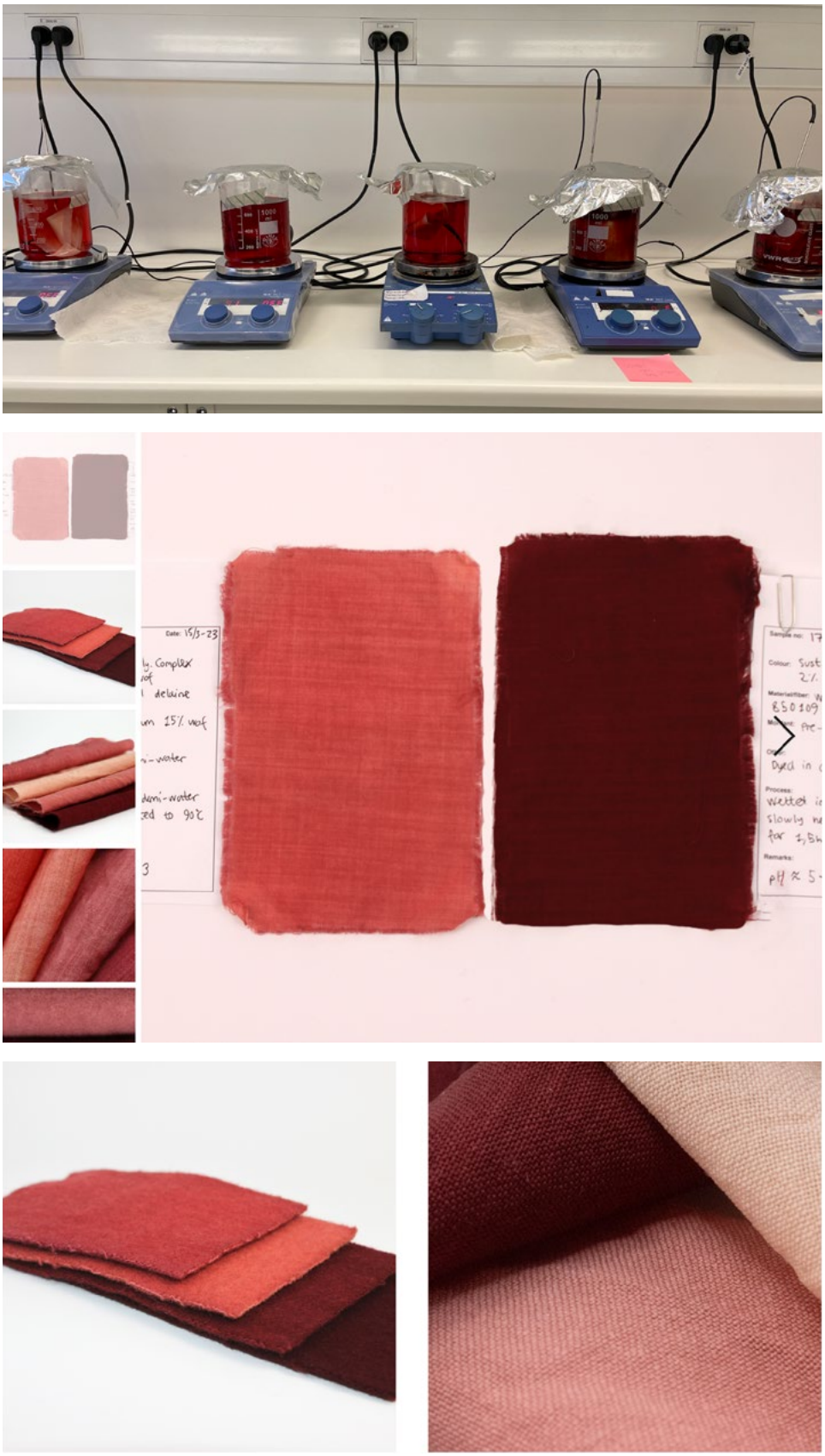


Figure 1.114 Testing Atrosorin(E) for textile colouring from https://www.chromologics.com/textile.

During my employment, I held a meeting with DILLING to discuss the potential of Chromologics Red and gather their thoughts on its colour performance.

Evaluation

Chromologics lacked expertise in textile colourant application, which I was able to provide, and they found this knowledge highly valuable.

Working at Chromologics gave me valuable insights into scaling up microorganism based production and exploring the application potential of using dyeing processes. However, light fastness remained a significant challenge. While we attempted to improve it using mordants, the improvements were not sufficient to meet the standards of “normal” industrial scales.

Chromologics is primarily targeting food colour applications, where light fastness is less critical.

The experiments I conducted at Chromologics were comparable to those that could be carried out in a DIY lab. However, the higher-quality products and equipment at Chromologics allowed for more controlled and less “random” results. This demonstrated that scaling from prototypes created in a DIY lab to an industrial scale is feasible, as many aspects of the processes are similar.

There is potential for using Chromologics Red in the right context, such as in products like underwear, which are not heavily exposed to sunlight. Additionally, fashion companies appeared to have lower requirements for light fastness and believed that storytelling could play a significant role in user acceptance.

Chromologics expressed interest in conducting their own testing to further explore the potential of their colourants

DIA 39: Commercial microbial colour tests

DIA 39

Time period: April 2023

Location: Aarhus University, Department for Biochemical Engineering

Motivation: Comparing commercially sold products coloured with microbially produced dye to my own tests with violacein

Summary

I tested two commercially available products coloured with microbially produced dyes: one from Colorifix and one from Fabulous Fungi. The results of the tests are shown in Figure 1.115, with a Blue Wool Scale included for comparison. The left side of the samples had no exposure, while the right side was exposed to indirect sunlight .

The textiles were exposed to indirect sunlight for six weeks (in March and April).

Evaluation

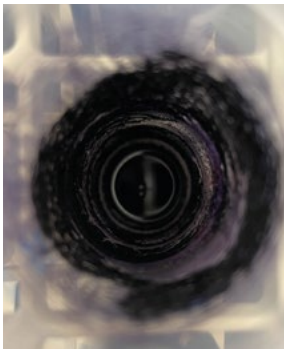
The products were not lightfast, and the results were comparable to those of my own experiments.

Colorifix's storytelling focuses on the fact that the dye is lab-grown, presenting it from a scientific and sustainable perspective. However, there is generally no mention of the fact that the lightfastness is below industry standards.

Fabulous Fungi's storytelling is more transparent, as they acknowledge the fading issue by offering a re-dye service with a discount when the product fades. This approach creates a more emotional connection by telling the story of the colour directly on the product.

Figure 1.115 Testing commercialised microbial colours for colour lightfastness.

DIA 40: Melt-spinning of violacein



DIA 40

Time period: November 2022 to July 2023

Location: Research Institutes of Sweden (RISE), Mölndal

Motivation: Increasing lightfastness of violacein with melt-spinning

Summary

I had an online meeting with Anja from RISE, where we discussed the possibility of conducting a melt-spinning test with violacein. Additionally, I had an online interview with Mikael Skrifvars from Borås, who guided me on how to perform a small-scale TGA (Thermogravimetric Analysis) test to determine the melting temperature of violacein. Based on his guidance, I found an article that described the melting temperature of violacein.

Anja and I planned how she and her colleague could conduct a small-scale melt-spinning test and decided which fibres to use based on their melting temperatures. I hired RISE to carry out the experiment, and we planned the process through multiple discussions. Together, we developed a protocol to ensure alignment throughout the process.

I sent them the dried pigment from **DIA 19**, and after receiving it, they further purified the pigment to increase the chances of success, as their initial tests showed some clumping. Figure 1.116 shows the state of the pigment they received, pigment mixed with polypropylene (PP), and the initial tests.

RISE conducted melt-spinning with three different pigment concentrations, using PP as the plastic type. After receiving the melt-spun samples, I conducted lightfastness testing. The samples were spun onto spools, and the results of the lightfastness test are shown in Figure 1.117. The top part of the spool had no exposure, while the bottom part was exposed to indirect sunlight for six weeks (in June and July). A Blue wool scale is included on the right for comparison.

Evaluation

II need to determine the particle size and melting temperature of violacein using a thermogravimetric test (TGA).

It is possible to conduct small-scale melt-spinning experiments now that the melting temperature of violacein is known. PP was chosen as the fibre material because PET has a higher melting temperature, which could degrade the violacein pigment.

The melt-spinning process was successful, embedding the pigment inside the fibre. Lightfastness was better than with traditional dyeing methods, though it still did not reach a level above 2 of 1 out of 8. Using a higher concentration of pigment to achieve a darker colour might improve lightfastness further.

More experiments with melt-spinning would be interesting, but the process is expensive and time-consuming, particularly due to the effort required to produce the pigment.

To improve results, the pigment should be purified further to achieve a more even distribution. Using the filter multiple times during purification could help achieve this.

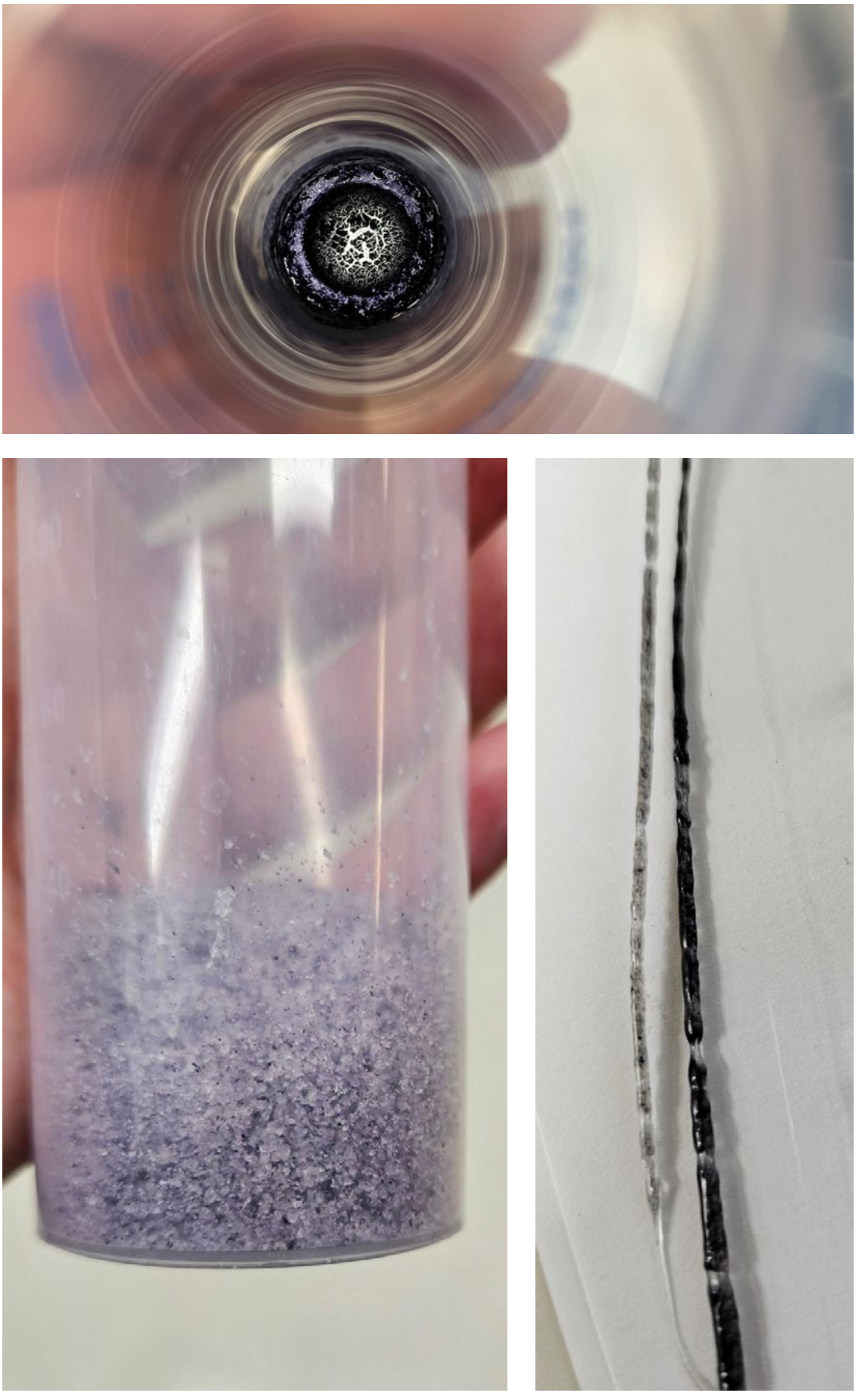


Figure 1.116 Colouring PP with violacein via melt-spinning technology at RISE.

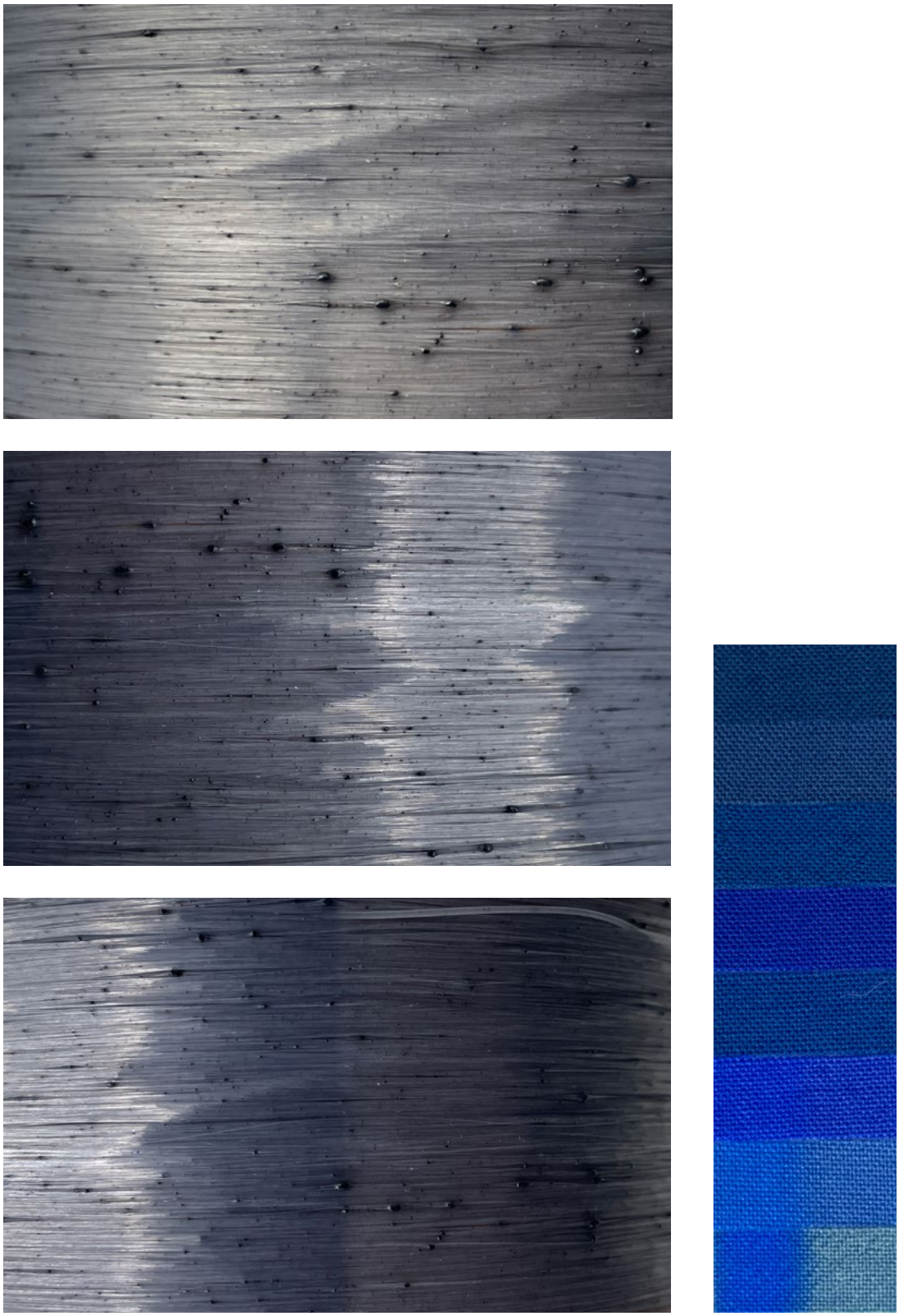


Figure 1.117 Melt-spinning with violacein and PP.

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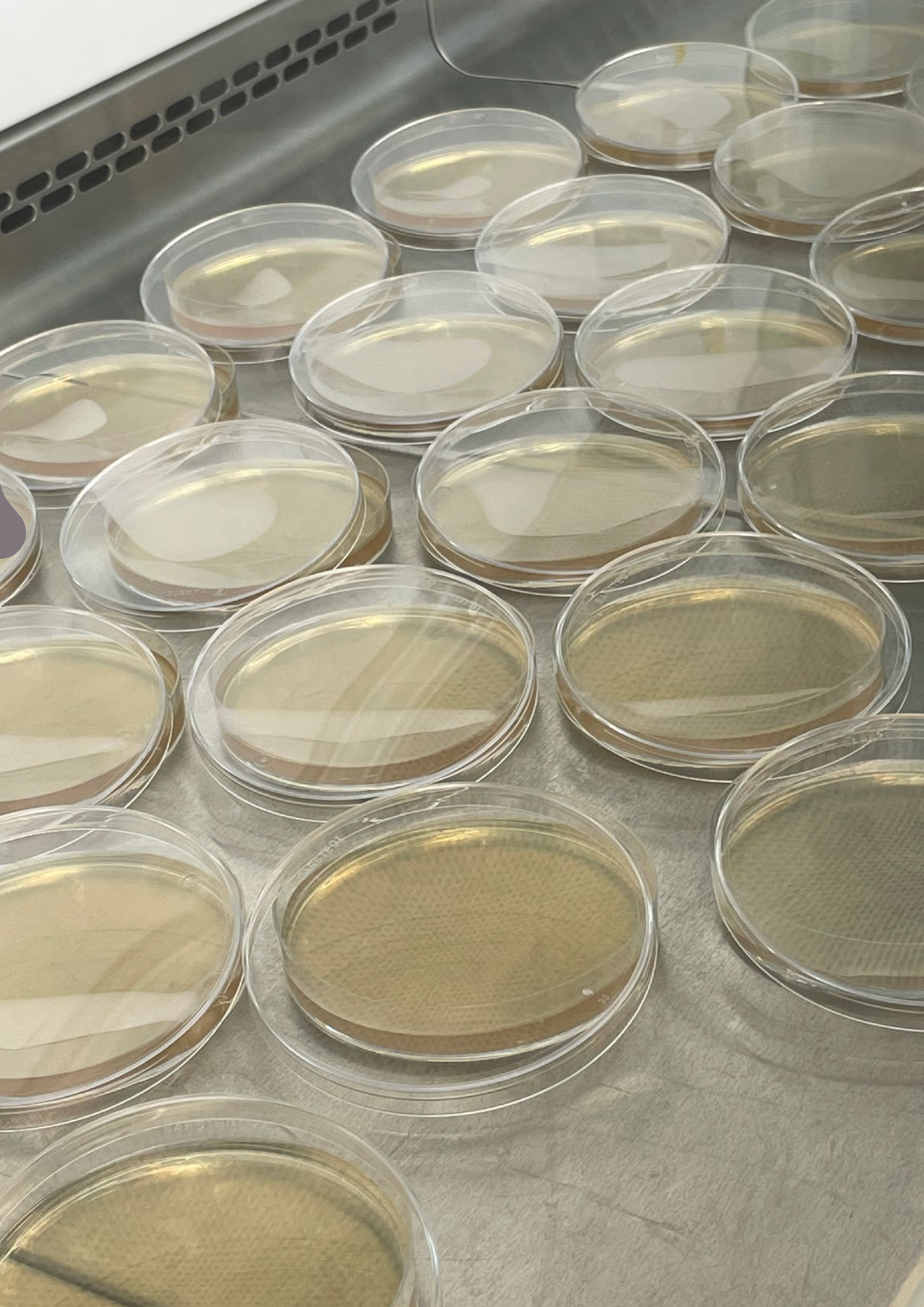

Appendix 2: Contemporary Colour Demonstrators

In this appendix, examples of ‘Contemporary Colour Demonstrators’ (CCD’s) are presented. CCD’s are researchers and inventors from diverse backgrounds who share a common goal: rethinking the concept of colours. It is important to note that additional examples may emerge over time, as research within the field of biocolours is expanding rapidly.

These CCD’s are presented in four tables, each organised alphabetically by different topics. The four tables are divided into the following categories:

- **Design Research Demonstrators** are designers or design researchers working with biocolours.
- **Industry Directed Research Demonstrators** are researchers with various backgrounds, working directly or indirectly with projects for commercial application of biocolours.
- **Educational Demonstrators** are design educations, architecture educations or other educational institutions open for designers working with biodesign and biocolours.
- **Commercial Application Demonstrators** are companies applying biocolours to textile products.

Design Research Demonstrators

Colour Demonstrator	Year	Resource	Product	Process	Location	Reference
Microbial produced biocolours						
Blond and Bieber	2014	Algae	Pigment	Textile printing with algae pigments	Germany	(Glomb et al., 2014)
Célina Camboni	2022	Cellulose	Structural colour	Structural coloured coating for luxury textile	Central Saint Martins, UK	(*Emotional Iridescence, A Living Colour - Célina Camboni - UAL Graduate Showcase*, n.d.)
Charlotte Werth	2022	Bacteria	Pigment	Dyeing process by demonstrating a cultivating and dyeing machine in one.	Central Saint Martins, UK	(*Moving Pigments - Charlotte Werth*, n.d.; Werth & Hénaff, 2022)
Clarise Risseeuw	2021	Bacteria	Structural colour	Structural coloured surface response with Flavobacteria	TU Delft, Netherlands	(Karana, 2020; Risseeuw, 2021)
Emma van der Leest	2019	Bacteria	Structural colour	Growing Flavobacteria on bigger surfaces in a closed container	Avans University of Applied Sciences, TU Delft, Blue City Lab, Netherlands	(Karana, 2020; van der Leest, 2016)
Ilfa Siebenhaar and Laura Luchtman	2017	Bacteria	Pigment	Demonstrating clothing coloured with violacein pigment in a collab PUMA	Waag Society, Biomedical faculty of Rotterdam University, Netherlands	(Luchtman & Siebenhaar, 2017; PUMA, n.d.)
Ilse Kremer/ Fabulous Fungi	2020	Fungi	Dye	Producing fungi colours and colouring textiles	Netherlands	(*Fabulous Fungi*, n.d.)

Colour Demonstrator	Year	Resource	Product	Process	Location	Reference
Julia Moser	2021	Bacteria	Dye	Bacterial colouring of textiles Collab with Vienna Textile Lab	Germany/ Austria	(Fleck, 2021)
Liene Kazaka	2021	Fungi	Dye	Colouring textile with the fungi green elf cup	Central Saint Martins, UK	(*Myco Colour - Liene Kazaka - UAL Graduate Showcase*, n.d.)
Mycocolors	2022	Fungi	Dye	Producing fungi colours and colouring textiles	Germany	(*MycoColors*, n.d.)
Natsai Chieza / Faber Futures	2015	Bacteria	Pigment	Streptomyces coelicor	Central Saint Martins, UK	(Chieza & Ward, 2015)
Neri Oxman	2019	Bacteria	Melanin pigment	Incapsulating melanin in acrylic	MIT, Mediated Matter Group	('Totems by Neri Oxman', 2021)
Roya Aghighi	2019	Algae	Photo-synthetic living cells	Photosynthetic living cells on natural fabrics (cellulose, protein based)	University of British Columbia, TU, Delft, The Netherlands	(Karana, 2020)
Ruth Lloyd	2020	Bacteria	Pigment	Collab Colorifix	Central Saint Martins, UK	(Lloyd, 2020; Maison/0, 2022)
Uncolour	2023	Plants	Food and agricultural waste	Biobased ink and binder for silkscreen printing	Eindhoven, Netherlands	(*Portrait UNCOLOUR Studio Lottozero*, n.d.)
Biobased colour coatings						
Elissa Brunato/ Radical Matter	2019	Plant based cellulose	Structural coloured sequins	Sequins with an iridescent surface	RISE, Sweden	(*Elissa Brunato*, n.d.; *Glittering Sequins of Wood*, n.d.)
Heleen Sintobin and Maria Boto	2020	Melanin	Structural colour	Coating created with melanin forming structural colour	Laboratorium KASK Ghent, Belgium	(*Ecology of Colour | Henry van de Velde Awards*, n.d.)
Noora & Konrad	2019	Wood based cellulose	Structural colour	Structural coloured wood surfaces with cellulose nanocrystals	Aalto University, Finland	(Klockars et al., 2019; Yau et al., 2020)
Biocolour network						

Colour Demonstrator	Year	Resource	Product	Process	Location	Reference
Julia Kaleta	2020	N/A	Database	Mapping of textile biocolour network	Amsterdam, The Netherlands	(AOSC, n.d.)
Julie Beeler	2021	Fungi	Database	Teaching resource about fungi derived colours	USA, Washington, North Pacific	(*Mushroom Color Atlas*, n.d.)
Rebecca Burgess	2019	N/A	Local system	Local fibershed system	Northern California	(Burgess & White, 2019)

Industry Directed Research Demonstrators

Colour Demonstrator	Year	Resource	Product	Process	Location	Reference
Microbial biocolour production						
Ditte Hededam Welner	2021	Bacteria	Indigo	Enzyme produced by E.coli for indican treatment	DTU, Denmark	(Petermeier et al., 2021)
Gerit Tolborg	2018	Fungi	Pigment	Study potential of the red pigment producer T. atroroseus and Monascus	DTU, Denmark	(Tolborg, 2018)
Maria Kanelli	2018	Bacteria	Violacein	Cultivation of bacteria to produce violacein	National Technical University of Athens, Greece	(Kanelli et al., 2018)
Niédja Fittipaldi Vasconcelos	2017	Bacteria	Cellulose nano crystals	Production of cellulose nanocrystals	UFC, Brazil	(Vasconcelos et al., 2017)
Nora M. Elkenawy	2017	Bacteria	Prodigiosin	Cultivation of bacteria to produce prodigiosin	National Centre for Radiation Research & Technology, Cairo, Egypt	(Elkenawy et al., 2017)
Seri Robinson	2017	Fungi	Quinones	Cultivation of xylindein producing fungi	Department of Wood Science and Engineering, Oregon State University, USA	(Court et al., 2020; Hinsch & Robinson, 2018; Palomino Agurto et al., 2017)
Shristi Ram	2020	Bacteria	Carotenoid	Cultivation of bacteria to produce carotenoid	CSIR, India	(Ram et al., 2020)

Colour Demonstrator	Year	Resource	Product	Process	Location	Reference
Silvia Vignolini	2018	Bacteria and fungi	Structural colour	Genetic manipulation of bacteria to create structural colour	University of Cambridge, UK	(Droguet et al., 2022; Schertel et al., 2020)
Stephanie Stange	2019	Fungi	Xylindein	Cultivation of fungi to produce Xylindein	Technical University of Dresden, Germany	(Stange et al., 2019)
Vijay Kumar	2021	Bacteria	Violacein and PHA	Co-production of violacein and PHA by one bacterial strain	CSIR-Institute of Himalayan Bioresource Technology, India	(Kumar et al., 2021)
Biocolour testing and evaluation						
Chidambaram K. Venil	2016	Bacteria	Violacein	Violacein coloured textiles fastness testing	Technical University of Malaysia, Malaysia	(Venil et al., 2016)
J. C. Lapenda	2015	Bacteria	Prodigiosin	Culturing prodigiosin to test antimicrobial properties	Federal University of Pernambuco, Brazil	(Lapenda et al., 2015)
Khaled Faidi	2016	Fruit	Carotenoid	Carotenoid coloured textiles fastness testing	Faculty of Sciences of Monastir, Tunisia	(Faidi et al., 2016)
Madhura Nerurkar	2019	Bacteria	Prodigiosin	Prodigiosin coloured textiles fastness testing	Institute of Chemical Technology, India	(Nerurkar et al., 2019)
Riika Räisänen	2002	Fungi	Emodin Dermocybin and more	Fungal coloured textiles fastness testing	University of Helsinki	(Räisänen, 2002)
Vinod K. Nathan	2018	Bacteria	Violacein	Culturing violacein to test antimicrobial properties	SASTRA University, Kerela, India	(Nathan et al., 2018)

Colour Demonstrator	Year	Resource	Product	Process	Location	Reference
Biocolour technology						
Avinash P. Manian	2022	Melt-spinner	Indigo coloured fibers	Indigo dope dying regenerated cellulose	University of Innsbruck, Austria	(Manian et al., 2022)
Hadiqa Javaid	2022	Wet-spinner	Ioncell fiber coloured with beta-cyclodextrin and curcumin	Wet-spinning and ioncell fibers with curcumin	Aalto University, Finland	(Javaid, 2022; Voncina et al., 2013)
Neri Oxman	2019	3D printer	Bacteria	3D printing Hybrid living fibers	MIT, Mediated Matter Group, USA	(Bader et al., 2019; Smith et al., 2020)
Vincent Nierstrasz	2019	Supercritical CO2 dyer	Curcumin textile	Dyeing textile with pressure and biobased curcumin dye	University of Borås, Sweden	(Chiango et al., 2022; Malm et al., 2019; Tadesse Abate et al., 2019)
Vincent Nierstrasz	2019	Supercritical CO2 dyer	Chitosan coated polyester	Chitosan coated polyester for antimicrobial functionalisation	University of Borås, Sweden	(Tadesse Abate et al., 2019)
Vincent Nierstrasz	2019	Inkjet printer	Printed curcumin	Inkjet printing with ink-based curcumin	University of Borås, Sweden	(Zhou et al., 2019)
Vincent Nierstrasz	2020	Plasma coater	Plasma	Plasma treatment	University of Borås, Sweden	(Iyer et al., 2020)
Biocolour coatings						
Ilona Leppänen	2022	Cellulose	Structural colour	Hybrid films from cellulose nanofibrils and cellulose nano crystals	Aalto University, Helsinki, Finland	(Leppänen et al., 2022)
Javed Sheikh M. D. Teli	2013	Waste shrimp shells	Chitosan	Mordanting textile with chitosan	Department of Fibers and Textile Processing Technology, Institute of Chemical Technology, Mumbai, India	(Teli et al., 2013)

Colour Demonstrator	Year	Resource	Product	Process	Location	Reference
Karl Alexander Henn	2021	Wood	Lignin	Coating of wood	Aalto University, Finland	(Henn et al., 2021)
Orlando Rojas	2017	Cellulose	Structural colour	Cellulose nanocrystals coating of textile displaying structural colouring	Canada, Finland	(Klockars et al., 2018; Tardy et al., 2017)
Rafael Grande	2023	Chitosan	Mordant	Chitosan mordant for red onion dye	Aalto University, Helsinki, Finland	(Grande et al., 2023)
Silvia Vignolini	2022	Cellulose	Structural colour	Upscaling structural coloured coating	University of Cambridge, UK	(Droguet et al., 2022; Parker et al., 2022)
Smriti Rai	2021	Plant	Cellulose hydrogel	Nano fibrillated cellulose hydrogel	University of Georgia, USA	(Rai et al., 2021)
Tiffany Abitbol	2014	Cellulose	Cellulose nano crystal films	Study cellulose nano crystals self-assembly films	RISE, Sweden	(Abitbol & Cranston, 2014)
Vincent Nierstrasz	2020	Plasma	Plasma coating	Plasma treatment	University of Borås, Sweden	(Iyer et al., 2020)
Biocolour network						
Fashion for good – sustainable dyestuff library	2023	Various	Database	Digital Dyestuff Database	Amsterdam, Netherlands	(Fashion for Good, n.d.)
Riikka Raisanen	2019	Biocolour consortium	BioColour Database	A database sharing information on biobased colour production, safety and consumption	BioColour consurtium, Finland, USA	(Räisänen et al., 2020, 2021; Räisänen & Primetta, 2019)

Educational Demostrators

Colour Demonstrator	Year	Resource	Product	Process	Location	Reference
Design institutions						
Aalto University	2012	Pirjo Kääriäinen	Chemarts courses and summer school	Course and summer school with various themes focusing on combining material science and design	Helsinki, Finland	(Niinimäki et al., 2018; *NNN / Pirjo Kääriäinen on New Ecological Biomateriality*, 2019)
Bartlett School of Architecture	2018	Marco Cruz Brenda Parker	MA Bio-ID, postgraduate programme	Master's programme educating architecture directed biodesign	London, United Kingdom	(UCL, 2017)
Central Saint Martins	2019	Nancy Diniz (Carole Collet)	MA Biodesign, postgraduate programme	Master's programme educating design directed biodesign	London, United Kingdom	(Hitti, 2019)
Delft University of Technology	2022	Elvin Karana	Postgraduate courses (MSc Industrial Design Engineering)	Courses introducing biodesign principles	Delft, The Netherlands	(TU Delft, 2023)
ENSAD, Softmatter	2015	Aurélie Mossé, Jean-François Bassereau	Courses, workshops, project work	Explore how materials and technologies can contribute to the design of a more resilient culture	Paris, France	(*Softmatters*, n.d.)
Hub for Biotechnology in the Built Environment	2019	Newcastle University and Northumbria University	Project work	Biotechnology applied to architecture from micro to macro scale	Newcastle upon Tyne, United Kingdom	(*About – HBBE*, n.d.)
KEA, Material Lab	2013	Mette Bak-Andersen, Anke Pasold	Courses, professional undergraduate programme	Courses educating material driven design and design for sustainability	Copenhagen, Denmark	(Bak-Andersen, 2019; Ferraro & Pasold, 2020)

Colour Demonstrator	Year	Resource	Product	Process	Location	Reference
Kolding School of Design (DSKD)	2018	Kolding School of Design	MA Design for Planet, postgraduate programme	Course teaching material narratives in design for sustainability	Kolding, Denmark	(*Design for Planet*, n.d.; *Material Narratives*, n.d.)
Laboratorium, Gent School of Art (KASK)	N/A	María Boto, Heleen Sintobin	Project work	Biolab focusing on colour research	Gent, Belgium	(*LABORATORIUM*, n.d.)
Living Lab, Atlas, CU Boulders	N/A	Mirela Alistar	Courses, Project work	Intersecting art and technology to research healthcare accessibility	Boulder, Colorado, United States	(*Living Matter Lab*, 2018)
MIT, Mediated Matter	2010-2021	Neri Oxman	Project work	Nature-inspired design and design-inspired Nature	Massachusetts, United States	(*Group Overview ‹ Mediated Matter*, n.d.)
Royal Danish Academy, CITA	2005	Mette Ramsgaard Thomsen	MA Computation in Architecture programme, postgraduate programme	Living materials applied to architectural scale, technology and protocols	Copenhagen, Denmark	(*CITA - Centre for Information Technology and Architecture*, 2014; *CITA Research Projects*, 2015)
Other educational institutions						
Bio-tech lab, Fablab Vejle	2022	Fablab Vejle, Novo Nordisk Foundation	Open access biolaboratory	Laboratory teaching microbial material cultivation methods	Vejle, Denmark	(*Naturvidenskabelige projekter for børn og unge modtager 20 mio. kr.*, n.d.)
Bioart Laboratories	2011	Jalila Essaïdi	Laboratory for crossover innovation	Catalyst for emerging talents to explore biotechnology and life science innovations	Eindhoven, The Netherlands	(*BioArt Laboratories | Organisation*, n.d.)
Bioart Society	2008	N/A	Art association	Making and facilitating activities combining art and natural sciences	Helsinki, Finland	(*SOLU / Bioart Society | About*, n.d.)

Colour Demonstrator	Year	Resource	Product	Process	Location	Reference
Blue Citylab	2015	Siemen Cox and Mark Slegers	Rentable laboratories	Laboratory facilities for start-up and entrepreneurs	Rotterdam, The Netherlands	(*Home BlueCity* | *English – BlueCity*, n.d.; Ventures, 2020)
Fabricademy	2017	Anastasia Pistofidou, Cecilia Raspanti, Fiore Basile	6-months course	Educating new technologies by combining biology, digital fabrication and textiles	HQ in Amsterdam, The Netherlands, Around the world in local environments	(Fabricademy, n.d.)
London Biohackspace	N/A	N/A	Community laboratory	Laboratory exploring molecular biology and microbiology	London, United Kingdom	(*London Biohackspace*, n.d.)
Opencell Labs	2018	Helene Steiner and Dr. Thomas Meany	Rentable laboratories	BSL2+ laboratory for biotech start-ups	London, United Kingdom	(*OpenCell Labs*, n.d.)
Waag Open Wetlab	2013	Pieter van Boheemen	Community open laboratory	Open access natural science laboratory educating biology	Amsterdam, The Netherlands	(Waag, 2013)

Commercial Application Demostrators

Colour Demonstrator	Year (product launch)	Resource	Product	Process	Location	Reference
Biocolour production						
Algaeing	N/A	Algae	Algae fibers and colours	Algae are used to produce fibers and colours for textile dyeing	Beit Yizhak, Israel	(*HOME*, n.d.)
Archroma	2018	Agricultural and herbal waste	EarthColours®	Agricultural and herbal waste is used to colour textiles	Pratteln, Switzerland	(*EarthColors® by Archroma*, n.d.)
Archroma	2023	Textile (cotton and polyamide) waste	FiberColors	Textile waste is used as raw material for dyestuff	Pratteln, Switzerland	(*FiberColors* Technology*, 2023)
Chromologics	2022	Fungi	Fungi pigment and dye	Industrial-scale fermentation of red colours	Søborg, Denmark	(*Chromologics | We Pioneer Natural Colors*, n.d.)
Colorifix	2021	Bacteria E. coli	Bacteria pigments	Fermenting, genetic engineering	Norwich, UK	(Colorifix, n.d.; Liu et al., 2021; Melton, 2022; Pangaia, n.d.)
Colours de plantes	2005	Plants and insects	Plant and insect derived colours	Plant and insect derived colours for textile colouring	Rochefort, France	(Couleurs de Plantes, n.d.-a, n.d.-b)
Dynawash	N/A	Tea by products	T-dyes	Natural dyes from tea waste for textiles	Sri Lanka	(*T-Hues*, n.d.)
Ecofoot	2018	N/A	H2COLOR, H2DENIM, H2CLEAR	Dye linked to polymer particle	Guimarães, Portugal	(*Technology – Ecofoot | Innovating Textile Industry*, 2022)

Colour Demonstrator	Year (product launch)	Resource	Product	Process	Location	Reference
Everdye	2021	Vegetable and mineral waste	Dyes for textiles	Vegetable and mineral waste used to create pigments for textile dyeing	Paris, France	(Everdye, n.d.)
Fabulous Fungi	N/A	Fungi	Dyes	Upscaling of fungi dye (still lab-scale)	Blue City Lab, Rotterdam, Netherlands	(*About - Fabulous Fungi*, n.d.)
Graviky Labs	2016	Air soot	Air based black print ink	Black printing ink for screen printing	Cambridge, United States	(AIR-INK, n.d.)
Hoekmine BV	N/A*	Bacteria	Structural colours	GMO organisms create structural coloured coatings	Utrecht, Netherlands	(Hamidjaja et al., 2020; *Hoekmine BV*, n.d.; Schertel et al., 2020)
Huee	2020	Bacteria, E. coli	Bacteria pigments, indican	Fermenting, genetic engineering	Berkeley, USA	(Hsu et al., 2018; *Huue*., n.d.; Landhuis, 2019)
Huntsman	2015	N/A	AVITERA® SE	para-chloro-aniline (PCA) free reactive dye	Texas, USA	(*AVITERA® SE*, n.d.)
Living Ink	2013	Algae	Black ink	Algae based ink for textile dye and printing	Colorado, United States	(*Living Ink*, n.d.)
MARM / MORE	2021	Marble	Marble coated textile material	Marble colour coat on textiles	Milan, Italy	(House, n.d.; MARM \ MORE, n.d.)
Natural indigo	2017	Natural colours	Natural colours	Local produced natural colours e.g. indigo	Nivala, Finland	(*Luonnonväriaineet | Natural Indigo Finland*, n.d.)
Nature coatings	N/A	Wood waste	Black pigment, BioBlack TX	Black pigment for textile colouring made from wood waste	Las Vegas, United States	(*BioBlack TX*, n.d.)
NIG GmbH	1999	Plants	NIG Natural dyes	Dye produced from plants	Magdeburg, Germany	(*Products*, n.d.; *Textile Applications of Our Natural Dyes*, n.d.)

Colour Demonstrator	Year (product launch)	Resource	Product	Process	Location	Reference
Octarine Bio	2025	Bacteria	Bacteria pigments	Tryptofan pigments produced by bacteria for textile dyeing	Copenhagen, Denmark	(Glover, 2023)
Officina+39	2016	Post-consumer textile fibers	Recycrom	Recycled fibers turned into dye powders	Biella, Italy	(*Recycrom – Officina+39*, n.d.)
Pili Bio	N/A*	Enzymes	Dye	Microbial enzymes, re-engineered to produce brilliant and effective dyes from renewable resources	Toulouse, France	(*Technology - Pili*, n.d.)
Pure.Tech	2018	Greenhouse gass	Puretech technology	Neutrilises greenhouse cases and converts it to colour textiles	Barcelona, Spain	(*Pure.Tech - PURE. TECH*, 2021)
Sodhani Biotech	2018	Plants	Plant extract	Plant based textile colours	Jaipur, India	(adititandon, 2023; *Natural Dyes | Leading Sustainable Natural Dyes - Sodhani Biotech*, n.d.)
Spira Inc.	2016	Algae	Algae pigments	Algae pigment for textile colouring	Culver City, California, United States	(*Spira*, n.d.)
Stony Creek Colors	2012	Plants	Plant based dyes	Traceable plant based dyes for textiles	Springfield, Tennessee, United States	(Colors, n.d.)
Vienna Textile Lab	N/A*	Bacteria	Bacterial pigments	Fermentation of pigment producing bacteria	Vienna, Austria	(*Vienna Textile Lab*, n.d.)

Colour Demonstrator	Year (product launch)	Resource	Product	Process	Location	Reference
Vienna Textile Lab x Living Colour	N/A*	Bacteria	Biogenic ink (BInc)	Circular inks for textile printing	Vienna, Austria and Rotterdam, Netherlands	(*BInc – Biogenic Ink, Natural & Circular*, n.d.)
Helping agents in textile colouring						
Borregaard	N/A	N/A	Dispersants	Dispersants for dyeing of textiles	Sarpsborg, Norway	(*Dyestuffs*, n.d.)
ColorZen	2011	N/A	N/A	Pre-treatment before cotton dyeing eliminating toxic chemicals	New York, USA	(*ColorZen® - Environmentally Friendly Solution to Cotton Dyeing*, n.d.)
Huntsman	2018	N/A	Univadine E3-3D	Dying auxiliary	Texas, USA	('Huntsman Unveils UNIVADINE E3-3D Diffusion Accelerant to Help Industries in Sustainable Standards', 2018)
Nano-Dye	2019	Cat-ions	Nano dye cations technology	Cat-ionic treatment to reduce water use in textile dyeing	Dhaka, Bangladesh	(*Less Energy*, n.d.; Mowbray, n.d.)
Novozymes	N/A*	Microbes	Enzymes	Enzyme treatment in the textile finishing process	Bagsværd, Denmark	(*Enzymes for Textiles | Novozymes*, n.d.)
Tanatex chemicals	2021	Tanatex	TANADYE®	Auxiliaries for polyester, polyamide and cellulosic fibers	Ede, Netherlands	(*TANADYE*, n.d.)
Textile colouring technology						
Airdye®	2009	Printer	Textile printing	Water-free printing on textiles	Osaka, Japan	(*Airdye | Fabric to Print at Your Fingertips!*, n.d.)
Albini	2023	Bacteria	Yarn dyeing	Conventional dyeing machinery	Bergamo, Italy	(ALBINI_next, n.d.-a, n.d.-b)

Colour Demonstrator	Year (product launch)	Resource	Product	Process	Location	Reference
Alchemie Technology	2014	Digital dye technology	Endeavour™ technology	Waterless digital dyeing machine	Cambridge, United Kingdom	(*Our Technology*, n.d.)
CleanKore	N/A	Dyeing process	Dyeing technology	Indigo denim dyeing without potassium permanganate	Westlake, Ohio, United States	(*CleanKore*, n.d.; Mutual, 2021)
Deven supercriticals pvt. ltd	1999	Supercritical fluid	Supercritical fluid dyeing technology	Liquid CO2 is used to dye textiles	Mumbai, India	(*Scfe*, n.d.)
DyeCoo	N/A	Supercritical CO2 dyer	Supercritical CO2 dye	Using CO2 to dye textiles	Weesp, Netherlands	(*CO2 Dyeing*, n.d.)
DyeRecycle	2020	Textile waste	Dye from textile waste	Recycled textile waste used to create a dye	London, United Kingdom	(*DyeRecycle*, n.d.)
Dystar and Rota Spray	2018	Spray dyer	Spray dyeing	Indigo spray dyeing with rota spray	Singapore	(*Breakthrough in Bulk Production of Indigo Spray Dyeing*, 2018)
eCO2Dye	N/A	CO2 dyeing	CO2 dyeing technology	Carbon dioxide is used as the solvent for dyeing of polyester textiles	Pennsylvania, United States	(*Waterless Textile Dyeing with eCO2Dye| eCO2Dye - Waterless Textile Dyeing*, n.d.)
Grinp	2001	Plasma technology	Grinp Plasma Technology	Treatment to reduce chemicals and water usage	Turin, Italy	(*Home*, n.d.)
Holistex (Apreslan, Dobert, IBQ Fabrica, Meroltex,)	N/A	Green technology	Textile production	Using technology and certifications to create responsible textiles	Europe	(*Certifications – Holistex Group*, n.d.)
Imogo	2021	Spray dyer	Dye-Max	Spray dyeing	Limhamn, Sweden	(Products, n.d.)
IndiDye	2010	Plant based colours	IndiDye®	GOTS certified plant based colours	Shanghai, China	(*IndiDye | Natural Dyes*, n.d.)
Indigo Mills	2017	IndigoZERO™	Foam dye technology	Foam dye to reduce water usage in denim dyeing of yarn	North Carolina, United States	(*Indigo Mill Designs' Foam-Dyeing Technology Set to Transform Denim Manufacturing*, 2017)

Colour Demonstrator	Year (product launch)	Resource	Product	Process	Location	Reference
Jeanologia	2005	Ozone laser	Ozone lase technology	Ozone laser finishing treatment to bleach jeans	Valencia, Spain	(*Innovative Technologies for Textile Industry - Jeanologia*, n.d.)
Kornit digital	2011	Organic materials	Kornit Neo Pigment™	On demand digital printing	Rosh Haayin, Israel	(*Our Revolution*, n.d.)
MTIX	2011	UV laser	MSLE® Technology	Multiplexed laser surface enhancement (MLSE®) system for dyeing textiles	Huddersfield, UK	(*MTIX LTD - Innovation In Textile Processing Technology*, n.d.)
Nano-Dye™	2019	Cations technology	Nano-Dye™ Process	Cationic textile dye technology for griege fabrics	USA / Bangladesh	(*Disruptive Sustainable Cotton Dyeing | Nano-Dye*, n.d.; Mowbray, n.d.)
NTX® Cooltrans®	N/A	Printing technology	NTX® Cooltrans® printing machines	Water reduced printing technology	Shanghai, China	(*NTX Cooltrans – a Revolutionary Waterless Coloration Technology*, 2020)
Senbis	2020	PLA	Senbis PLA yarn 9210	PLA dyed with environmentally friendly colours	Emmen, Netherlands	('Compostable Senbis PLA Yarn 9210', n.d.; *Senbis Expands Pilot Facilities for Sustainable Plastics - Bioplastics MAGAZINE*, n.d.)
Sonovia	2013	Ultrasonic dyeing	Sonovia technology	Water reducing dyeing process with ultrasonic cavitation	Ramat Gan, Israel	(Homepage, n.d.)
SPG print	1991	Digital printer	Digital printing technology with natural colours	Digital printing with plant-based colours	Boxmeer, The Netherlands	(*SPGPrints | Company*, n.d.)
Tintex	2013	Plant and fungi	Plant and fungi coloured textiels	Plant and fungi coloured textiles including biobased mordant process	Vila Nova de Cerveira, Portugal	(*About Tintex - T I N T E X*, n.d.)
Tonello	2019	Wake dye equipment	Wake technology	Dyeing process with plants and vegetable waste	Vicenza, Italy	('History', n.d.)
Transfertex.de	N/A	Printer	Digital print	Waterfree printing	Kleinostheim, Germany	(*Transfertex | Global Print Solutions*, n.d.)

Colour Demonstrator	Year (product launch)	Resource	Product	Process	Location	Reference
Vividye	2020	Print paste	Reversible print	Reversible printing technology of textiles	Gothenburg, Sweden	(*Reversible Coloring for Textiles | Vividye AB | Sweden*, n.d.)
We are SpinDye®	2021	Recycled fibers	SpinDye®	Recycled fibers with added pigment spin dyed to new fibers	Stockholm, Sweden	(*SpinDye - The Unique SpinDye Color/Management System*, n.d.; *The SpinDye Certificate - Transparency, Traceability & Certification*, n.d.)
Werewool	2018	Bacteria	Fluorescent fibers	Using DNA modification to colour textile fibers	New York, USA	(*Werewool*, n.d.)
Textile design industry applying biocolours						
Boldwill (former Iron roots)	2023	Fungi	Clothing	Collab with Fabulous Fungi	The Hague, Netherlands	(Iron Roots, 2022)
Colorful Standard	2017	OEKO-TEX certified colours	Clothing	OEKO-TEX dyes used for garment dyeing	Barcelos, Portugal	(*Purpose*, n.d.; *Transparency*, n.d.)
Colour of saying	2018	Ethical colours	Ethical colour consulting	Consultancy in ethical colours	London, UK	(Colour of Saying, n.d.)
Ege Carpets	N/A	Dyeing technology	Carpets	Recycle colour and water	Herning, Denmark	(*Our Sustainability Strategy | Ege Carpets*, n.d.)
Elemental coloring	N/A	Plants and minerals	Clothing	Plant and mineral dyes for textiles	Ikast, Denmark	(*Om Elemental Coloring*, n.d.)
H&M	2021	Bacteria	Clothing	Collab Colorifix	Stockholm, Sweden	(Warren, 2021)
Indo count	2020	Organic waste	Bedding Pure Earth™ sheets	Earthcolours	Maharashtra, India	(*Pure Earth Color Raw Material from Spain*, n.d.)
Marimekko	2020	Plant	Shirt	Indigo printed shirts	Helsinki, Finland	(Marimekko, n.d.)
Pangaia	2021	Bacteria	Clothing	Collab Colorifix	London, UK	(Pangaia, n.d.)
Pangaia	2022	Organic waste	Clothing	Collab earthcolours	London, UK	(Velasquez, 2022)
Patagonia	2017	Organic waste	Clothing	Earthcolours	Ventura, USA	(*Archroma's Earthcolors Selected In Patagonia's Newest Clean Color Collection*, 2019)

Colour Demonstrator	Year (product launch)	Resource	Product	Process	Location	Reference
PureDenim	2014	Smart indigo	Denim clothing	Indigo applied to jeans fabric in an eco-friendly process	Milan, Italy	(*PureDenim – Make the World a Better Place*, n.d.)
SAGES	2021	Food waste	Bio-chemical dye	Phytochemical extractions and biochemical dyeing processes for sustainable colouration	London, UK	(SAGES, n.d.)
Vaude	2020	Organic waste	Clothing	Earthcolours	Germany	(Troester, n.d.)

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Appendix 3: Article and papers

In this appendix, the following peer-reviewed dissemination is included:

- **Journal article 1**: Bacterial colouring: Using multi-disciplinary methods for eco-friendly textile design (2022)
- **Conference paper 1**: Designers prototyping in the lab: Introducing an extracurricular activity exploring bacterial colouring in a design educational setting (2023)
- **Conference paper 2**: Exploring sensuous qualities of textiles (2022)
- **Conference paper 3**: Futuring alternatives biobased colour systems – testing possibilities of fading and redyeing with (SMC) Danish lifestyle companies (2023)
- **Conference paper 4**: THE BIOMATERIALS SPECTRUM – exploring emerging pathways for textile design education (2023)

Journal article 1:
Hartvigsen, M., & Rees, V. E. (2022).
Bacterial colouring: Using multi-disciplinary methods for eco- friendly textile design.

Bacterial colouring: Using multi-disciplinary methods for eco-friendly textile design

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Bacterial colouring is a study on, how bacterial pigments can be used in a textile design context as a more climate and environmentally friendly alternative to the synthetic dyes used in the industry. The project is positioned within the field of natural science and design research using methods from the two disciplines, hence carrying out multi-disciplinary research. It is a part of the design research field 'growing design' where designers often collaborate with natural scientist to carry out biofabrication, thus providing new knowledge to the biodesign field. The natural science methods used are from biotechnology and are used to isolate, identify bacteria and produce bacterial pigments. The design methods are comprised of several prototyping studies from material research to application as a textile design proposal. For the design prototyping we applied projections divided into three steps: scenario 1, 2 and 3, where it was envisioned, how the colour range could broaden, if all colours were replaced with bacterial pigments.

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Introduction

From the minute we are born textiles become an essential part of life. We wear textiles on our body, and it surrounds us in our homes, where they provide comfort and protection. Textiles are appealing to our senses. The way they are haptically perceived and how they are characterised by the visual language and especially use of colour. We all have our individual taste, as to what we consider aesthetically appealing, sometimes based on cultural background and the surroundings we are a part of in our everyday life, and thus we are attracted to different textile expressions: colour, material, pattern and texture. At the same time textiles are contributing to great climate and environmental challenges within the whole textile life cycle, due to its use of unsustainable energy, production methods, exploitation of materials and waste contribution.

Environmental issues

Textiles are a substantial contributor to the global pollution of the planet with the consumption of 4% of global freshwater annually, 10% global industrial CO2 production, 20% global wastewater emission and 16% global pesticide use [1]. This is in accordance with the statistics in the publication Pulse of the Fashion Industry from 2017 from Global Fashion Agenda [2]. In United Nations Sustainable Development Goals (SDG) Report from 2020, they report an increase in global material footprint from 2010 to 2017. Even though the SDG Report describes that progress in sustainable production and consumption is being made, we have far from succeeded in doing so [3].

These figures are connected to the production of textiles in which the raw materials are harvested or produced. They are then further processed through different processes: spun, woven, knitted, tufted, printed, dyed and getting after-treatment [4].

The pollution problems connected to the dyeing process are water use, energy consumption, use of toxic chemicals and wastewater emission [5]. In the dyeing process there are 72 toxic chemicals of which 40% are impossible to remove from the wastewater [5]. This creates a need to act to ensure a more sustainable future of textile colouring.

Sustainability has in the last decade revolved around reuse, reduce, recycle and upcycle still fitting within the model of mass production [6]. We are now at a point, where we need to look at other paths to lead eco-friendly manufacturing.

Historical perspectives of colours

Textiles and colour are deeply connected, since the visual appeal of a textile is often connected to colour. Historically it is also interesting to look at colour. Natural dyes from our surrounding including plants, fruits and insects were being extracted and applied to textiles as early as 3500 BC [5]. The major problem connected to natural pigments is the durability of the colour when washed and exposed to light. To enhance the durability a mordant is needed to fix the dye to the textile. The mordants can be toxic and impact the quality of the wastewater. Besides natural dyes require large amounts of water in the dyeing process [5].

The industrialisation changed the origin of the colours from being extracted naturally to being chemically produced from fossil-oil in a laboratory environment [7]. In 1856 William H. Perkin was successful in producing the world's first synthetic pigment called *anilin purple*. This marked the shift in textile dyeing and led to the replacement of most natural pigments for synthetic pigments instead [8]. The synthetic pigments are durable and cheap to produce, hence creating a low incentive to search for a more climate-friendly alternative.

The synthetic dyes have contributed to the climate catastrophe we are facing now and as the industrialisation changed the textile industry, we now have the chance to change how we produce dye and invent new solutions.

Industrial applied bacterial colours

The biotechnological development has made it possible to produce a new type of natural pigment in this paper referred to as bacterial pigment. This have been extensively studied in the natural science research field, where it has been studied which types of bacteria produce pigments and the structure behind these molecules and hence the colour [9-10], also suggesting that it could be applied within the textile area [11].

Bacterial pigments have several advantages compared to the natural and synthetic pigments, according to Vienna Textile Lab a start-up working on producing bacterial pigments [12]. Their bacterial pigments use 90% less CO_2 in dye production process, 95% less water in the textile dyeing process and produces 99% less toxic waste [13].

Besides Vienna Textile Lab there are two other start-ups in Europe called Pili and Colourifix also working on creating bacterial pigments for industrial scale textile colouring [14,-15]. Colorifix started a pilot project in a dyehouse in Portugal in July 2020. They have created strong partnerships within the textile industry and are backed by H&M, which show that commercial interests are also starting to see bacterial dye as a potential solution. Colorifix describes their process: "Compared to conventional dyeing step for cotton, the Colorifix technology reduces water consumption by at least 49%, electricity by 35% and CO_2 emmisions by 31%" [15].

Established designers are also starting to see possibilities in working with bacteria for textile colouring. The London based agency Faber Futures founded by Natsai Chieza have worked on several projects creating textiles dyed with bacteria in collaboration with scientists from Gingko Bioworks [16]. Also, the Dutch based design studio Kukka founded by Laura Luchtman has created bacterial coloured sportswear in collaboration with PUMA [17]. Until now designers have worked with bacterial pigments, mainly researching what is possible at this given point in time, and created beautiful textiles often with an organic pattern. In this study we want to study the bacterial pigments as surface colours and use future design scenarios to try and visualise how the design potential of bacterial pigments could be approached.

The biodesign research field

The biotechnological development and the accessibility of science have influenced the design practice. In the last decade the field of biodesign have emerged enabling designers to work within the intersection of biology and design using biofabrication in their design process [18]. Biofabrication is incorporation of living material or living matter. It presents an eco-friendly way of developing material and material technologies, since it uses renewable resources that feed living organisms and thus replaces the fossil-based material technology [19].

The research presented in this paper is part of growing design meaning: "*fabrication of materials and products from living organisms*" [20]. A corresponding terminology to growing design is nature as a co-worker as a part of the hierarchy of working with living organisms: *Nature as a model, nature as a co-worker, reprogrammed nature, hybridised nature and conceptualised nature* [21]. In the field of growing design several researchers are experimenting with living materials and organisms either in collaboration with natural scientists or in a 'Do-It-Yourself" approach, where the designer has full control of the material development [19].

The collaboration between natural science and design disciplines, often present in growing design projects, have been studied various researchers [22-25]. In this project the collaboration has a multi-disciplinary foundation between natural science and design, where disciplines utilise knowledge from each other [22]. In this project a biochemical engineer and a textile designer have worked together to explore the design potential of bacterial pigments.

The design research part builds on research through design [26], prototyping various material experiments and design artefacts as our main knowledge contribution. Prototyping is a way for designers to make manifestations of design ideas which concretises and externalises conceptual ideas [27-28]. The prototyping studies made it possible to make tangible experiments with the colours, hence creating knowledge about design potential of bacterial colouring but also in regards of a design-science

collaboration, which the growing design builds upon. We applied this knowledge in the further design process, developing prototypes for colour compositions and textile patterns.

Future perspectives of bacterial colours

In our research project *Bacterial Colouring* we wanted to address the problems connected with the use of synthetic dyes. Our study presents a climate and environmentally friendly way to dye with locally occurring soil bacteria, as an alternative to the conventional dyeing of polyester textile with synthetic pigments. This was tested in a design context by designing a woven textile design coloured with bacterial pigments.

It was important for us to study if the bacterial pigments could create uniform-coloured surfaces and expanding the aesthetic possibilities and thus not only create organic patterned surfaces, but research for an industrial application potential.

In this paper we will present the applied methods both within natural science and design. Then we will present how these methods have contributed with new knowledge to create design experiments. A discussion of the applied methods and paths for further studies will follow and finally a short conclusion.

Methods

The applied methods are a combination of natural science methods from biotechnology and design research methods focusing on prototyping studies. The project starts by applying the natural science methods and the outcome of those are then used in the design research methods emphasising their co-dependency, the outline of the research is shown in Figure 1.

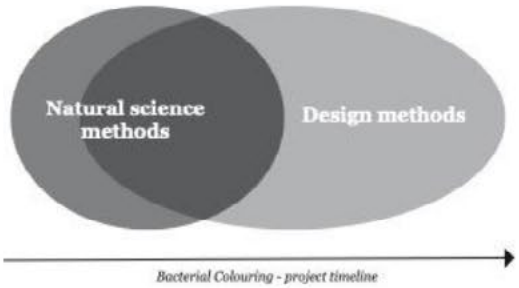

Figure 1: Colour preference among college students.

The natural science methods are comprised of fieldwork, bacteria isolation, DNA purification, Polymerase Chain Reaction (PCR), gel electrophoresis, DNA sequencing and finally our pigment production. The design research methods are comprised of different prototyping studies from material research to colour composition analysis and textile application. We wanted to bring the results from the laboratory into a design context, where a textile design is created from several prototyping studies.

Natural science methods

Collecting bacteria samples locally outside

The bacteria we worked with, were all soil bacteria, which can be found in our local surroundings, which according to the Köppen Climate Classification is a part of the Marine West Coast Climate (Cfb)

[1]. Figure 2 (left side) shows different locations, where we collected the samples. We collected 21 samples from different surfaces by taking a sterile inoculation loop and picking up a small sample. The sample was transferred to a sterile petri dish prepared with Luria Broth (LB) agar. LB agar provides the nutrients for the bacteria to grow and is comprised of a gelatinous agar containing peptones, yeast extract and sodium chloride [29].

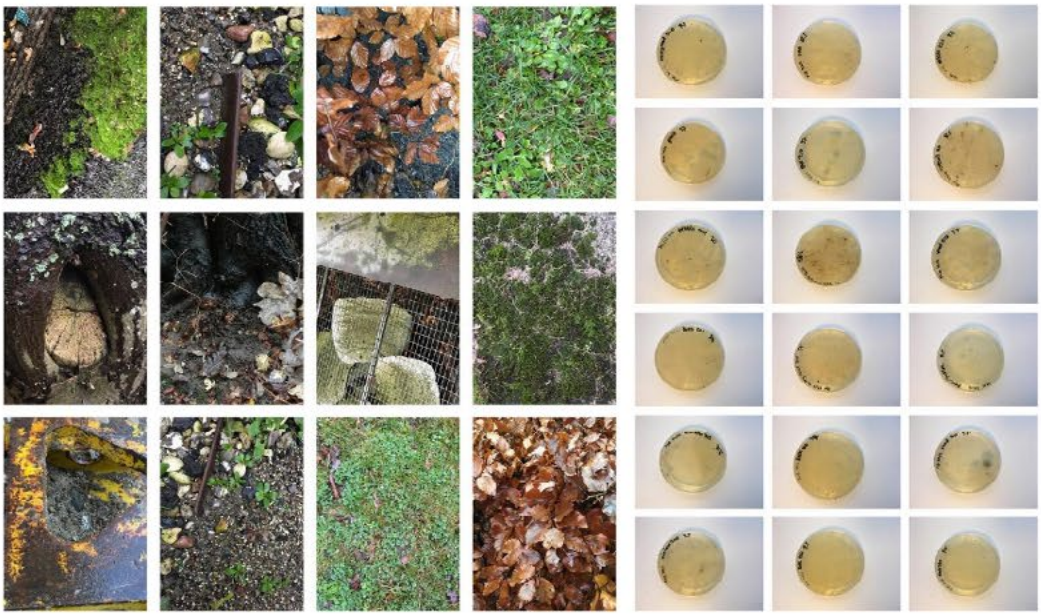

Figure 2: Surfaces for collecting bacteria samples.

The LB agar plates with the bacteria samples grew at either room temperature, 25 degrees Celsius or 37 degrees Celsius. This was chosen to have different conditions, since the optimal growth temperature of bacteria can vary. We did not know, which bacteria we had collected, so to get as much variety of bacteria as possible, we tried different growth temperatures, hence enhancing growth for some bacterial strains. In figure 2 (right side) the bacterial samples are displayed and show their growth on the agar plates after a period of 2-3 days. At this point the bacterial colonies can be seen on top of the LB agar in the petri dish as small dense material clusters, some of which were coloured, but most of them were white or opaque and not of interest to us in this study.

Isolate and identifying bacteria

The samples were not bursting with colour, but when we looked closely, we could spot small pigmented colonies. Figure 3 shows one of the plates, where a pigmented colony is visible, which was then isolated on a new sterile LB agar plate and grown under the rights conditions and hence the pigmented bacteria become clearly visible.

The name of the isolated bacterium was still unknown, so the DNA sequence was mapped to find the name of the bacterium and hence whether it was safe for us to continue working with. In figure 4 the different steps in the process are shown. First, we needed to extract the DNA from the bacterium. A sample was collected from the isolated bacterium and the DNA was extracted with a DNA extraction kit. The extracted DNA were run through a copying machine in a process called Polymerase Chain Reaction (PCR). In the PCR process two small synthetic DNA fragments (primers) which complement

the extracted DNA are used to perform the copying process. To check if the PCR was successful a gel electrophoresis was performed. Gel electrophoresis consists of a polysaccharide gel called agarose gel with small wells, where the sample of interest can be loaded in one of the wells and a control sample in another well. A current run through the gel and since DNA is negatively charged it migrates through the gel according to its size. The DNA sample is made visible with a DNA-binding dye and seen as a band on the gel. The DNA band is then cut out, purified and sent for DNA sequencing.

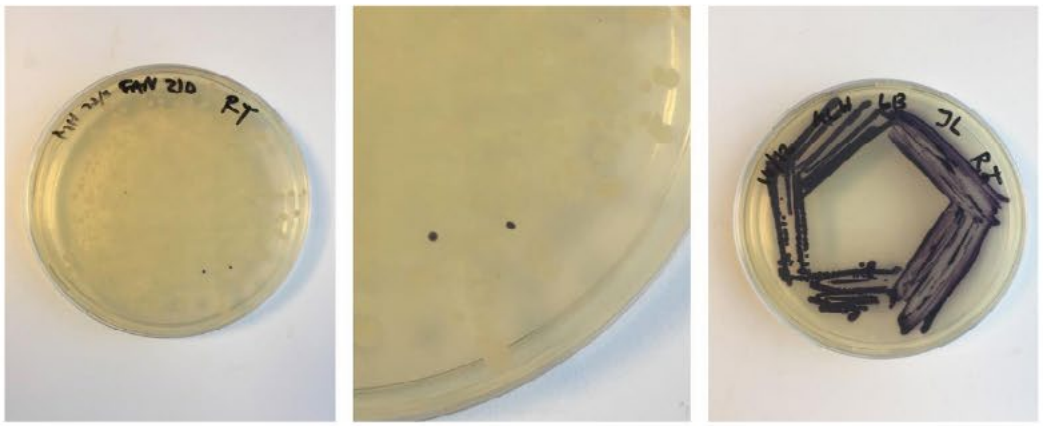

Figure 3: Sample with bacteria containing a pigmented colony is isolated.

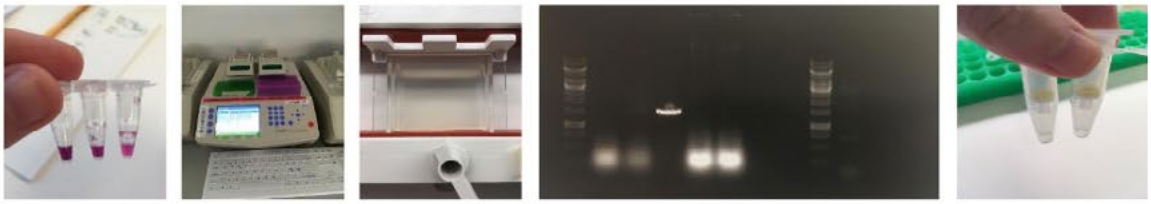

Figure 4: DNA is copied in the copying machine, run on a gel to check for DNA and finally sent for sequencing.

A company called Eurofins specialised in DNA sequencing performs this step. With the DNA sequence known a program called Basic Local Alignment Search Tool (BLAST) can tell the name of the bacterium. BLAST is an online search tool and here the DNA sequence of interest is uploaded, and the program provided us with a name for our isolated bacterium with a probability of approximately 98-99%.

Pigment production

Three different soil bacteria were used in the project: Janthinobacterium lividum (purple pigment), Serratia marcescens (red pigment), Micrococcus luteus (yellow pigment). The three soil bacteria are biosafety level 1 and thus safe for us to work with, when we take precautions and thus wear gloves and a lab coat. The bacteria all have an optimal growth temperature between 25-37 degrees, so we could grow them together in the same incubator, which is a storage box keeping a constant temperature in our case at 28 degrees Celsius.

The bacteria were grown in sterile petri dishes prepared with sterile liquid LB, which is made the same way as LB just without the agar called *LB broth*, in an incubator at 28 degrees for 3-5 days. Over time the bacteria produced a pigment, which can be used to colour textiles, shown in Figure 5.

Figure 5: Pigment production of the three pigments: purple, red and yellow .

Design methods

Material research: dyeing textile samples

The pigments produced by the bacteria are to some extent similar to the synthetic pigments used to dye polyester fibers. This can be seen from their chemical structure, since they have chemical groups which reminds of the chemical groups present in disperse dyes [30]. The bacterial pigments are insoluble in water, which also is the case with disperse dyes. This knowledge provided the foundation for choosing our dyeing method, since polyester was chosen as the textile to be coloured.

The dyeing process were performed in a pressure cooker through a heating process. Polyester textile is normally dyed in a heating process at 130 degrees. It was not possible to reach this temperature with the available equipment, so the pressure cooker was a compromise, since it can reach temperatures above 100 degrees. Polyester fibers get soft and starts to vibrate, when heat is applied. The pigment can then adhere to the fiber and colour the textile. The textile samples were prepared as 9cm × 18cm samples and put in a glass jar, which was placed in the pressure cooker and dyed for 2 hours. This process is no different from the dyeing process normally used to colour polyester textile, even though bacterial pigments were used.

Prototyping: material experiments

The material experiments were created in a three-step scenario projecting how bacterial dye could evolve. We used a scenario to try and predict what the next five years could look like, if bacterial pigment were developed and implemented instead of the conventional synthetic dyes. The three-step scenario is shown in Figure 6.

Scenario 1 is based on the bacterial pigments available now and is textile samples dyed using only bacterial pigments. Scenario 2 is a prediction of what could be possible within 1 -2 years and the textile samples for this scenario are created from scenario 1 and mixing bacterial pigments with conventional synthetic dyes for polyester. Scenario 3 is a prediction of what could be achieved in 5 years and the textile samples are made from scenario 1, 2 and using synthetic dyes. The reason we have divided the replacement into steps, is due to fact, that creating and implementing the bacterial pigments is a time - consuming process.

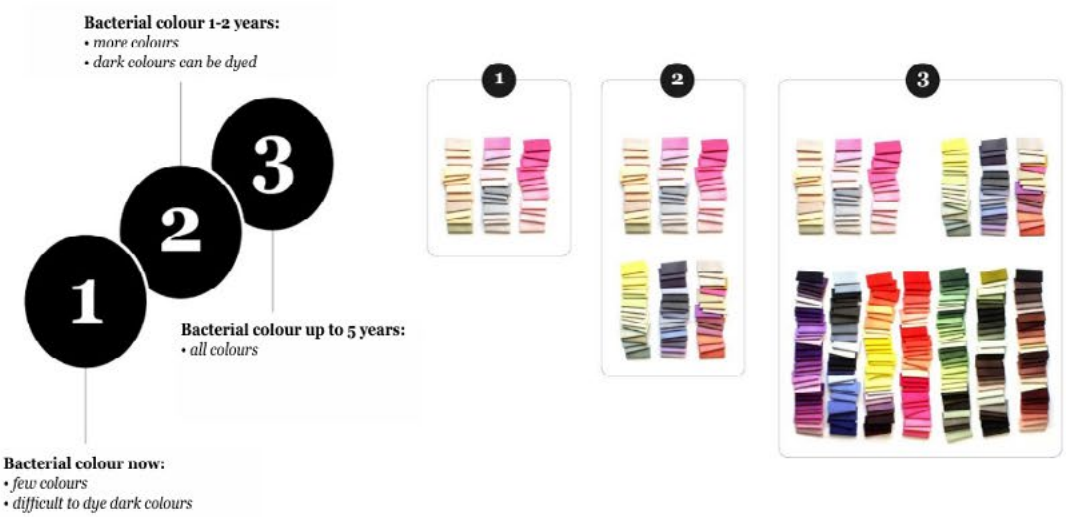

Figure 6: Three-step scenarios.

Prototyping: design case

The coloured textile samples from each scenario were used to create a wide range of colour composition, in an iterative process, contributing with knowledge of how the colours look, when they are placed next to each other, hence providing knowledge to the further development of the textile design. Afterwards the different versions were used in a comparative analysis, a selection of colour compositions from scenario 1 areshown in Figure 7.

Figure 7: Development of colour compositions.

Textile design practice builds on knowledge, teaching methods and design theory of which some dates back to the designers from the Bauhaus movement: Walter Gropius and Johannes Itten [31]. One of the first colour theorist you meet as a textile designer is Johannes Itten, who published *The Art of Colour* in 1961. We chose to use Ittens colour theory principles and his twelve-step colour circle as an inspiration to create different themes for the different colour compositions e.g., contrast colours or neighboring colours. The colour composition development was done separately for each of the three

scenarios. The colour compositions provided a way to study, if the colours where possible to produce in a range, that would be visually appealing to apply in a textile design context.

Figure 8: Textile samples and the chosen colour compositions from each of the three-step scenarios 1, 2 and 3.

Design experimentation

In the textile development process our previous studies could be applied. We wanted to create a woven textile design and to do this we needed to study, how the colour and colour compositions would behave in yarn instead of a textile surface.

First, we attempted to translate the chosen colours from the textile surface samples to yarn samples, displayed in Figure 9. It was important to experiment with the colours and colour compositions in the yarn to see if the colours were still appliable.

Figure 9: Yarn and colour compositions yarn samples from scenarios 1.

Second, we attempted to create a binding pattern for the woven textile design. The binding pattern describes how the textile is woven, hence its structure. It was created from the simplest woven structure called plain weave. We chose to use a plain weave, due to its strong structure and we wanted to emphasise the colour as the major design element. The development process is shown in Figure 10, where the colour changes how the binding pattern looks, even though it is the same pattern.

Figure 10: Different colour expression in plain weave structure.

In Figure 11 samples from the woven structure development are shown. We printed out paper samples with our textile design structure to get an overview of the different colour compositions and also to get an idea of how the textile design would look in the right scale. From the paper samples we chose the colour compositions for the final textile design and created 15cm × 15cm handwoven samples to get an idea of how the textile could look, if it was woven on an industrial weave.

Figure 11: Paper samples of the textile pattern and handwoven textile samples.

Findings

Design prototypes

The studies show, that it was possible to use bacteria as an alternative to synthetic pigments and apply in a design context and have led to results in different stages, which could be applied in the following design process.

The first result is the material samples we created from the three-step scenario. They are displayed in Figure 6. It was not possible for us to work with more than three different bacterial pigments, but we were still able to produce a range of colour from those pigments creating a varied colour expression from pink, violet and yellow to orange, green and brown of which some were very vibrant. In the coming years more pigments will become wide available for designers to use, which we tried to depict with scenario 2 and scenario 3. Scenario 2 is a mix of synthetic and bacterial pigments, thus indicating that until all pigments become available from bacteria, we can substitute them along the way and decrease the need for synthetic pigments.

The material samples from each scenario were used to create the colour compositions for the final textile design. Figure 8 shows the chosen colours and colour compositions for each of the three scenarios. Here we can see an increase in the colour range and colour intensity through the three scenarios. The final result is a woven textile design 36 colour compositions in total, 12 in each scenario.

Collaborative approach

The collaborative nature of the project made it possible to carry out experiments not normally possible in either of the two disciplines on their own. Without the natural scientist, it would not have been possible for the designer to go out in the nature, find and isolate the bacteria and produce pigment from them, hence the collaboration made it possible for the designer to experience all of the steps from cultivating bacteria to designing a textile, where in a 'normal' design process, the designer would have to imagine, what the natural science process would be. On the other hand, the natural scientist would not have tested the bacterial pigments in a context, they would have stopped their process after they had seen the bacteria were capable of producing pigment and possibly worked on optimising the pigment yield and cultivation method.

The collaborative approach made it possible for the designer to apply knowledge from the natural science field and use the knowledge to explore a design potential. Thus, the collaboration gave new ideas and reflections for both disciplines.

Future work

The research described in this paper could be developed further in several directions. We will present 7 paths A-G, where we see future studies could be carried out from the challenges, we met in the present research project.

A) A study on the full effect of the bacterial pigments: We had six weeks to produce our bacterial pigments. This affected scenario 1, where all the material samples were dyed with bacterial pigments, narrowing the colour range we could create, not only the number of different colours but also their intensity. We would have liked to study, how intense the colours could get using our dyeing method, but we chose to study the colour range instead, since it was important for

the further study and our hypothesis, that bacterial pigment in the future can replace synthetic dyes.

B) A study of several different bacterial pigments: This could determine if the colour range could be expanded and if it truly can replace synthetic dyes as we envisioned in scenario 2 and 3.

C) A study of the bacterial pigment's lightfastness: It is crucial for the industry to create textiles, which are lightfast, making it relevant to study if our dyeing method creates lightfast bacterial colours, not only for polyester but also dyeing other materials e.g., wool, cotton and silk.

D) A study in the materials, which can be coloured with bacterial pigments: In the present study we chose to work only with a polyester textile, since we from the chemical structure of the pigments knew, that it would bind the pigments. It would be relevant to apply other textiles produced from different fibers: synthetic fibers, natural fibers and recycled fibers. D) would be relevant to study in combination with A), B) and C).

E) Several studies in user involvement: In our research project we did not involve possible users. Colouring with bacteria is a radical change for both the industry and the consumer, so their feedback would have been valuable to our further study, since colours are perceived differently by every human being and affected by the surroundings, they are presented in. If the bacterial pigments should be brought closer to end-market, consumer insights should be studied. The consumers are essential, since they are the ones using designs created with bacterial pigments. First, what are they thinking about wearing or using designs created with bacteria? Second, what do they think of the colours produced by the bacteria?

F) A study of bacterial pigments as a dynamic entity: Until now our thoughts have been directed to using the bacterial pigments as an alternative to synthetic pigments. Another approach could be to change the way, we think about colour as a static material and instead look at the colour's dynamic possibilities in combination with the bacteria. Bacteria are living organisms, so we could study, if it is possible to grow the colours directly in the textile, hence creating dynamic textiles using biofabrication and questioning our relationship with other species. F) could also be studies together with E) e.g., how does it feel to wear living bacteria on your body?

G) A study of the bacterial pigment's future possibilities using synthetic biology: Bacterial dye has the ability to evolve within the design field. According to Collets hierarchy from nature as-coworker to re-programming nature, as is the case with the company Colorifix. Their methods use synthetic biology to create their pigments genetically modifying a bacterium's DNA in line with class I genetically modified organisms (GMO) [15]. This implies a whole new design field to investigate, where the bacterial pigments can lead the way for future research. Designers here get the possibility to push the sustainable agenda forward and create interesting and sound design products, where new material technology such as biofabrication and synthetic biology can be applied in a design context.

Conclusions

Our project *Bacterial Colouring* studied if synthetic pigments could be replaced with bacterial pigments as a climate and environmentally friendly alternative and applied in a textile design. We used biotechnological methods to produce our bacterial pigments and applied them in design research through prototyping doing material research and investigating colour compositions suitable for the final textile design proposal. At this point in time, it is not possible to produce all colours from bacterial pigments, so in the scenario projections we envisioned a world, where all colours were made with

bacterial pigments. Our study finds, that it is possible to apply bacterial pigments in a textile design context and develop a design and natural science collaboration to explore and eco-friendly design potential of colouring.

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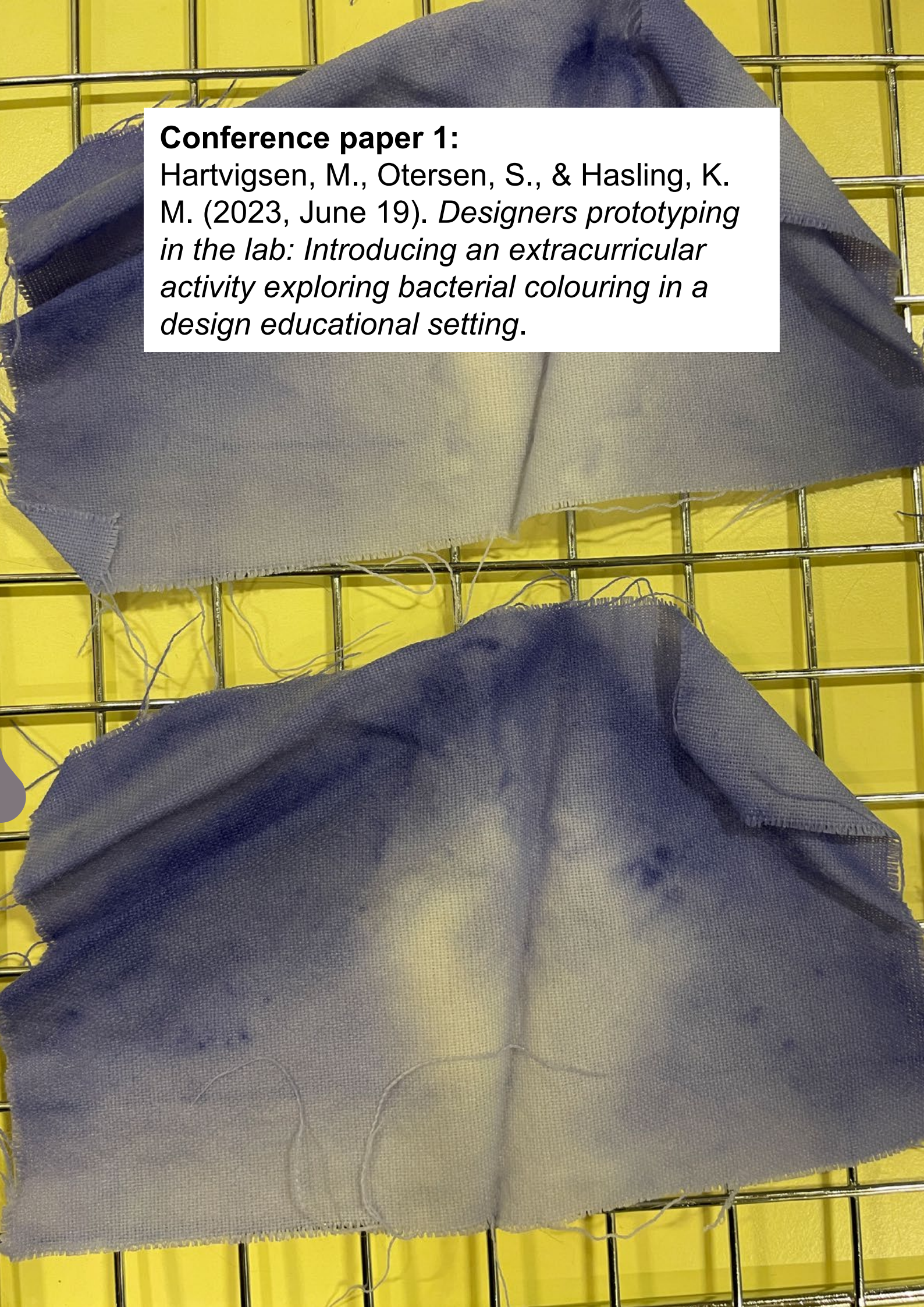

Conference paper 1:
Hartvigsen, M., Otersen, S., & Hasling, K. M. (2023, June 19). *Designers prototyping in the lab: Introducing an extracurricular activity exploring bacterial colouring in a design educational setting*.

Designers prototyping in the lab: Introducing an extracurricular activity exploring bacterial colouring in a design educational setting

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Abstract

This paper presents research from an ongoing PhD project on microbial colouring applied to textile design practice and education. In this paper, we study how bacterial colouring can be implemented as an extracurricular activity in a design school setting. By conducting a series of three workshop prototypes combining theory and hands-on experience, we explore how bacteria grow, how a special type of pigment-producing bacteria can be applied to textiles, and how to work with aseptic techniques and handle biological waste. As we were interested in how the students experienced the workshops, we gathered insights during the individual workshops and asked them to fill out an evaluation form.
To understand how theoretical and practical skills have influenced each other in the workshops, we propose a model. The model is used to understand and expand on how workshops can be used to provide and generate knowledge by combining theory and practice from both bacterial dyeing and textile design. We find that the model can be adapted for further workshop activities combining other design disciplines with an overlapping or adjacent discipline like in this study, where it has been biology.

Keywords: Bacterial colouring; Design education; Experiential knowledge

Introduction

As a response to the environmental impact of the industrial revolution an alternative perspective on production through biofabrication (producing materials from the growth of living organisms or cells) is emerging within the design research field (Myers, 2012). Designers are using biofabrication to be involved in not only *selecting* a material but also *producing* a material and Camere and Karana describe this material design practice as *growing design* (Camere & Karana, 2017).

In addition to design practice, European design schools are beginning to explore and incorporate biodesign as a part of their research and educational focus. In the United Kingdom, the Master's program in Biodesign was launched in 2019 (*Central Saint Martins Launches Masters Course in Biodesign*, 2019). In Finland, the ChemArts Summer School

combines material science and design (Kääriäinen et al., 2017; Kääriäinen & Niinimäki, 2019; Kaarianen et al., 2020). In Belgium, the LABORATORIUM at the School of Art Ghent is a place for design students to explore the intersection of design and biotechnology (*LABORATORIUM*, n.d.). In December 2022, the Technical University of Delft opened a biodesign laboratory in conjunction with courses in biodesign (*Opening van het hypermoderne Biodesign Lab van de TU Delft*, n.d.). In between design educations and the FabLab maker-movement Fabricademy emerged and provides designers with practical courses on textile, digital fabrication and biology (*Fabricademy Network Worldwide*, n.d.). In addition to the practical development's, studies into the taxonomy (Camere & Karana, 2018; Collet, 2020; Ertürkan et al., 2022) and knowledge on the biomaterials produced by living organisms (Rognoli et al., 2022) have emerged in cohesion with the practical elements.

In this paper we present a study, which has been conducted as part of a PhD project investigating how microbial colours can be applied to textile design practice and education. The research in this paper contributes to the field of biodesign education, by exploring how bacterial colouring can be implemented in design education as an extracurricular activity for students to develop useful skills for biodesign and textile design practice by participating in a series of hands-on bacterial colouring workshops in a design school setting. In the paper, we first introduce our understanding of and use of prototypes in the given research, we then argue for the reasons to develop the structure and content of a series of three workshops followed by a description of the workshops and finally we conclude with our findings and how these can be used for future research.

Prototyping in the context of the workshop

In this paper we discuss prototyping as having a multitude of meanings and modes, from the concrete bacterial pigments and the workshops to the intangible interaction happening among the students present in the workshops.
We align our understanding of prototyping as described by Sanders and Stappers (Sanders & Stappers, 2014; Stappers, 2014). Here prototypes in design research are described to carry out many roles; they evoke a focused discussion in a team; they allow testing of a hypothesis; they confront theories; they confront the world making tangible suggestions and they can change the world via intervening (Sanders & Stappers, 2012).
In figure 1, a visual representation of the different prototypes identified in this study is presented. The representation has been inspired by Redström's continuum between what *a* design is (product) to what designing is (paradigm) (Redstrom 2017), translated here into a continuum from a physical outcome (left) to the framing and design pedagogic and structural considerations (right). Hence, we see the prototypes presented here in different ways as carriers of concrete knowledge relevant for design research, which can be extracted and shared with others.

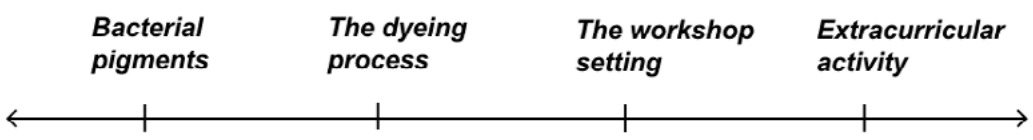

Figure 1: The different modes of prototypes in this research.

Below we provide an overview on the different modes of protypes identified in the study together with a question for each prototype to further expand on:

- The bacterial pigments: A concrete prototype of the tangible material applied in the workshops. How to learn about bacterial pigments in a design school setting?
- The dyeing process: A process prototype covering the bacterial dyeing processes, which is applied in the workshop. The first process prototype is the bacteria growing and producing pigment in a closed container with textiles. The second process prototype is the conventional textile dyeing process, where bacterial pigments produced prior to the workshops are used. How to introduce different dyeing processes with bacterial pigments for textile application?
- The workshop setting: A learning activity prototype proposing a frame for introducing knowledge emphasising a practical hands-on approach to students. How to frame a series of workshop activities that supports students' learning a new topic?
- The extracurricular activity: An organisational activity prototype facilitating knowledge exchange between (facilitators and) students beyond mandatory course work. How to use extracurricular activities to advance investigating specific topics for both researchers and students?

Method: Experiential approach to the workshops

The workshops are a part of a PhD project with an overall research through design approach (Koskinen, 2011), and in this study, design practice and prototypes are used as research means to gain insights. This allows the design researcher to actively engage in real-world problems or "*wicked-problems*" by constructing and exploring complex scenarios (Forlizzi et al., 2009).

Here, we are using a workshop setting involving participants and we find it relevant to briefly touch upon the concept of experiential knowledge. As designers and design researchers, we are actively engaging in the design activity; thus, we are using the dialogue and direct interaction between the students and the facilitated reflection for the individual student as means for us to extract knowledge (Niedderer & Reilly, 2011).

To document the interaction and experience, one of the authors was responsible for taking photos throughout the workshops. We also had a notebook to write down reflections after each conducted workshop. This included what we had observed during the workshops but also what the students had verbally expressed. This type of knowledge extraction is building on Schön's understanding of reflection-on-action (Schön, 1991, 1992), where our experiences are used as data for research findings (Mäkelä & Nimkulrat, 2018). In addition, a written evaluation form was developed beforehand to provide a framing for the feedback from the students' experiences.

Motivation for conducting the workshop series

We wanted to introduce the design students to bacterial colouring for several reasons. The first reason was to develop the workshop to provide the design students with a hands-on exploration of an environmentally friendly textile colouring process and learn about alternative bio-colourants, inspired by material tinkering (Parisi et al., 2017).

The second reason was the importance of having a practical element to the workshop. Since designers are used to have hands-on knowledge combined with theoretical knowledge: *"thinking and knowing are inseparable from making in any craft or designerly practices"* (Nimkulrat, 2012:2), we wanted to have an emphasis on mixing theory and experiential knowledge, while maintaining a focus on the practical elements.

The third reason was to use the workshop setting to teach students about biodesign and spark their curiosity about this growing research field. This provides them with introductory knowledge of laboratory work from a natural science perspective but situated in a design school. We believed that this would equip them with the foundational knowledge to explore this field further throughout their design education.

The fourth, and last, reason for conducting the workshops was to generate empirical knowledge for the PhD project conducted by one of the authors, to explore if or how bacterial colouring could be implemented at the design school. Hence the workshop was created as an extracurricular activity, intended for all interested design students at the school.

Creating the workshops

The series of workshops was created based on the pedagogical framing already present at the Design School Kolding. The school, originating in arts and craft, is building on Schön's approach of making and reflecting (Schön, 1991). Part of the research conducted at the school revolves around developing design skills, methods and tools (Bang, 2009b, 2009a; Hartvigsen & Hasling, 2022; Hasling & Bang, 2015; Møller et al., 2016; Ræbild & Hasling, 2019; Riisberg et al., 2014), which students individually or together can combine and develop further to match their individual interests, processes and design disciplines. Therefore, the workshops were also seen as an opportunity to formalise and test a structure for future learning activities within and beyond the curriculum.

The workshops were created as a series of three individual workshops that were building on each other and conducted within three weeks. In figure 2, the overall frame for the workshops is presented including the focus and content for every workshop. Each workshop started with a presentation introducing the theory behind the practical explorations in the individual workshop.

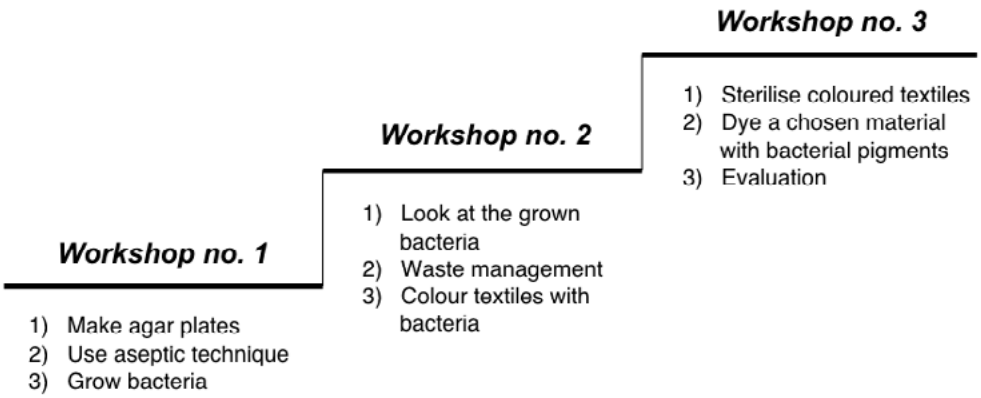

Figure 2: An overview of the content explored in each of the three workshops.

Another practical aspect of dividing the workshops into three parts was to allow time for the bacteria to grow and produce colour, thereby attempting to provide the students a transparent and full process from start to finish of bacterial colouring.

Conducting the workshops

The three workshops were conducted at the Design School Kolding and exclusively offered to the school's students. To attract students to join, all students were invited via email with a poster describing the workshop series. Out of the 350 students, 60 wanted to sign up, which indicates the relevance and interest in the given topic.

However, as the workshop space and resources were limited, we had to select a smaller group of students to conduct the workshops with. Therefore, we chose 14 students in total–seven textile design students, three fashion design students, three industrial design students, and one communication design student–and divided them into two groups.

One group (Group 1) predominantly consisted of students from the same interdisciplinary master's program and year, which, in parallel with the workshop, had a course on material roles in design for sustainability that initially served as a framing and context for the workshop series, while the other group was composed of a mixture of students from different disciplines and years (Group 2).

Workshop no. 1

In the first workshop, the students were introduced to the basics of how to work with microorganisms by showing them how to prepare a nutritious solution for creating agar plates and letting them actively participate in the process.

A crucial step during this phase was to autoclave the solution in a pressure cooker to ensure the absence of unwanted bacteria or microorganisms. This meant that the solution had to sit inside the pressure cooker for approximately 30 min. During this time, we gave the students a presentation about the theoretical part of the workshop in a separate classroom. The presentation entailed introducing them to what bacteria are, how to cultivate them, how to work with them in a sterile manner, and practical input regarding the next steps in the

workshops.

After the autoclave process was completed, the students were brought back into the lab, and shown how to pour the liquid medium into petri dishes to create the finished agar plates. This was done by showing them how to do it and ensuring that the most crucial steps were pointed out. Afterwards, the students went up one by one to try out the process under the supervision of the workshop leader. The agar plates must be poured when the solution is still warm and must be set for a couple of hours to solidify. Therefore, the students proceeded to work with premade agar plates in the next steps, see figure 3. They were asked to swab different surfaces for bacteria at the school, transfer them onto agar plates, and label them with their name, date, and the area they had swabbed. The workshop concluded by briefly touching upon what the students could expect from the next workshop and explaining what would happen to the agar plates that they had created.

Figure 3: Workshop no. 1 – (from left to right) Students are preparing agar plates, they are writing on the agar plates and using them swap surfaces to grow microorganisms from the local surroundings.

Workshop no. 2

The second workshop was initiated with an introduction and discussion of waste management in a biolab setting. The students reviewed the results of their previous experiments on swabbing different surfaces and instructed on how to grow bacteria on fabric swatches. We started the workshop by showing the students the results of their previous experiments and had a casual conversation about the results, as well as letting them discuss their results amongst each other, see figure 4 (middle). Furthermore, the students were shown how the agar plates that they had poured in the last workshop turned out and given input on which ones turned out well and were usable and which ones were not, clarifying which mistakes could be avoided in the future.

In the next step, students learned how to dispose of their waste properly when working with living organisms. They were asked to place the previously discussed agar plates in an autoclave bag and close them with tape. The bags were then placed in a pressure cooker and sterilised for 30 min. In the meantime, the students received another theoretical lecture as preparation for the practical part of the workshop as well as background information about dyeing with bacteria. We also showed them fabric samples that were dyed with a bacterial dye as examples of what the fabrics they would work with might look like. As the students

returned to the lab, they were shown that it was now safe to dispose of sterilised plates in the residual waste bin.

We prepared several autoclaved bags with undyed textile swatches, each containing different types of textiles such as wool, cotton, and polyester. Furthermore, we brought in previously sterilised liquid growing medium and agar plates that carried streaks of two different pigment-producing bacteria: one that produced a yellow pigment and one that produced a blue/violet pigment. The students could choose one bag of swatches each and choose which bacteria they wanted to use to dye their swatches, see figure 4 (right). It was emphasized that not all bacteria would produce the pigment, as we were working with wild-type bacteria, which cannot always be controlled to produce colour, although applying the same process.

Therefore, students would have to share their final results with each other so that everyone could obtain a dyed sample. The students were then shown how to pour the medium into the textile bags, streak the bacteria from the agar plate, and transfer it into the bags. As in the previous workshop, the students came up individually and carried out the process under the supervision of the workshop instructor. At the end of the workshop, we explained what the students would expect from the next workshop and asked them to bring in material samples that they would like to dye.

Figure 4: Workshop no. 2 – (from left to right) Students are looking at the microorganisms from the local surroundings, they were introduced to cultivate pigment producing bacteria and prepared textiles with pigment producing bacteria in a local sterile environment.

Workshop no. 3

In the final workshop, the students sterilised the fabric samples they had made in workshop no. 2 and learned how to dye them with pre-sterilised bacterial pigment dye. At the start of the workshop, the bacteria-dyed textiles made in Workshop no. 2 were shared, and the students were encouraged to discuss them.

Prior to the workshop, we autoclaved the bags of dyed textile samples, so they were ready for the students to open, wash and dry, see figure 5 (top row). While the samples were drying, the students entered the presentation room for the theoretical part of the workshop. In this lecture, they were introduced to different bacterial pigments, including their molecular structures, to understand why the pigments bind to the fabric. Moreover, the students were

introduced to the practical part of the workshop: dyeing with sterilised bacterial pigments.

Back in the lab, we asked the students to find the materials they had brought with them. We then asked them to place the samples in previously prepared jars, containing 40 ml of bacterial pigments, and then filled the jars with water until the samples were fully submerged. The students were then asked to place the jars with their samples in a large pot partially filled with water. After all the jars were placed inside the pot, we explained that the pot would be heated for at least 30 min, so that the hot steam would fix the pigment to the materials. During the time needed to fixate the pigment, the students returned to the presentation room and were asked to fill out an evaluation form for all three workshops.

Afterwards, the students took their samples out of the jars and placed them onto a grid, where they could observe how the colour had been absorbed by the different types of materials, and discuss and compare them in the group, see figure 5 (bottom row). To conclude the workshop series, the students shared their dyed samples from Workshop no. 2 and took home the samples from Workshop no. 3.

Figure 5: Workshop no. 3 – (top row) Students look at the textiles which have been coloured by the pigment producing bacteria. (bottom row) Students use already prepared bacterial pigment to colour various materials.

Findings from the students

To further gather student's insights from the workshop series, after the final workshop they were asked to fill out an evaluation form. While the ongoing discussion and reflection focused more on the individual workshops. We used the evaluation form get the students to reflect on

the workshops as a whole. We received twelve evaluation forms, since two of the students were not able to participate in the last workshop.

In the following section we will describe the students' feedback and insights using the prototype hierarchy introduced in figure 1 to guide the insights.

Bacterial pigments

We had planned the workshops around the possibilities of the bacterial pigments. Hence it was difficult to separate the bacterial pigments from the dyeing process. The students had good reflections on the potential of the bacterial pigments.
One student was wondering whether it was possible to manipulate the patterns that the bacterial pigments created, while another student responded that it was difficult to work with bacteria as a designer, because the outcome is so spontaneous.

The dyeing process

In the evaluation form, the students were asked to describe their thoughts on the designs that came out of the bacterial dyeing process. The majority of students responded that they liked the organic and unique designs given by this kind of dying process and that they liked the imperfections and found the designs to be meaningful and inspiring. *"I feel very inspired, and I think it is still (a) quite unexplored technique for designers, so I'm glad I could try it."*

The workshop setting

As a part of the evaluation, we asked the students to grade the workshop from being boring (grade 1) to being interesting (grade 5). Based on this, the average grade was 4.67, which corresponds with the general impression that students found the workshops to be interesting. In the evaluation form, the students were also asked to describe how they experienced the workshops and here their responses were similarly positive. Many of the students responded that they found the workshops interesting and insightful while others answered that they learned something new and got inspired and that they liked working with a different medium. They furthermore responded that they liked the hands-on approach and the combination of theory and practice. One of the participants stated "*it was really interesting to discover new natural alternatives to chemical dyeing. Also, I really liked the fact that we were both provided with theoretical courses and hands-on practices.*"

Since we had structured the activity as a series of three consecutive workshops, we were interested in better understanding, which workshop the students found most interesting and relevant. Two students favoured Workshop 1, six students favoured Workshop 2, four students favoured Workshop 3 and one student favoured all workshops equally or favoured them as a whole.

While many students found Workshop no. 2 more relevant and interesting as they got to work with bacterial dye and "*see the magic happen*", many also stated that they liked the combination of all three workshops. One student said *"I loved all workshops equally since all of them had both theory and practice. Seeing the results is as exciting as doing the agar petri dish."*

In the evaluation form, we also asked the students which parts of the workshops they found to be difficult and which parts they found to be easy. The students overwhelmingly replied that the workshops overall were easy to follow and very understandable. Many answered that they did not find the workshops difficult at all, while several others replied that it was challenging for them to work in a sterile way.

We also asked the students if they would like to change anything about the workshops. Most of the students responded that they would have liked even further theoretical explanation about bacterial dyeing and getting to know more about one of the author's PhD project with bacteria. Several students responded that they would have liked to create a bigger piece of bacterial dyed fabric and to be able to design patterns and products, as well as wanting to receive more tips on how to get started with biodesign on their own. One student responded that it would have been great to receive a leaflet with more detailed information about the workshops.

Extracurricular activity

As we were also interested in understanding the potential of the workshop series as an extracurricular activity with the same or similar topic, in the evaluation form, the students were asked if they could imagine working with biodesign in the future and if they would be interested in taking part in further biodesign workshops for example about mycelium or kombucha. Except for one student, who was not interested in pursuing biodesign, all others replied that they find it an interesting topic that they would like to incorporate in future projects. One student stated: *"I believe that there is a lot to explore in the field and I see great potential on this approach in specific."*

Findings from our experience as workshop facilitators

The following section will focus on our experiences as workshop facilitators using the identified prototype hierarchy to guide the insights.

Bacterial pigments

During the workshops, we saw that the students were good at reflecting on how they could apply bacterial colouring and living materials to their own design discipline. This sparked interesting conversations during the workshops on how the students could proceed if they wanted to continue working with bacterial pigments, thus creating new connections between students with similar interests.

The dyeing process

As already mentioned, the bacterial pigment and the dyeing process are closely connected. The students were mostly interested in the dyeing process using the living bacteria, as it was an approach which the students had not experienced before. Most of the students had a background within textile and fashion and therefore knew about the process of conventional dyeing, which were the other approach to the bacterial dyeing process.

The workshop setting

As facilitators we experienced how the students participated in the workshops. Here we could observe, how students from Group 1 (predominantly students from the same course and year) found it easier to approach the workshop format and content, while students from Group 2 (mixed group of students) had more questions, found it difficult to discuss output and reflect on insights from the workshop with each other during the workshops. Here it can be relevant to mention that the workshops were conducted in English, the language commonly used for the master students, but not for the bachelor students, which might have made some more reluctant to actively engage in conversations.

Extracurricular activity

From the workshops, we were interested in gaining insights on the students' willingness to and motivation for engaging in extracurricular activities building on and advancing concepts and methods introduced as part of the curriculum but also to enable students – and us as researchers – to explore new and emerging topics that might not fit into or have not yet found their way into the curriculum. To discover the balance between what to offer as part of the curriculum, what to offer as extracurricular activities internally in the school and what to propose to and expect from students to take initiative and explore on their own.

Some students asked us, in case they wished to explore the biodesign field further, how to continue on their own, since they felt a barrier towards continuing on their own. It would thus be interesting to follow students as they continue their educational journey, to see if they incorporate biodesign into their practice.

Proposing a model to navigate between prototype hierarchies

Based on the identified hierarchy of prototypes and findings from the practice-based study engaging students, we find it relevant to elaborate on this based on a proposed model used to navigate between prototype hierarchies and that considers the design discipline (or sub-discipline) in dialogue with overlapping or adjacent disciplines (vertical axis) and that promotes input from theory-based knowledge as well as a practice-based skillset (horizontal axis). Visually, the model has been inspired by the shape of neurons and illustrates how knowledge and skills relate to each other, see figure 6. Dependent on the emphasis of the four domains, the shape of the model can be altered.

Here the workshop format has been valuable as a protype to explore and expand on the model to understand the overall framing and mindset needed to facilitate the meeting between different disciplines.

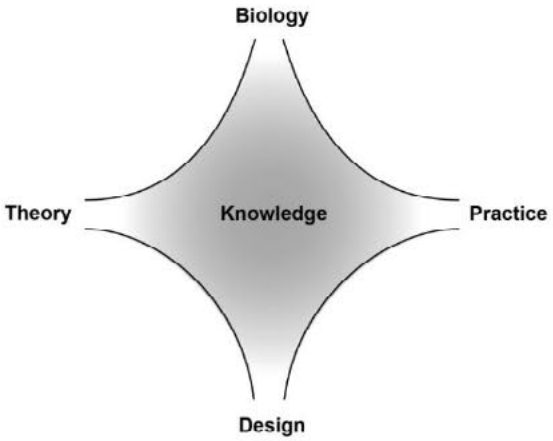

Figure 6: The general model where there is an equal distribution between theory, practice, biology and design.

The model illustrated in figure 7 shows how the different knowledge and skill domains that the students have engaged with during the workshop series connect to create new knowledge. The knowledge and skill contributions are shown as bubbles that are feeding into a pool of shared and common knowledge at the centre of the model.

In this particular workshop series prototype, we wanted to bring together bacterial dyeing and textile design practice and the majority of students participating came from fashion and textile design. As textile design to them is a familiar domain where students come with prior knowledge and practice experience, we experienced that they found it easy to understand and engage in the workshops.

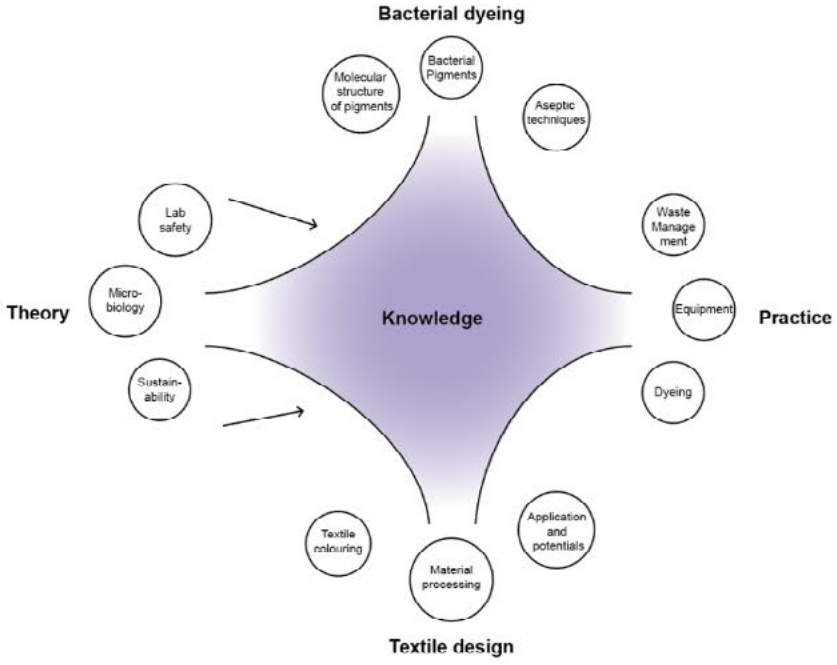

Figure 7: The model used to illustrate relevant aspects of the study - within and between the four domains and how domains push the balance of the overall frame.

The model can also be used to describe and illustrate the focus of workshops and other learning activities, by shifting its centre between the domains, depending on the target group of the workshops e.g., other groups of students or other professional disciplines. In this way it could be adapted to suit more advanced students, who want to know more about the theory and practice behind a topic, as illustrated in figure 8.

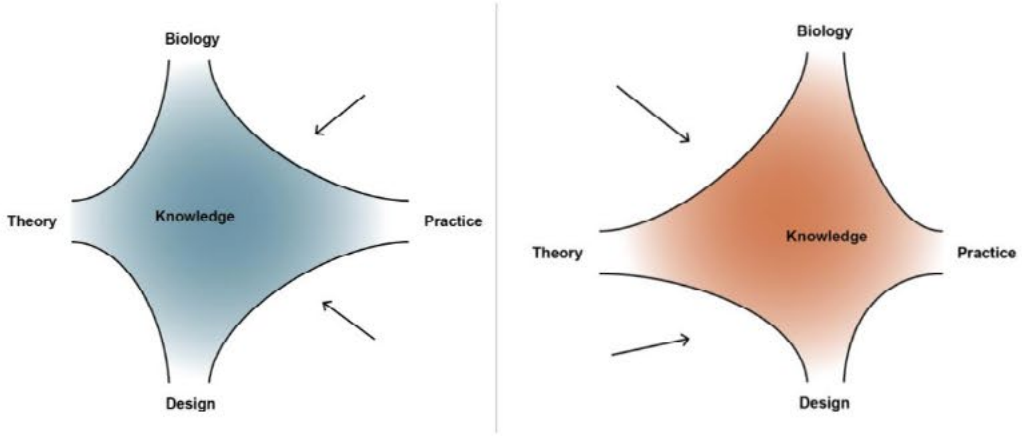

Figure 6: Left: the model where focus has been shifted towards theory and biology and right: the model where focus has been shifted towards design and practice.

Because the model emphasizes the connection of knowledge and skills from different domains and sub-domains, we see that the model can be used for other workshop prototypes that have a focus on bringing together design practice with biological practice as well as possibly a design practice with other intersecting or adjacent practices, see figure 9.

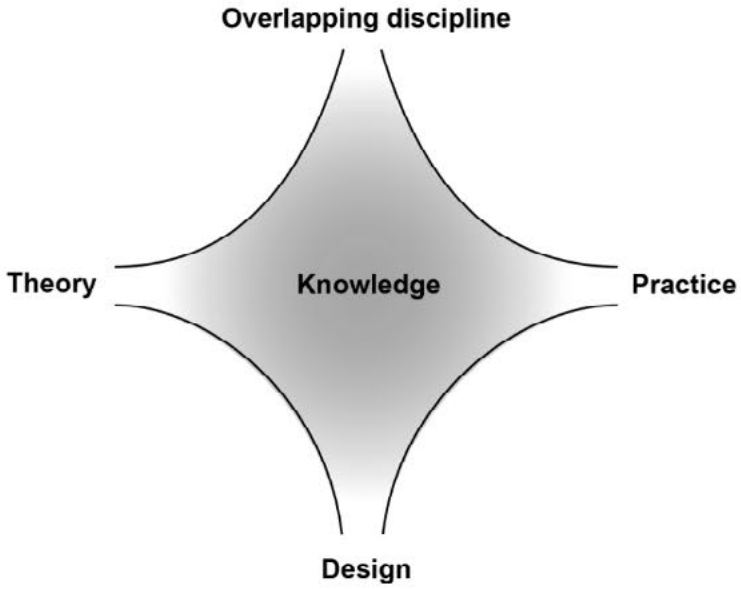

Figure 9: A proposal for a general model where there is an equal distribution between theory, practice, the overlapping discipline and design.

Conclusion

In this study we have investigated how bacterial colouring could be implemented in a design school setting using a workshop format.
We described our prototype hierarchy of the different roles of protypes in this study: *bacterial pigments; the dyeing process; the workshop setting and the extracurricular activity*.
By conducting a series of three hands-on workshops we introduced the students to bacterial colouring combined with textile design practice. In this first workshop we introduced how to grow bacteria, in the second workshop we introduced how to apply pigment producing bacteria to textiles using aseptic techniques and handle waste and in the third workshop we introduced how the bacterial pigment could be applied in a conventional dyeing process.

The students found the bacterial pigment and the dyeing process interesting and had some good reflections over the possibilities of how they could continue exploring the bacterial pigments. Overall, they all found the workshops inspiring, although most of the students favoured the second workshop. They also expressed an interest in joining other extracurricular activities exploring biodesign.

As workshop facilitators we experienced that the students were engaged and enjoyed the mix of theory and hands-on explorations. For understanding how the theory and skills had influenced each other we developed a model which helped us visualise how the knowledge was achieved in this particular series of workshops combining bacterial dyeing with textile design practice. We propose this model can be used for further workshop prototypes combing the design discipline with biology or other overlapping or adjacent disciplines.

Acknowledgements

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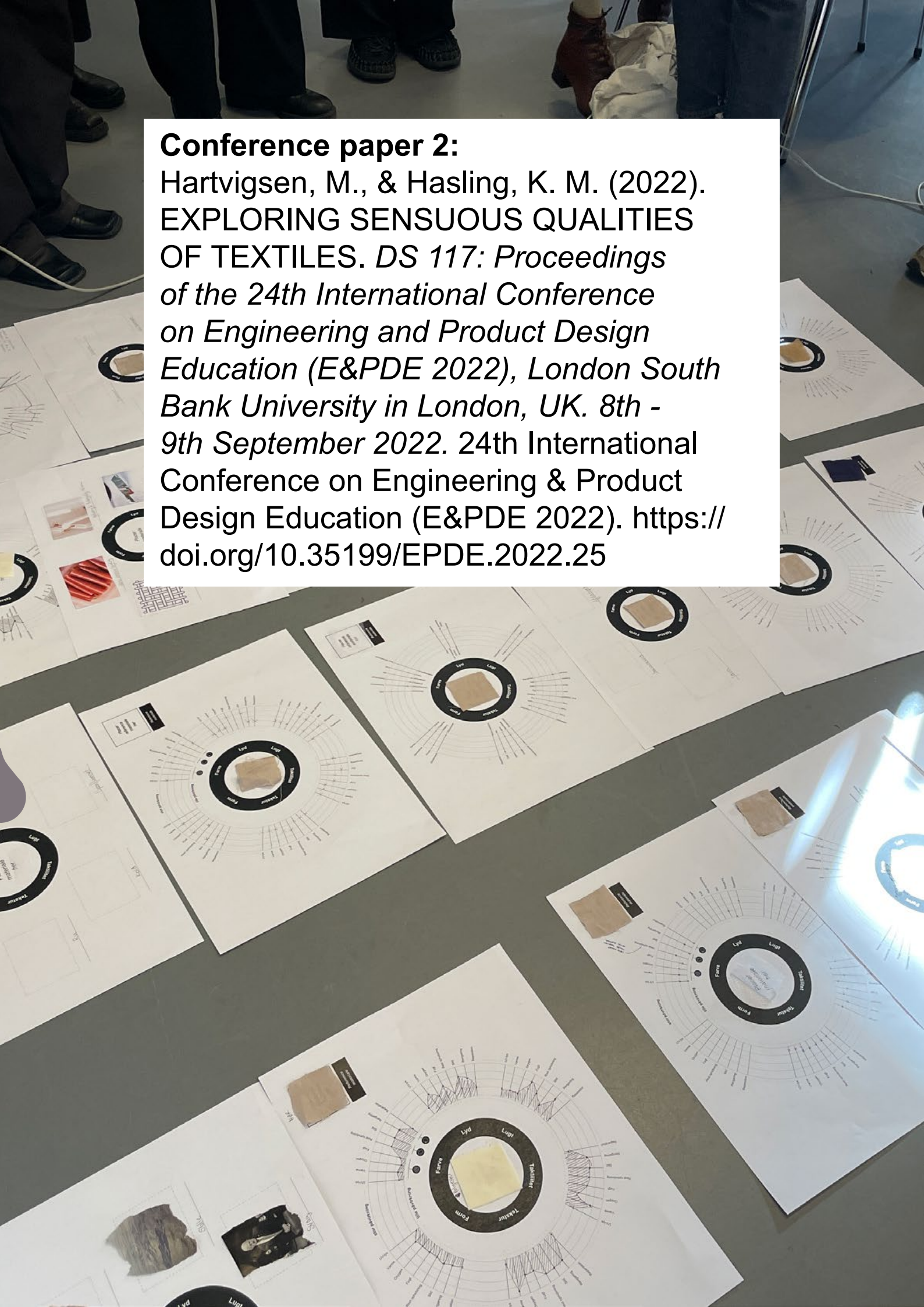

Conference paper 2:
Hartvigsen, M., & Hasling, K. M. (2022). EXPLORING SENSUOUS QUALITIES OF TEXTILES. *DS 117: Proceedings of the 24th International Conference on Engineering and Product Design Education (E&PDE 2022), London South Bank University in London, UK. 8th - 9th September 2022.* 24th International Conference on Engineering & Product Design Education (E&PDE 2022). https://doi.org/10.35199/EPDE.2022.25

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

EXPLORING SENSUOUS QUALITIES OF TEXTILES

Monica Louise HARTVIGSEN and Karen Marie HASLING
Design School Kolding, Denmark

ABSTRACT

As designers we engage with materials in various ways throughout the design process. Especially textile designers who are met with a demand to be able to describe and communicate textiles – in words as well as in physical materials. In this paper we propose a tool consisting of a sensorial wheel and a visual wheel aiming at textile design students at a foundational level.
The tool is meant to develop textile designers' awareness and language by evaluating existing textiles, but at the same time providing the students with an open tool to readjust and combine with other methods and include in their existing design process.
The tool has been tested in a workshop at BA level and showed that students were able to evaluate and vocalise their chosen textiles and the sensorial qualities the textiles expressed by using the two wheels. In the reflection session afterwards, we have focused on the outcome of the sensorial wheel for the students to reflect on the use of the tool and how they experience sensorial qualities differently, thus developing their individual design language and process.

Keywords: Design education, textile design, textile expression, sensuous qualities, learning tool

1 INTRODUCTION

Making, describing and selecting material is something design students are engaged with throughout their education. In this paper we look closer at the textile as material of investigation. We find it relevant to explore textiles specifically, as textile designers are highly engaged with the development of textile materials, including choices on fibre, yarn, construction and after-treatment level. Here students are met with a need to explain their material choices in relation to technical, aesthetic and functional aspects. Furthermore, since textiles are applied to a certain context, it is essential that the embedded sensuous qualities expressed in the textile match the context of use.
With this paper we want to develop and explore a tool mainly for textile design students to engage with the sensuous qualities of textile materials. This is done as a support for students to further develop a vocabulary to enrich their decision making and communication of design choices, when developing textile materials or selecting them for certain applications.
In design education different scholars have contributed with tools and methods aimed for design student to explore the sensorial dimension of materials. Examples of these are *The Experience Map* [1,2], *The Comparative Scale of Materials Attributes* [3], *The Repertory Grid* [4], *The Tripod Approach* [5], *The Atlas of Materials* [6], *The Meaning of Materials Tool* [7], *The Materials in Product Selection tool* [8]. The proposed tool is not meant to be used instead of these, but in addition to, together with or before these, as we wanted to develop a tool for design students on a foundational level. Consequently, the tool provides the student with an uncomplex approach to work with sensorial qualities using the tool as an entry point for further and more complex exploration of materials and their attributes.
To develop our tool, we used *The Experience Map* (ExpMap) as a primary inspiration source and build on parts of the framework it presents. The ExpMap presents a procedure of five steps that takes the user from an existing product and a vision statement ending with a sensorial analysis [2].

1.1 Why create another learning tool?

In our tool we wanted to have emphasis on the textile itself and less on the context of use, here being an existing and envisioned product or vision statement. Furthermore, since the tool is aiming for mainly textile design students at a foundational level, these can be regarded as novice designers, we have wanted to develop a tool consisting of two activities that can be used together but also independently. Moreover, representing an institution with strong focus om design methods and processes, we have wanted to

propose ways to approach and understand textile materials that can add to students' existing tools introduced in the programme rather than a defined framework. In our tool, emphasis can be put on the reflection and discussion session after comparing the sensorial wheels, building on the work of Schön's theory of reflection-on-action [9,10].

The tool proposed in this paper is also a part of a larger pedagogical frame and teaching methods, for instance we have asked the students to build a repository of materials, a material library, which the students collect and produce themselves, which they afterwards can use in different exercises, taught at the school, and as a part of their design projects. This means that the tool can be presented in class as a brief exercise and then be modified and combined with other tools in multiple ways.

Finally, we found it crucial to develop a tool that encourages students to actively engage with – and sense - physical material samples (e.g., collected materials or materials produced as course work) using a hands-on and analogue tool that can be printed and worked with by students individually, in smaller groups as well as in class settings.

In the paper we first introduce the tool, we then explore and test the tool in a workshop with design students and we present the findings and discuss the insights from the workshop and present future work.

2 SENSORIAL AND VISUAL WHEEL

The developed tool consists of two wheels: a sensorial wheel and a visual wheel. In Figure 1, the templates for the two wheels are shown. For the wheels, we have worked with six categories: *Colour, Shape, Sound, Odour, Tactility and Texture*. Some of these categories relate to a certain sense while others are a combination of senses e.g., *Colour* relates to our visual sense, while *Texture* combines both the visual and touch senses. This approach forces the user of the wheel to focus on all the sensorial qualities of a textile simultaneously.

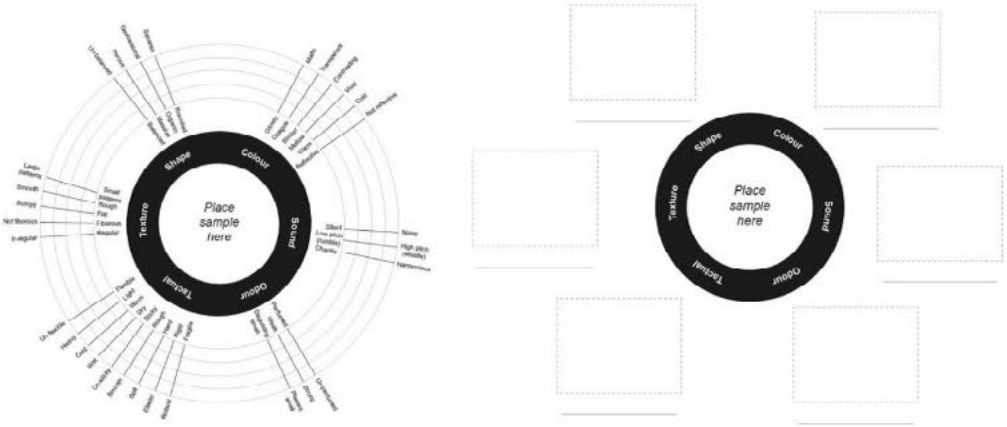

Figure 1. The sensorial wheel (left) and the visual wheel (right)

Inspired by the ExpMap, in the sensorial wheel we use multiple contrasting word pairs to create scales to assess each category. In the *Colour* category the word pair *Mellow-Vivid* is contrasting each other as a scale to subjectively evaluate the colour from. Contrasting word pairs continue around the wheel and gives a visual representation of the sensorial qualities of the textile. In the sensorial wheel new word pairs can be added to allow the user to personalise and thus describe the textile of sensorial investigation as thoroughly as possible, an example can be seen in Figure 2 visualised by a dashed line.

The visual wheel is a continuation of the sensorial wheel. The user chooses one word from each of the six categories and writes the word under the square assigned to each category. The chosen words are used as inspiration to find a visual material representation that describes the word of interest, thus adding a visual 'layer' to describe the textile.

The tools are meant to be worked with in a physical form, providing the user a hands-on approach to evaluating sensorial qualities of textiles, thus allowing easy reflection and discussion, since the wheels can be placed next to each other and shuffled around to allow multiple configurations. Configurations could be e.g., comparison of multiple material samples by individual students as a means to understand contrasts in materials or comparison of material samples amongst a group of students to understand contrasts in students' understanding and interpretation of the samples.

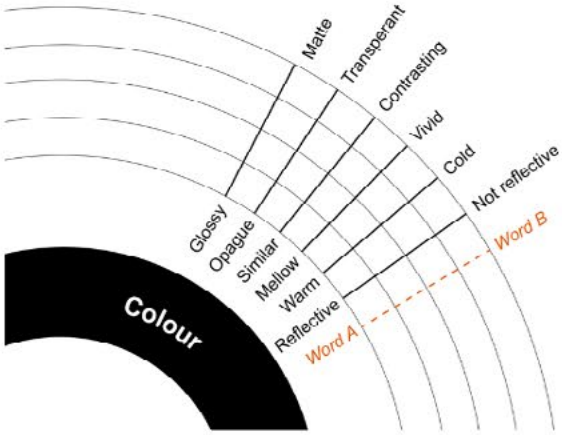

Figure 2. A section of the sensorial wheel showing how a word pair could be added

3 THE WORKSHOP - CONTEXT

The workshop was carried out as a part of a BA course at our institution on material strategies during the sixth semester. The workshop was attended by four textile design students, two accessory design students and six industrial design students. In the workshop, we wanted to introduce the wheels as a learning tool to understand expressions of already existing textile samples. For the workshop, we prepared 5x5cm textile samples of various compositions, differentiating in fibre, construction, colour and texture to provide the students with samples holding contrasting sensorial qualities.

We also provided the two wheels on A3 size paper to emphasise the physical interaction with the textiles and to allow for a physical, hands-on discussion. In Figure 3, the two wheels with the same sample made by one of the students is shown.

Figure 3. An example of one of the students filling in the two wheels

The students were asked to choose two textiles and evaluate these based on both wheels. Some students chose to work individually while others worked together. After students had evaluated their chosen textiles, all wheels were placed next to each other, shown in Figure 4, to provide a visual overview and allow for direct comparison between wheels and to support reflection and discussion among students on their evaluations and how the use of the tool was experienced. To evaluate the tool and the workshop, notes and insights from the students were written down, while the students were working with the wheels as well as in the discussions afterwards.

Figure 4. Students discussing their wheels in groups comparing how they have analysed the sensorial attributes of the chosen textile

4 FINDINGS

During the workshop, some students found it easy to work with the wheels, while others were a bit more apprehensive until they got started. After a few initial questions, the students worked concentrated on the two wheels. It seemed to help the students working in groups, being able to discuss together on how they would evaluate the sensorial qualities of the chosen textiles, already reflecting on the sensorial qualities and vocalising their understanding with each other, while filling out the wheels.

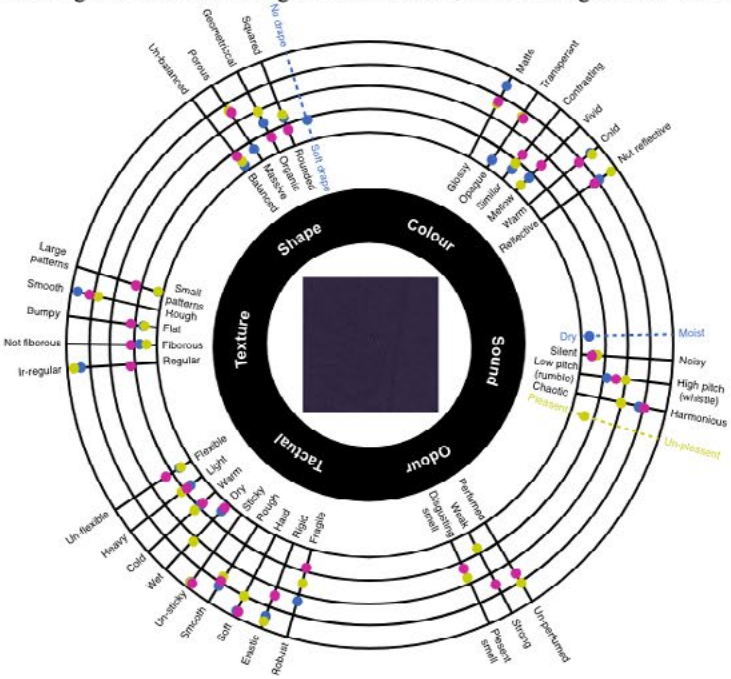

Figure 5. Examples of how students have filled in the sensorial wheel for one of the samples. Sensorial wheels for three students have been placed on top of each other

In Figure 5 the three sensorial wheels from students having chosen the dark blue knitted cotton textile are shown. Each of the students is indicated with a colour. This represents differences as well as similarities between the different sensorial wheels, thus visualising how students evaluate sensorial expressions in different ways.

In the following session where the wheels were compared, students mentioned that they found it useful to work with textile materials, which are easier to compare, because they are in "family." It was evident, that students compared the two textile samples with each other, which was not initially something we asked them to do. Here they evaluated the sensorial qualities by contrasting the two textiles they had chosen and, in some cases, using the same wheel templates. In addition, some also personalised their sensorial wheels and added contrasting word pairs, mainly in the sound category. On this, one student expressed that it could be a challenge to compare contrasting materials e.g., metal and textiles as their sensorial qualities would differ extremely. Overall, the students found the wheels useful and expressed an interest in using this approach in future design projects, also adjusting the tool to fit into their own design process.

Since different design disciplines were participating in the workshop, it was interesting to observe how these worked differently and thus evaluated the sensorial qualities differently. E.g., in one group, with an accessory and a textile design student, they discussed that the textile design student was biased, because he was trained in working with textiles and thus had a larger vocabulary and already existing knowledge of textile materials.

5 DISCUSSIONS

With this tool we wanted to create a way for the students to explore sensorial qualities of already existing textiles and to further develop a language around textiles, expanding their vocabulary on textile qualities and to train the student in nuancing their reflections with the textile material itself and about textiles qualities with others.

We chose to develop an easy to use and open tool to allow the design students to modify and integrate it into their own design process.

Based on feedback, it was important for the students to realise, that there were no 'right' answers and that we as educators are not to describe differences, but for students themselves to discover and acknowledge that they experience textile samples in different ways; subjectively as 'users' and objectively as 'design professionals,' thus training their ability to distance themselves from the experiment afterwards.

We have chosen to aim the tool for textile design students, since they are occupied with physical materials as their primary focus and are trained throughout their education to develop a language around sensorial quality. Textile designers deal with sensorial qualities as a core part of their design practice and providing them with this tool, we wanted to communicate in a tangible way, how they can explain and visualise, how they evaluate textiles and thus how they make decisions in their design process and being able to argue for those decisions.

It was a big advantage to test the tool with third year bachelor students, since they are almost graduated designers, they could very well articulate their evaluations and reflect on the tool, which provided valuable feedback. In future work we are planning to test the tool with more novice design students in earlier semesters, thus seeing if students in their early education can use the tool and how they evaluate sensorial qualities of textiles, also allowing us to follow how they incorporate and iterate on the tools in their own projects. One example, was a group of students in the BA course, where we introduced the tool. They used the tool as a part of the evaluation of their own material samples, thus applying the tool in another contexts than textiles, shown in Figure 6.

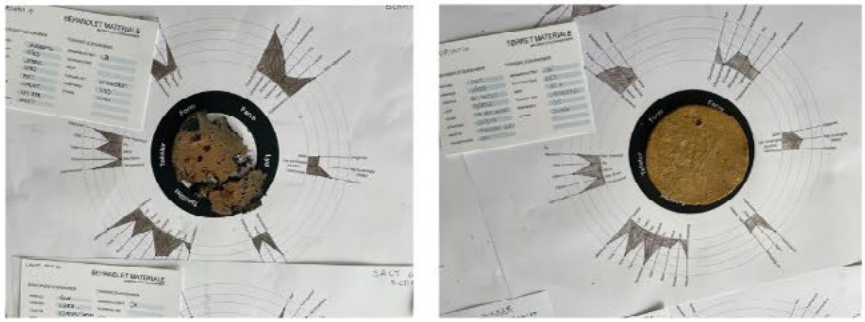

Figure 6. Examples of how students have worked with their own design project using the tool on DIY material samples

6 CONCLUSIONS

In this paper we introduced a tool inspired by the ExpMap as further development to use for foundational design education for primarily textile design students to develop the design student's language about textiles by evaluating already existing textile samples. The tool consists of a sensorial wheel and visual wheel, where the sensorial wheel describes contrasting word pairs based on sensorial qualities and the visual wheel shows chosen words from the sensorial wheel as pictures. We tested the tool in a workshop with third year bachelor design students, of which some were textile designers. Findings indicated that students overall found the tool useful and were able to reflect on the tools afterwards both in comparing their sensorial evaluations of the textile samples with each other, but also reflecting on whether they thought they could apply it in their own design process and how.

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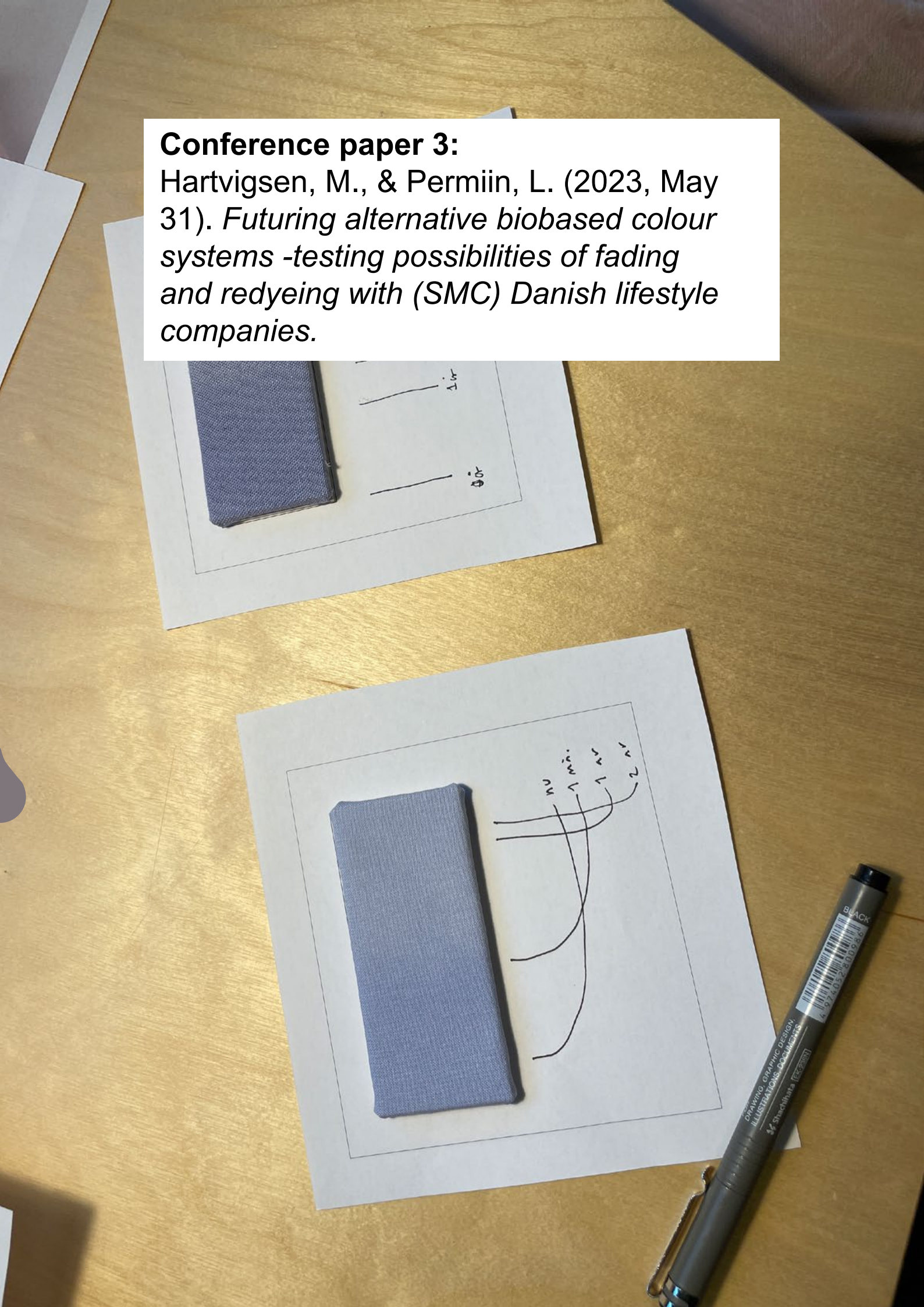
Conference paper 3:
Hartvigsen, M., & Permiin, L. (2023, May 31). *Futuring alternative biobased colour systems -testing possibilities of fading and redyeing with (SMC) Danish lifestyle companies.*



Aalto University
School of Arts, Design and Architecture

PLATE
Product Lifetimes And The Environment

5th PLATE 2023 Conference
Espoo, Finland - 31 May - 2 June 2023

Futuring alternative biobased colour systems – testing possibilities of fading and redyeing with (SMC) Danish lifestyle companies

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Keywords: Biocolour; colour fade; redye; storytelling.

Abstract:

The research presented in this paper focuses on how small Danish lifestyle companies view acceptable colour changes and in which timeframe fading and redyed colours could be implemented into their existing colour practices and thereby increasing the lifetime of textile products.
To break down small Danish lifestyle companies' capacity to incorporate and benefit from the use of bicolourants, we have conducted research centered on a future scenario-based workshop with relevant local companies and an educational institution.
The workshop was conducted in three parts: (i) Mapping the companies' current product lifetime systems; (ii) Dividing faded biocolorant samples in the scale of acceptance; (iii) Creating imaginary scenarios for a near-future timeline. From the subsequent discussion and evaluation of the workshop, four themes emerged: *Missing transparency; the need for storytelling; challenge in future thinking; knowledge sharing*. The themes could serve as future strategies to unfold how biocolorants could be implemented in Danish lifestyle companies, thus providing insights into how designers can work with biocolorants for alternative textile colouring systems in the future.

Introduction

We live in an exciting era, a paradigm shift within textile production, that forces the industry to reimagine future strategies and systems for textile dye colours. Currently, textile dye colours are an important factor in production, in marketing, and of how textile products are consumed. Additionally, faded textile colours also determine the end of the product life cycle, as products with faded coloring are often discarded by the consumer (Cooper & Claxton, 2022).

But what if fading textile biocolorants were more widely accepted by consumers, thereby expanding the product's lifetime? What should such a new perspective on fading textile biocolorants entail? What kind of system thinking is needed to implement this mindset?

Around the world, research into alternative local textile production and colour systems are emerging. This paper draws on insights from textile researcher Rebecca Burgess's practice on building an alternative, local, and natural textile dye system in California, called *Fibershed* (Burgess et al., 2019). Fibershed is a vision that enhances social, economic, and political opportunities for communities to define and create their fiber and dye systems, thus redesigning the global textile process (Burgess, 2019, p.7). Burgess has catalysed a regenerative textile movement that seeks to create biocolorant products from *soil to skin and back to soil* (Burgess, 2019, p.7). This movement has inspired the organisation, *Fashion Revolution*, in establishing *Textile Garden* (Fashionrevolution, n.d.); an organisation that emphasise the potential in the resources, we have on our doorstep. Additionally, Textile Garden explores, how we can utilize natural resources in more creative ways, showcasing native UK wildflowers. By doing so, Textile Garden is sowing a seed of curiosity about the materials, dyes, and chemicals in our clothes.

Consumers are getting more familiar with what chemicals are being used to fixate the colour in clothes. Still, it is a limited number of fashion brands that have pursued a new orientation towards operating with environmentally friendly textile colours in production. The fashion brand *Puma* has launched a collection called 'Designed to Fade' in collaboration with *The*

Living Colour Lab; the collection seeks to motivate their consumers to rethink the relationship with colours, as well as invite the consumer to consider faded colouring as beautiful. In Finland, the natural textile dye company *Natural Indigo* is collaborating with the Finish textile brand *Marimekko*; together they have launched a natural dyed shirt that fades over time and therefore ask the consumer for care and attention (Marimekko Corporation, 2020). This careful attention to product treatment invites the consumer to become familiar with the story of the biocolorants origin, their possibilities, and their limitations.

Framing our study

This paper seeks to unfold Danish lifestyle companies' applicability in implementing the use of biocolorants and explore the qualities that this dyeing method embody. This paper's focus is an investigation of exploring how companies can introduce a new understanding and appreciation to fading bio-colours. The research presented in this paper is focused on what Danish lifestyle companies see as acceptable colour changes, and in which timeframe fading and redyed colours could be implemented into the company's current colour practices, to increase the lifetime of textile products. The research commenced with the workshop *Futuring biocolorants* conducted in November 2022 included representatives from four Danish textile companies.
The workshop was divided in three parts including (i) Mapping the companies' current product lifetime systems; (ii) Dividing faded biocolorant samples in scale of acceptance; (iii) Creating imaginary scenarios to a near-future timeline, to address possible implementations of biocolorants to the participants companies.

Methodology

Research through design

We are building on research through design, where insights are acquired through design practice, to uncover and understand complex and future oriented problems within the design field, also termed *wicked problems* (Farrell & Hooker, 2013; Godin & Zahedi, 2014). Exploring sustainable issues in relation to colour emphasises the 'wickedness' as sustainability deals with complex issues stemming from actors beyond this lifetime.

Action research

As we are exploring alternative biocolorants for textile design through the data obtained during a workshop session, we are applying action research by using a *participatory design approach*. By constructing a workshop session as a research arena, the paper seeks to gain knowledge from the participants by actively involving the participants throughout the exploration (Archer, 1995; Koskinen, 2011).

Future scenario(s)

A part of our workshop applies a futuring or scenario building as a way for the participants to actively engage in how the future implementation of biocolors could be explored. Thus, we are also applying an aspect of speculative design (Malpass, 2013), using future scenarios (Fahey & Randall, 1997) to envision how the future of biocoloured textiles could be integrated together with the participants.

Empirical data and evaluation

The data used in this paper has been collected from the conducted workshop, *Future biocolorants,* in November 2022. In addition, we gained permission to record, photo-document, and retain all documents that were used during the workshop; these collected materials are also included in our data collection. The empirical data include recorded, photo-documented, and written material, as well as field notes, which were conducted after the workshop; the field notes reflect on the three introduced parts - *(i) Mapping, (ii) Scaling and (iii) Futuring* - and on what the participants had discussed during the workshop.

Conducting the workshop

The participants

The participants in the workshop included three representatives from smaller Danish companies within the textile sector and one representative from a Danish university college participated: An overview hereof is illustrated in table 1. It was found relevant to include the university college in our workshop, as it educates textile designers in close collaboration with the Danish textile and lifestyle sector.

Autors: Monica Louise Hartvigsen & Louise Permiin
Title: Futuring alternative biobased colour systems – testing possibilities of fading and redyeing with (SMC) Danish lifestyle companies.

Participants	Company	Product(s)
Participant 1	VIA University College	Design education
Participant 2	Amoode	Women's Clothing
Participant 3	Margit K	Scarfs
Participant 4	TinyCozyStore DK	Textiles for bath interior

Table 1. Overview of participants.

First Part; Mapping a current product lifecycle.

In the preliminary part of the workshop, we asked the participants to map the current lifetime system of a chosen coloured product from their company. Figure 1 depicts a participant is filling out the lifetime of their chosen coloured product. In the first part of the workshop the participants were asked to describe which material(s) or resources the product was made from, what type of colouring method had been used to colour the product and what happened to the product after end of use.

Figure 1. A participant filling out the lifetime of a current-coloured product from their company.

Second Part; Scale of colour fade acceptance.

In the second part, the participants were asked to fill out a scale of colour fade acceptance, by indicating how much colour fade they could accept for their products within a specific timespan. For this task, we had prepared a faded biocolour sample and chosen a timespan from the present to the near future: *Now, 1 month, 1 year* and *2 years*. In figure 2 and 3, two participants have filled out the scale of colour fade acceptance by drawing lines from the different timespans to the fade they could accept.

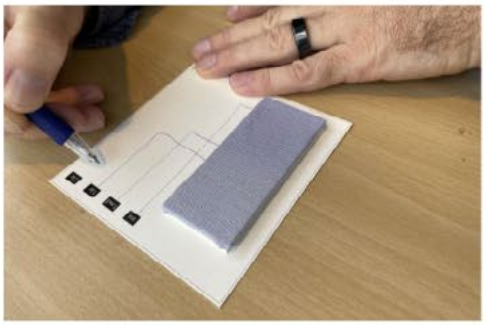

Figure 2. A participant filling out the scale of colour fade acceptance.

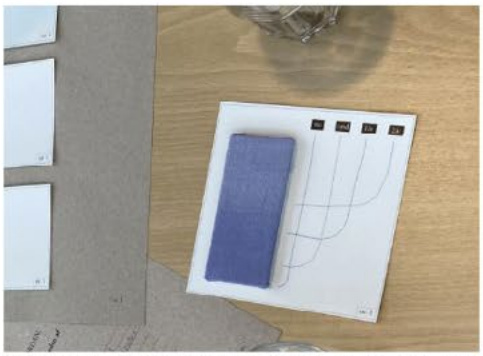

Figure 3. A participant's scale of colour fade acceptance.

Third Part; Near future scenarios using biocolorants.

In the third part of the workshop, we turned to the future and asked the participants to imagine a world where only biobased colours exists; thus, only having colours available which fades over time. We had prepared a timeline from 2022 to 2052. In figure 4, one of the workshop facilitators is explaining how the third part of the workshop is conducted.

Figure 4. One of the workshop facilitators explaining the future scenario part of the workshop.

As inspiration for future strategies to implement biobased colours, we provided the participants with the sustainable design cards, SDC, (Ræbild & Hasling, 2017, 2019). The SDC's explain different sustainable strategies e.g., re-use, upcycling, and user understanding. In addition, we had prepared posters, where the participants could write down their future strategies; each participant had to imagine three future scenarios. In figure 5, two participants are discussing chosen SDC's and how they can imagine a future of biobased coloured products in their company.

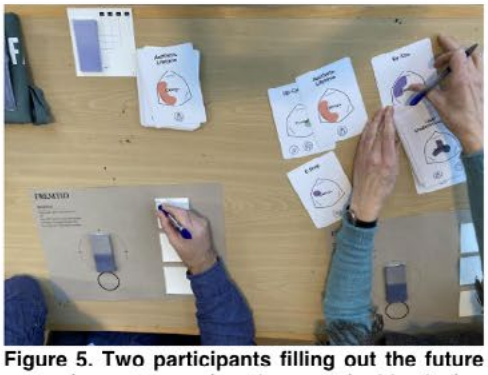

Figure 5. Two participants filling out the future scenario posters using the sustainable design cards as inspiration.

After the participants had registered future scenarios, we asked them to place the posters on the timeline and envision when they think their strategies could be implemented between 2022 and 2052. This activity led to a discussion on why the participants placed their scenarios, where they did, as shown in figure 6.

Figure 6. Discussion on the imagined future scenarios placed on the timeline between 2022 and 2052.

Insights from the workshop

The following paragraph depicts relevant insights that the workshop has supplied. The accumulated insight is grouped as following; missing transparency, need of storytelling, challenge in future thinking, and knowledge sharing.

Missing transparency

The first part of the workshop showcased that the participants attain a diverse range of engagement and knowledge regarding their product's coloring processes. *Participant 2* works with deadstock; the textiles are sourced from many producers and thus vary in how it is produced and which colouring methods are applied; Participant 2 express: *"I do not know enough about the colouring methods applied. As a small company, it is hard to find out how the textile is produced, whereas bigger companies have more control and capacity in knowing about this process.*" (Own translation from Danish to English) In the case of Participant 2, As Participant 2 explicate, it is problematic that there is no transparency regarding information about which dying method that has been used on dyed deadstock. Such a transparent system that presents which substances that are applied during the coloring of products, could provide an equal opportunity for both smaller and larger companies in choosing between conventional colour or biocolorants.
Participant 3 works with handmade silk scarfs and has visited the production company that dye the textiles in India. This visit had assured the participant of the colouring process and it has given a deeper understanding of which colours that are applied when dyeing the textiles. In this case, it was possible for the participant to obtain clarifying knowledge concerning the dying process of their products; this was possible because of the participant's capacity to visit the production site, as well as them working with a supplier that was willing to invite and show their process.

Need for Storytelling

The second part of the workshop disclosed the need for storytelling of how biocolorants are

applied to the modern dye processes and how the colour appearance changes over time. In general, the participants were not very flexible in accepting the change of colour in our proposed colour samples shown in figures 2 and 3. Their acceptance of colour change depended on how the colour faded, as well as the comparison between other products. It appeared that the colour samples which we introduced were not specifically addressed as being bicolored samples which urged the need for storytelling.
Participant 2 addressed the need for storytelling to accept the change in colour over time. According to Participant 2 "*a careful and deeper understanding of the origin of the dyes and impact on the products change of colour would be needed*" ... "*the issue is when you compare products e.g., conventional dyes with biobased. The storytelling should be part of the marketing strategy and thereby I would more easily accept that the colour of a product would fade over a year.*" (Facilitators field notes).
According to Participant 1, "*the storytelling is important and can lead to accept of colour change.*" (Own translation from Danish to English)
The acceptance of fading biocolorants would, according to both participants, deeply depend on the storytelling to be implemented in their company strategy.

Challenge in future thinking

The third part of the workshop highlighted the difficulty of the participants in widening their own business strategy with biocolorants, when creating probable future-scenarios. The timeline started from 2022, which obliged the participants in relating their future scenarios to the very-near future (2022 – 2032), see figure 7. The use of the SDC's helped the participants in guiding their future scenarios. Before the workshop, we had preselected the most relevant SDC's for the participants, however, it was found that we should have narrowed the selection even more, as this might have sharpened the discussion within the given timeframe of the workshop.

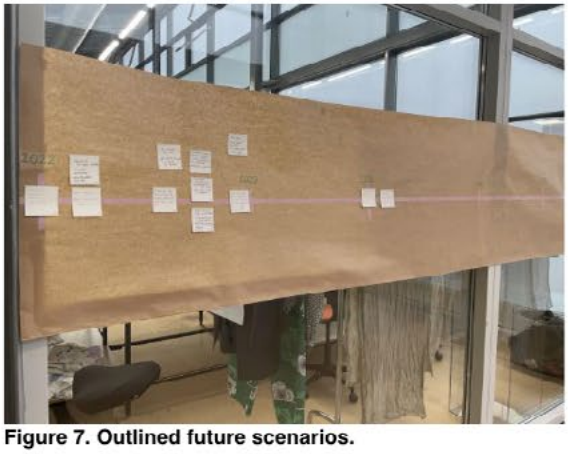

Figure 7. Outlined future scenarios.

The participants created scenarios involving *small scale production*, *local communities* and *designing with layers* which made the textile fade differently over time. In hindsight, it would have been interesting to see if an introduction to current textile fading methods such as the earlier mentioned Textile Garden, Fibershed, the Living Colour Lab, could have sparked the inspiration of the group allowing a wider future thinking with biocolorants.

Knowledge sharing

Overall, the workshop with the small Danish lifestyle companies showed that all the participants were eager to share their information about their supply chain, while still acknowledging whithin what areas they lacked information. They were all extremely interested in learning more about biocoloring methods and could see potential in involving their companies with biocolourants if the method improved regarding open access and knowledge sharing. In the reflection on the workshop, we discussed the importance of sharing information, and communicating the knowledge in a way that lifestyle companies find useful and have easy access to.

Conclusion

In this study, we explored how small Danish lifestyle companies within the textile sector viewed their (i) current product lifetime system for a colored product, (ii) evaluated on faded biocolorant samples in scale of acceptance, and (iii) how they envision near-future implementation strategies for using biocolorants in their products.

From the discussions during the workshop and our subsequent reflection, we found four emerging themes: The first theme is the *missing transparency* in the value chain; the participants expressed a need for open access and transparency in the textile dyeing sector, as it would make it easier for their small companies to take part in applying sustainable textile dyeing methods to their products.
The second theme is regarding the *need for storytelling*; this theme became especially important in the workshop's registrations of future scenarios as it provided a method to ease the acceptance of colour fading over time.
The third theme, *challenges in future thinking for implementing biocolorants,* showed us a need for the participants to be informed about already existing research to spark ideas that they could apply into their own company strategies.
The fourth theme, *knowledge sharing,* showed that the participants see a need to know more about the applied colouring methods for their coloured products.
Overall, this study emphasises that there is a potential to expand the product lifetime with the use of biocoloured textiles. However, this paper finds that smaller Danish lifestyle companies lack information regarding biocolorants and how they can apply them to their products and production processes.

Acknowledgments

We want to thank the participants who actively engaged and shared their thoughts on the future of biobased colours for the textile sector. We thank Lifestyle and Design Cluster for helping us reach a relevant audience for the workshop.

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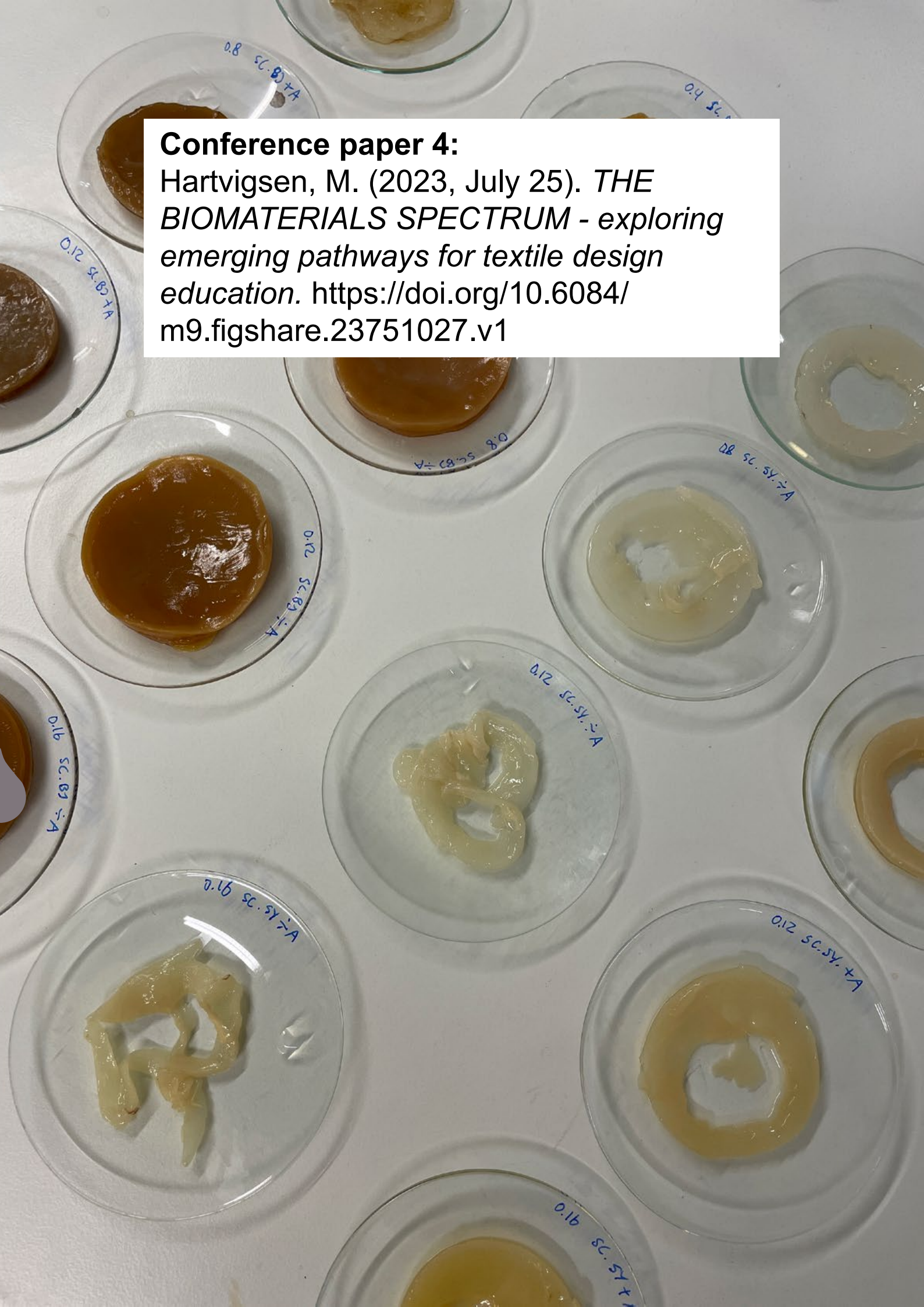

Conference paper 4:
Hartvigsen, M. (2023, July 25). *THE BIOMATERIALS SPECTRUM - exploring emerging pathways for textile design education.* https://doi.org/10.6084/m9.figshare.23751027.v1

THE BIOMATERIALS SPECTRUM – exploring emerging pathways for textile design education

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Abstract
This short paper explores the role of biomaterials in design education especially for textile students and the potential and challenges they pose. Through a biomaterials spectrum looking at how design students approach biomaterials and relating it to my PhD research, I have created a spectrum to explore where design students interested in working with biomaterials can start and which routes, they can take to advance their knowledge and skills. The approaches in the spectrum are related to the workshop space it requires increasing the complexity through the spectrum.
In the material spectrum it is envisioned how engagement with biomaterials could be planned covering easily accessible DIY approaches to more advanced collaborative-dependent approaches using examples from Design School Kolding students as well as insights from my own PhD project.

Keywords
biodesign, biomaterials, design education, textile design

Introduction
The need to care for our environment is urgent. We have to transition from a linear economy to a circular one, where one solution could be a biobased approach. Textile design practice and textile design education is also evolving to train designers in more sustainable production methods and material developments (Collet, 2018; Gale, 2002; Niinimäki et al., 2018).
The change has led to an influx of new materials and methods. We are seeing students being more interested in biofabrication and biomaterials from DIY(Do-It-Yourself) approaches to design-science collaborations, which is reflected in academic developments of the biodesign field, where students projects, models and taxonomies (Ayala-Garcia et al., 2017; Camere & Karana, 2018; Chieza & Ward, 2015; Collet, 2020; Karana, Barati, et al., 2015; Rognoli et al., 2022) have been developed and applied in design curricula. Although this paper focuses on textile design students, the author sees the potential of applying the biomaterials spectrum in other design disciplines as well.
In this paper the biomaterials spectrum is introduced as a way for textile design students to advance in biomaterials developments with a hands-on approach, emphasising experiential knowledge, especially biomaterials which are used within the biodesign field, aiming to take part of future sustainable material developments in multidisciplinary collaborations between design and science and thus provide textile design education with a framework to introduce and advance in biomaterial

developments.
First a contextual framing will be outlined followed by an overview of the methodology, where the data used to create the spectrum is outlined and the chosen cases are presented. Next the biomaterials spectrum will be introduced and the cases will be placed in the spectrum to show how they are progressing throughout the spectrum. The cases will be analysed using chosen categories as grounds for comparative analysis, ending with a discussion of the biomaterial spectrum.

Contextual framing

A brief introduction to biomaterials

Biodesign is a term that emerged in 2012:*"combining design with biology using biofabrication in the design process"* (Myers, 2012). A subsection of biodesign deals with *growing design*, a design approach where biofabrication with living organisms are used to explore: material functions, material expression, sustainable solutions (for product design) (Camere & Karana, 2017).
Biomaterials are in this research understood as material produced be living organisms or cells (Camere & Karana, 2018), as described in figure 1. Here living organisms, often microorganisms, grow to produce a non-living biomaterial as cellulose, chitin or pigments.

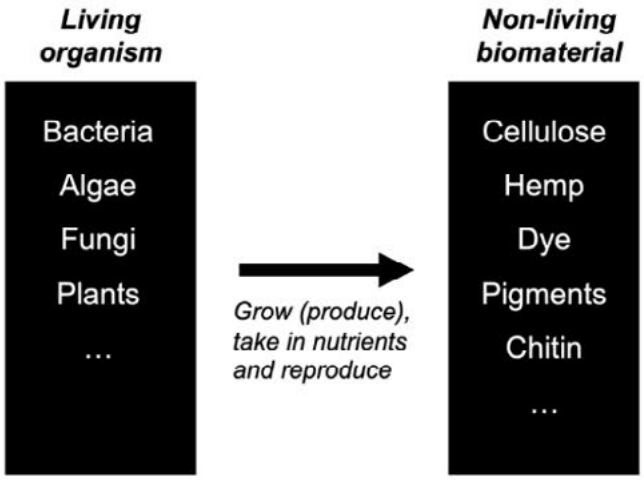


Figure 1: A visualisation of the process for the growth of biomaterials from living organisms.

The advantages of the biomaterials are their origin; they are produced from renewable resources, their end-of-life: they are safe for the environment and can be biodegraded and become a feedstock for the fabrication of new biomaterials.

Methodological framing

Empirical data collecting

Five design cases form the empirical data of this study. The cases consist of design experiments from a PhD project conducted at Design School Kolding, exploring microbial colouring for textile design practice, as well as textile design students' project examples, also from Design School Kolding. They were chosen since they all apply biomaterials development as a part of their design process. In figure 2 the five cases are presented. Case 1 explores a student project on agar bioplastic development as part of a 4-weeks bachelor 3rd year course on material driven design in 2022. Case 2 explores bacterial cellulose produced by a symbiotic culture of bacteria and yeasts (SCOBY) and is a design experiment from the authors PhD project. Case 3 explores mycelium, the fungal root network of fungi, as part of a master students master thesis project in textiles design. Case 4 explores another design experiment part of the authors PhD, where colour producing bacteria was used to produce a coloured pigment applicable for textile coloration. Case 5 explores cultivation of colour producing genetically modified fungi (GMO) for textile application, also a design experiment from the authors PhD project. The author followed both Case 1 and Case 3 as the students developed the projects, therefore invaluable insights from all of the cases was accessible for the author.

Table 1: An overview of the chosen cases.

Case 1	Bioplastic - agar
Case 2	SCOBY – bacterial cellulose
Case 3	Mycelium – fungal roots
Case 4	Bacterial colouring
Case 5	GMO - Fungal colouring

Where research through design and autoethnography intersects

This research builds on research through design (Frayling, 1993) where doing design is seen as a way of doing research. Reflection is used an evaluation method, building on Schön's methodology of reflection-in-action making notes and taking photos and reflection-on-action (Schön, 1988, 1991) as a way to analyse the cases and their relations in the biomaterials spectrum. The insights from reflection-on-action have been used to create the categories: *approach; materials; knowledge; challenges*; *design role*, to compare the cases with each other.
As research through design builds on experiences of the researcher, relevant conversations and experiences throughout the process of conducting the design experiments and following the textile design students' projects are valuable insights

used to develop the paper, building on autoethnography, where personal experiences can be applied as data (Kääriäinen & Niinimäki, 2019).

The biomaterials spectrum

Creating the spectrum

The biomaterials spectrum was created to have a visual representation to discuss possible pathways for design students to take applying biomaterials produced by living organisms, shown in figure 2. In the spectrum I propose three approaches where design students can work with biomaterials; DIY (green area), DIY with expert guidance (yellow area) and Design-science collab (red area). The spectrum starts from the left with a DIY laboratory and end in the natural science laboratory. In addition, the spectrum is further divided in a scale ranging from aesthetic to technical, since different biomaterial development can have different focuses either a more aesthetic or a more technical or a combination of the two.
The cases presented in this paper is marked with a number, which corresponds with cases presented in the previous section. The biomaterials placed in the spectrum which are not numbered is to show that a multitude of pathways are possible if advancement in biomaterial development is desired, meaning the spectrum is adaptable for the student's interest and workshop facilities in the design institution.

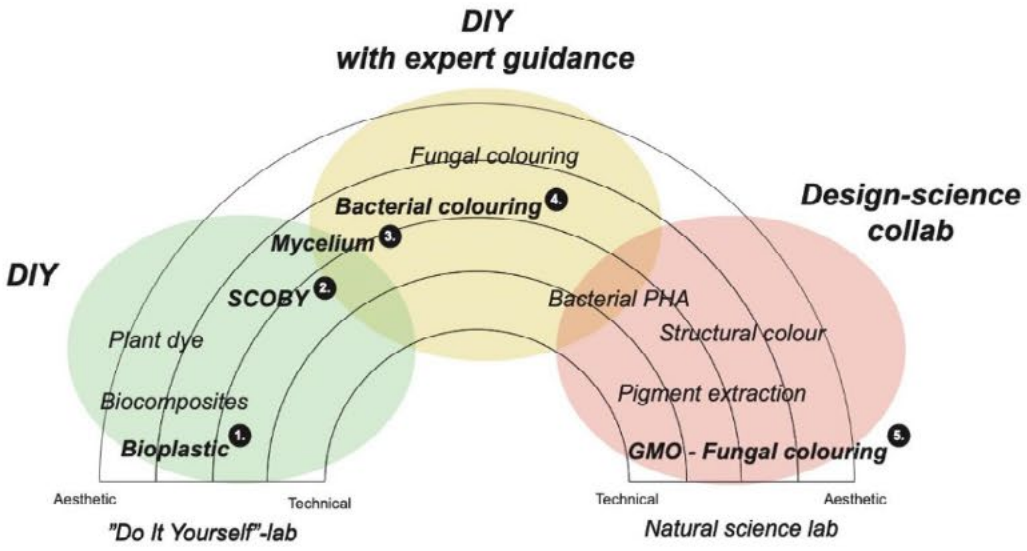
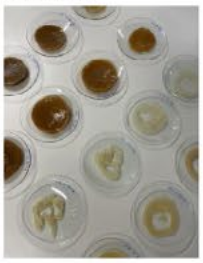


Figure 2: The biomaterials spectrum, where various biomaterials are placed. The biomaterials marked with a number constitutes the cases.

The biomaterial cases

In table 2 the analysis of the five cases is presented applying the categories mentioned in the methodology. *Approach* describes where the student project or design experiment were conducted, either in a DIY laboratory or a natural science laboratory. *Material* describes the ingredients, resources or equipment used to make the desired biomaterial. *Knowledge* describes the type of knowledge the biomaterial explorations are building on. *Challenges* describes some of the restrictions which are related to working with the explored biomaterials. The challenges could both be in relation to the biomaterial itself, the process of making it and keeping the biomaterial producer alive, if it was a living organism. *Design roles* describes the role which the designer applies in the given case, either a design maker being in charge of the whole process of the biomaterial development or design bridgebuilder using dialogue and collaboration to develop biomaterials.

Table 2: An overview of the analysed cases using the categories: approach, material, skills and knowledge, challenges and design roles.
Photo credits: Case 1 (Thilde Laursen), Case 3 (Shanice Otersen), Case 2, 4 and 5 (author).

	Approach	Material	Skills & knowledge	Challenges	Design roles
Case 1 	DIY laboratory, making a bio composite	Agar, water, glycerol	Material experience, material making	Scaling	Designer as maker
Case 2 	DIY laboratory, making kombucha and producing bacterial cellulose using a SCOBY	Green tea, sugar, water, mother SCOBY, cloth, jar	Material experience, material making, fermentation, can include biotechnology	Keeping the SCOBY alive, scaling	Designer as maker

Case 3 	DIY laboratory, making mycelium with organic matter	Grow kit (fungi spores), wood chips (or other organic matter), pressure cooker, plastic bag or box	Material experience, material making, microbiology, biotechnology, communication	Time-dependant, scaling, mould, experts can be helpful, safety	Designer as maker
Case 4 	DIY laboratory, growing bacteria with nutrient broth	Broth, pressure cooker, sterile petri dishes, autoclave bags, textiles, ethanol, isolated and DNA sequenced bacteria	Material experience knowledge, material making, microbiology, biotechnology, communication	Time-dependant, scaling, mould, expert help is needed, safety	Designer as maker and bridgebuilder
Case 5 	Natural science laboratory, growing fungi with specialized nutrient in collaboration with microbial scientists, since the fungi is GMO	Nutrients, autoclave, sterile petri dishes, autoclave bags, textiles, ethanol, flow bench, sterile glass flasks, shaking incubator, sterile knife, GMO-fungi	Material experience knowledge, material making, microbiology, synthetic biology, biotechnology, communication, collaboration	Time-dependant, scaling, mould, expert help or collaboration is needed, safety	Designer as maker and bridgebuilder

Discussion

Insights from the cases placed in biomaterials spectrum

From the analysis it is evident that as the cases progresses in the biomaterials spectrum the biomaterial development processes and equipment becomes more complex, which is also reflected in the applied knowledge and skills. Although an element of material making is applied throughout the pathway, at some point expert guidance is needed for the designer to progress on her own or establishing a collaboration either for help to develop the material or to use equipment, which is not available in at Design School Kolding. Here the design role switches from being a design maker to becoming a bridgebuilder, this also implies a need for good communication skills and collaborative skills.
One aspect which could act as a barrier for advancing is the time-dependency for growing biomaterials, which is often not taken into account when planning a design

course, thus the bachelor student is working with very approachable biomaterial and the master thesis students is working with a more complex but also more time-demanding biomaterial.

Insights from developing the biomaterials spectrum

At the Design School Kolding it is a challenge to advance in the current set-up, where only DIY material development are possible, since no formal collaboration partners with technical universities or research institutes within biomaterial development exists, providing an entry point for the design school and education to develop further. Design School Kolding is a small university having 340 students, which means we have less power and are dependent on collaboration with other institutions.
The spectrum provides suggestions for pathways that design students can take to advance in biomaterial development, that suits their project and design interests. In addition, it provides a framework for the developing materials skills and knowledge useful to work in the design-science setting, perhaps collaboration in multidisciplinary teams in material science research advancing from the role of biomaterial maker to becoming a bridgebuilder between disciplines. A bridgebuilder which can span both technical and aesthetic qualities of materials, which are necessary if we want new biomaterials to become accepted in society (Karana, Barati, et al., 2015; Karana, Pedgley, et al., 2015). This is a great advantage for textile designers having knowledge within both hard and soft skills, expanding the space for knowledge exchange and dialogue (Asbjörn Sörensen & Rosén, 2021; Kääriäinen et al., 2017; Niinimäki et al., 2018).

Conclusion

This paper presented the biomaterials spectrum as a framework for design students to develop their skills and knowledge for biomaterial development focusing on biomaterials produced by living organisms such as plants and microorganisms. Five cases applying biomaterial development ranging from DIY approaches to design science collaborations was presented to deduct insights and discuss how one pathway in the biomaterials spectrum could be envisioned ultimately leading to multidisciplinary collaborations on future sustainable biomaterial developments.

Acknowledgements

Thank you, Design School Kolding, for supporting the research and the two design students Thilde Laursen and Shanice Otersen, whom allowed me to use their design projects as examples of biomaterial developments.

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Appendix 4: Booklet and tools

In this appendix, the following tools and booklet can be found. For the intended size and resolution, please download them using the provided links.

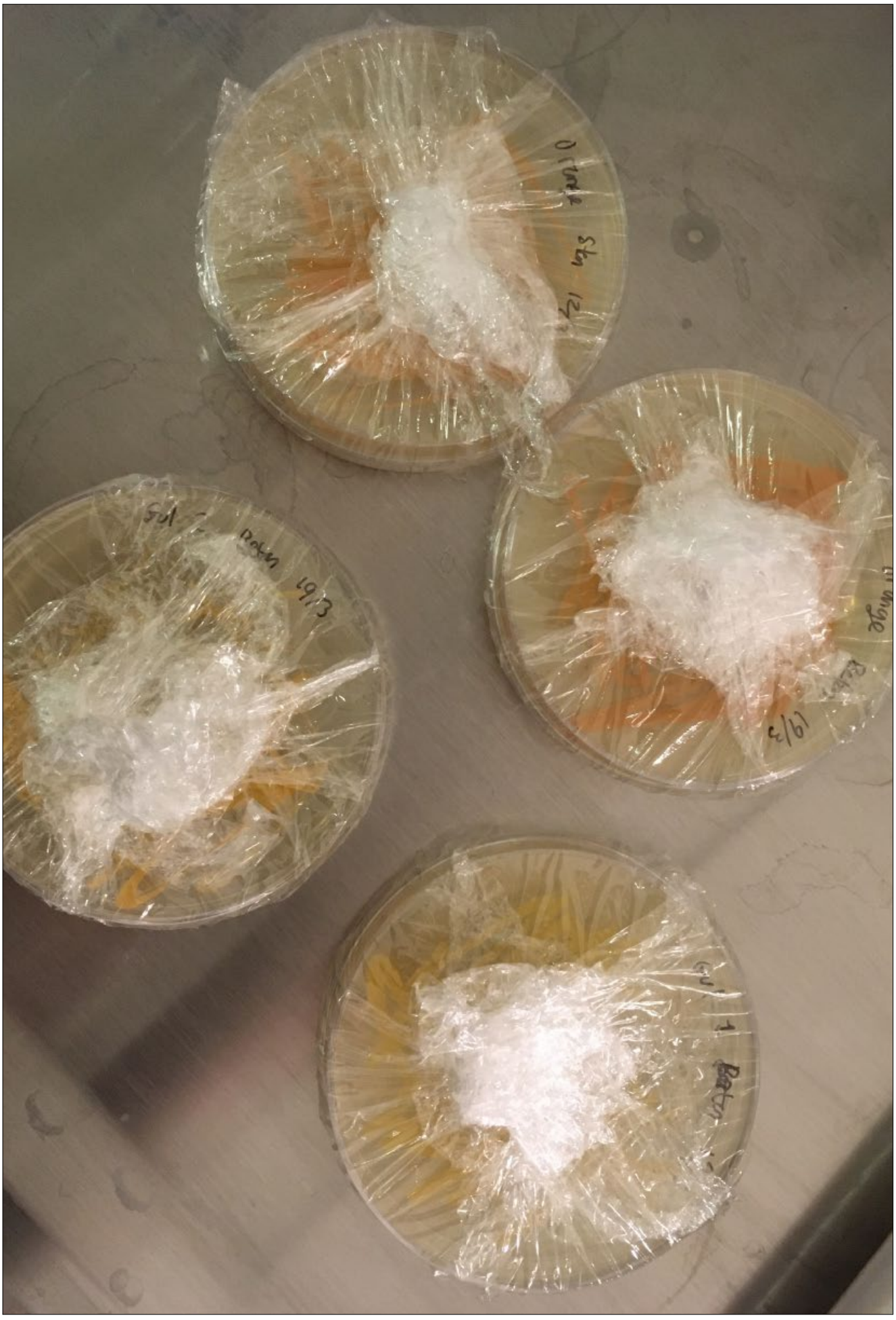
- **Biolab Booklet** (download at: https://monicahartvigsen.com/biolab-booklet/)
- **Bio Cards** (download at: https://monicahartvigsen.com/bio-cards/)
- **Sensuous Tool** (download at: https://monicahartvigsen.com/sensuous-tool/)
- **The Biodesigner Roles Cards** (download at: https://monicahartvigsen.com/biodesigner-roles-cards/)


B
AB O LA

Author: Monica Louise Hartvigsen
Publication date: June 2021

Contents

1. General guidelines



How to use this book

This book explores the biolab at DSKD and the methods applied within the biolab at DSKD to teach designers how to work within it, question and reflect upon the possibilites presented to expand, explore and inspire future workshop practice. The book is not a manual on how to set up a biolab elsewhere, as safety regulations have to be followed.

The first chapter covers a general guidelines to working in the biolab primarely covering safety issues and.

The second chapter gives an overview of how naturally pigments producing bacteria lifecycle works and how they produce pigments as well as an overview of the microorganims currently available in the biolab.

The third chaper descripes the recipes used in the biolab e.g. how to prepare media and petri dishes for growing the bacteria.

The fourth chapter is a collection of the different video tuturials showing how to carry out the different steps described in the recipes in chapter three.

The remaining chapters five, six and seven contains a glossery for words connected to working in the biolab, a list of suggested readings if you wish to explore a bit more about this area of design and a reference list used for the factual descriptions. In addition to the references several interviews with different biolabs and community labs around Europe have contributed with knowledge to this book as well as sharing relevant resources.

A special thanks to Shem Johnson from the Central Saint Martins Growlab, Roland van Dierendonck from Waag Amsterdam and Utrecht Univerity of the arts, Danial Gruskin from Biodesign Challenge (BDC), Anke Pasold from KEA, Maria Boto Ordonez & Heleen Sintobi from the biolab at KASK Ghent, Adrian Rigobello from CITA at the Royal Danish Academy and VTT in Finland for sharing past and present experiences, valuable insights all helping and guiding the contents of this book.

BEFORE WORKING IN THE BIOLAB YOU NEED TO GET AN INTRODUCTION

Laboratory hierarchy

DSKD BIOLAB	NATURAL SCIENCE LAB	
Biosafely level 1	**Biosafety level 2**	**Biosafety level 3**
Grow known BSL-1 microorganism at max. 25ºC	Grow known BSL-1 and BSL-2 microorganisms at all temperatures	Grow known BSL-1, BSL-2 and BSL-3 microorganisms at all temperatures
Prepare media for growth of microorganisms	Prepare media for growth of microorganisms	Prepare media for growth of microorganisms
Look at unknown microorganisms in a closed container wrapped with parafilm	Look at unknown microorganisms in a closed container wrapped with parafilm	Look at unknown microorganisms in a closed container wrapped with parafilm
Open access	Isolate an unknown microorganism under a laboratory fume hood	Isolate an unknown microorganism under a fume hood
No prior training	Extract pigment or other molecules produced by the microorganism	Extract pigment or other molecules produced by the microorganism
Uncontrolled and unreproducible	Some GMO work	GMO work
Small scale	Restricted access	Human tissue and cells
	Some prior training is advantageous	VERY restricted access due to laboratory costs
	Controlled and reproducible	Prior training is required
	Bigger scale	Controlled and reproducible
		Small scale

9


MONICA

DSKD Biolab

Welcome to the DSKD Biolab. Before starting any work in the biolab you need to get an introduction. Please familiarize yourself with this book and its contents.

Biosafety level 1
The DSKD biolab is classified as a biosafety level 1 lab (BSL 1), which means we are allowed to work with any biological material, so long as it is not a pathogenic (disease causing) agent, organism, parasite or virus that is hazardous to humans and/or the environment. Ask Monica Hartvigsen before bringing any microorganisms into the lab.

Human tissues not allowed
Please note that working with human tissues and fluids are not permitted because they can contain disease-causing agents.

Be aware of health hazards
There is a LARGE diversity of microbes that exist, each may have its own health hazards. One should be aware of what is being handled and what risks, if any, it may pose. If the organism is unknown, precautions should be taken to minimise contact/interaction with humans as the microbe(s) could pose health hazards.

Use sterile and aseptic techniques
Sterile/aseptic techniques should be practised wherever and whenever possible to avoid exposure to one's self and avoid the growth of unwanted microbes. Sterilising for microbial work often uses a high temperature oven or a pressure vessels containing hot steam, such as an autoclave (or pressure cooker). Steralizing is especially important for waste management.

Working with Genetically Modified Organisms (GMOs)
BSL 1 laboratories cannot work with genetically modified organisms (GMOs). GMOs are considered any organism (including cloning bacteria) that contains any foreign genetic material (DNA or RNA) or unnatural rearrangement of genetic material. Ask Monica Hartvigsen if you have questions regard working witg GMO's.

A shared space
Be mindful of others and their work, since it is a shared space. Try to minimize clutter and practice a good hygiene in the lab. In this way more people get to enjoy the space.

For introduction and questions please contact:
Monica Hartvigsen, mlh@dskd.dk, +4561401027


Wash hands
Ask for help and guidance
Never eat or drink
Mark your samples
Use protective equipment
Clean up after experiments
Read all instructions
Sterilize biological waste

Safety rules in the biolab

Wash hands
Before entering and leaving the biolab please wash your hand, to make sure you do not bring any unwanted chemicals or microorganisms with you on your skin.

Ask for help and guidance
Before you start working in the lab, you need to get an introduction. If you are in doubt with anything ask for guidance from more experienced students or staff.

Never eat or drink in the biolab
For your own safety, it is not allowed to eat and drink in the biolab. Even though you might not be working with chemicals, treat your ingredients as if you were.

Use protective equipment
In the biolab we need to wear protective gear, which in the biolab includes: labcoat, gloves (latex or nitril or the like). If you have long hair, you should tie it back. It is your responsibility to protect yourself from possible health hazards. The gloves and mask should be autoclaved before beeing disposed as waste.

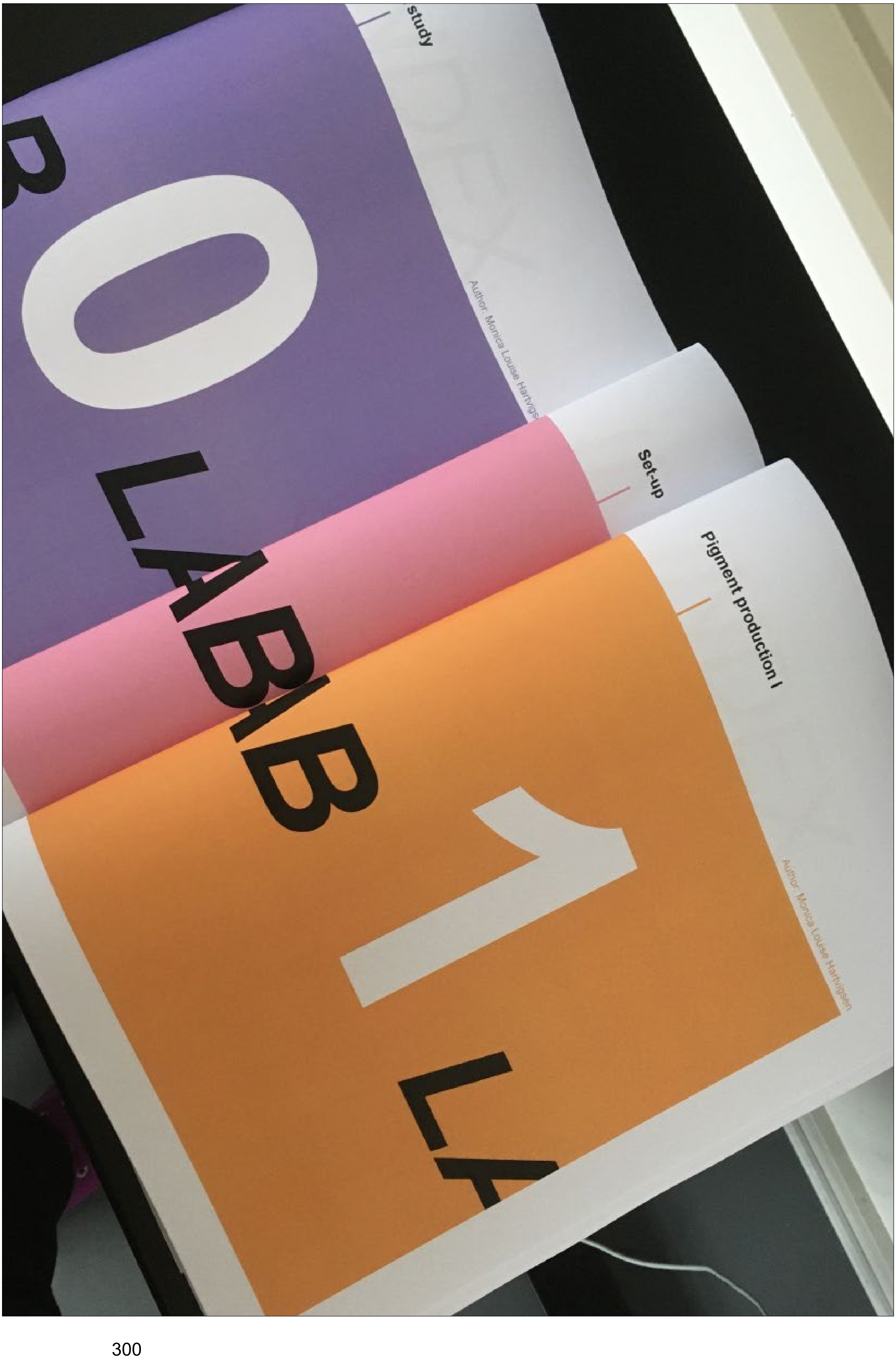
Familiarize yourself with the safety regulations
This booklet should provide the safety regulations needed for working in the biolab, but it is always good to think about and check the safety regulations before starting an experiment. For any chemical material safety data sheets (MSDS) are available online for almost all chemicals.

Read all instructions carefully
Take time to think about what you are doing to make sure you are taking the right procautions. Be aware of hot water and steam from the autoclave and the gasflame from the bunsenburner, **especially together with ethanol (explosion danger).**

Mark your samples
Work must be clearly labeled with a name, date, and description, or it will be immediately tossed in the bin.

Clean up after experiments
Do not take anything out of the biolab that has not been autoclaved or is properly wrapped. Ask for guidance if you are unsure on how to proceed. Wash your glassware and utensils, clean up, dispose of waste, and put everything in its right place. Wash your hands before leaving the biolab.

Waste management
All waste which have been in contact with living microorganisms should be autoclaved for at least 30min before being thrown out.


study
Set-up
Pigment production I
Author: Monica Louise Hartvigsen

Keeping a lab protocol

What is a protocol?
A protocol is a description of the different steps you are doing through out an experiment. There is no formal standard, so you can make yours in any way you want, as long as you understand how you did your experiment. It can be a good idea to prepare it in advance, so you have idea of what is going to happen.
You can document the steps by writing down all recipes and sample descriptions, as well as taking photos and videos.

Why should I keep one?
Keeping some kind of protocol will make make it possible to reproduce your work and allow others to assess how to handle your samples safely. If you need guidance in further experiments, it will also be valuable to the supervisor to have an idea about, how you carried out your experiments.


UN:2037
Gefahr · Gevaar
Danger · Pericolo · Nebezpečí
Nebezpečenstvo · Fara · Perigo
Veszély · Niebezpieczeństwo · Fare
Tartalma · Zawartość · Indhold
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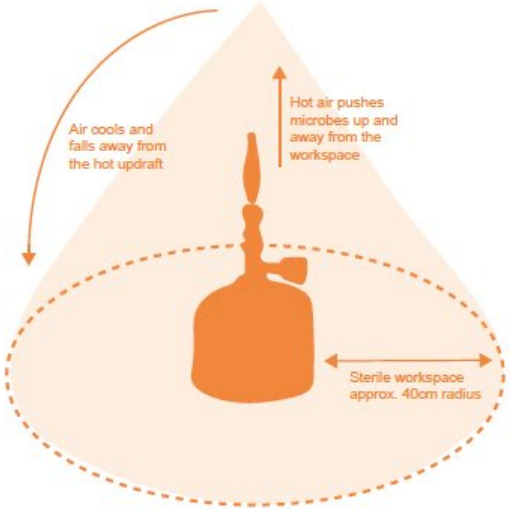
Sterile working area

Aseptic techniques
Researchers use aseptic technique to prevent contamination with unwanted bacteria, fungi, or viruses from the environment. The key elements of aseptic technique are a sterile work area, good personal hygiene, sterile reagents/media, and sterile handling (Thermofisher, 2021).

Ethanol
Ethanol can be used to disinfect the workspace. The workspace should be disinfected before and after working with microorganisms. **Ethanol is highly flammable!!** so it should be handled with care, especially because it is used near the Bunsen burner.

Bunsen burner
A Bunsen burner is a lab instrument that can be used to provide a single, continuous flame by mixing gas with air in a controlled fashion. The ratio of gas to air that is mixed together can be manually adjusted, allowing the user to control the intensity, temperature, and size of the flame. The Bunsen burner is the easiest way to create a relatively sterile environment on the lab bench. A major purpose of the open flame in aseptic technique is to create a cone of hot air above and around the lab bench to reduce the viability of organisms on suspended dust particles.The ability of the Bunsen burner flame to heat things very quickly also makes it an ideal choice for sterilizing inoculating loops or warming glass bottle necks (Thermofisher, 2021).



17

2 Bacterial descriptions


Microorganism metabolism
using CO_2 as carbon source is called
using chemical compounds as carbon source is called
Autotrophy
Heterotrophy
and the organisms are
and the organisms are
Autotrophs
Heterotrophs
whose energy source is
whose energy source is
light
inorganic compounds
organic compounds
light
Photoautotrophs
Chemoautotroph
Chemoheterotroph
Photoheterotrophs
which include
which include
which include
Nitromonas and Nitrobacter
Many Bacteria, Fungi, Archaea and Eukarya
Green and purple nonsulfur bacteria
that use H_2O to carry out
that do not use H_2O to carry out
those feeding on dead organic matter
those feeding on living organic matter
Oxygenic photosynthesis
Anoxygenic photosynthesis
Saprobes
Parasites
which include
which include
Cyanobacteria, Plants and algae
Green and purple bacteria

Microorganism metabolism

Metabolism

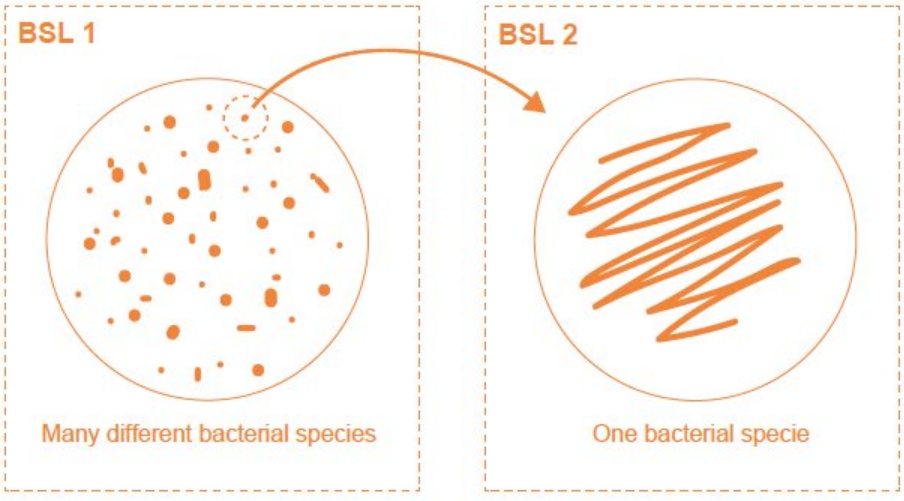
Metabolism refers to all the biochemical reactions that occur in a cell or organism. The study of bacterial metabolism focuses on the chemical diversity of substrate oxidations and dissimilation reactions (reactions by which substrate molecules are broken down), which normally function in bacteria to generate energy. Also within the scope of bacterial metabolism is the study of the uptake and utilization of the inorganic or organic compounds required for growth and maintenance of a cellular steady state. These respective exergonic (energy-yielding) and endergonic (energy-requiring) reactions are catalyzed within the living bacterial cell by integrated enzyme systems, the end result being self-replication of the cell. The capability of microbial cells to live, function, and replicate in an appropriate chemical milieu (such as a bacterial culture medium) and the chemical changes that result during this transformation constitute the bacterial metabolism (Burgin et al, 2011).

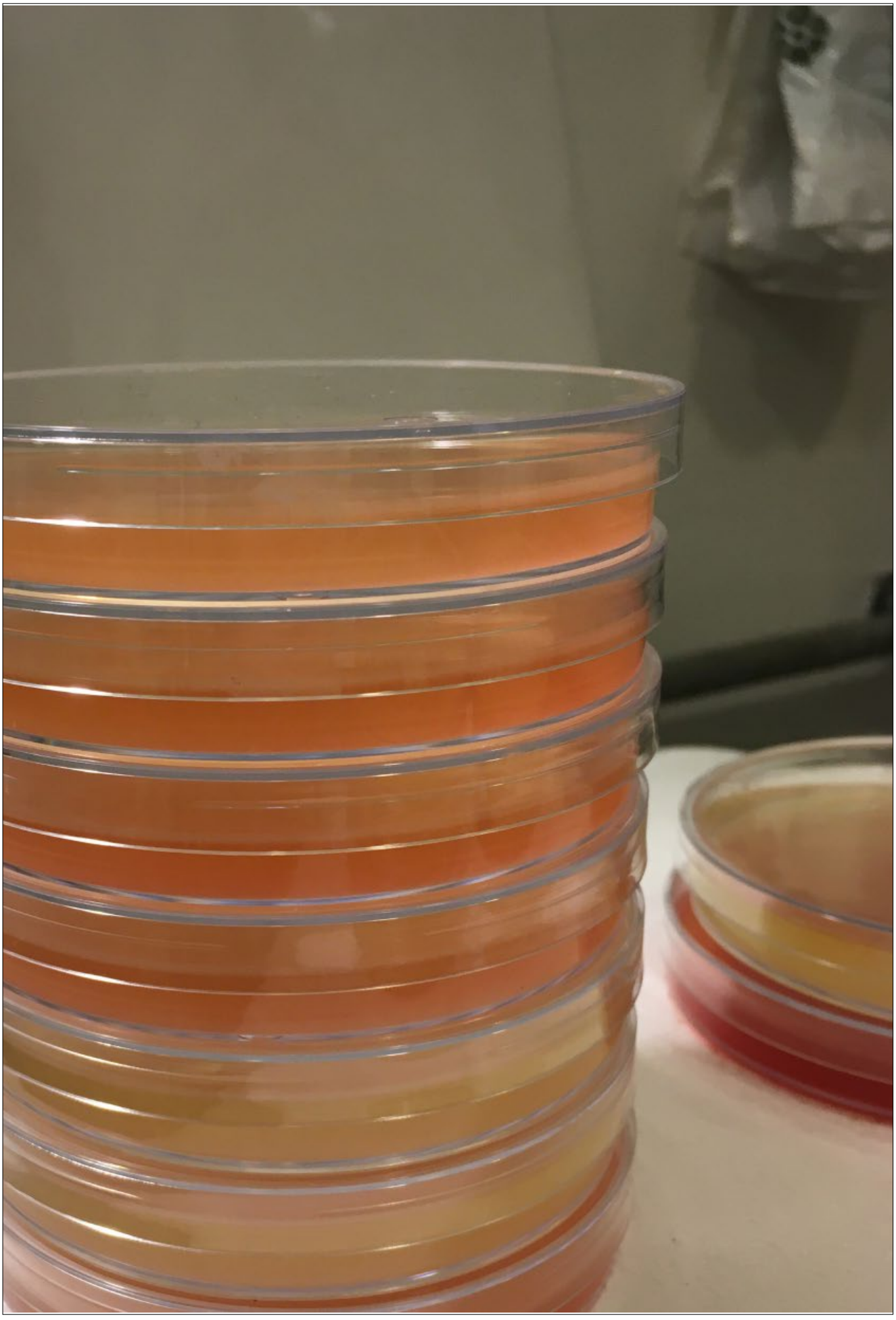
Heterotrophs

The natural pigment producing bacteria, we have available in the lab are all heterotrophs. They require preformed organic compounds, which we prepare for them using a standard bacterial growth medium called LB Broth, which consists of casein digest peptone, yeast extract and sodium chloride. These carbon- and nitrogen-containing compounds are growth substrates, which are used aerobically or anaerobically to generate reducing equivalents (e.g., reduced nicotinamide adenine dinucleotide; NADH + H^+); these reducing equivalents in turn are chemical energy sources for all biologic oxidative and fermentative systems e.g. pigment production. Heterotrophs are the most commonly studied bacteria; they grow readily in media containing carbohydrates, proteins, or other complex nutrients (Baron, 1996).

Isolating microorganisms
- and why we cannot do it the lab

The diverse nature of microorganisms
When taking a sample and streaking it onto an agar plate with prepared media from outside e.g. the soil, the air, your own skin, many different kind of microorganisms will start growing on the plate.
We do not know which kind or microorganisms grow on the agar plate (sadly, they cannot tell us). It could be something potentially very dangerous e.g. antrax and we need to think of the health hazard we are exposing ourselves to as well as collegues.
Once we have grown an unknown species on an agar plate, we can look at it in a microscope, but we cannot open it. If we need to know what kind of microorganism we have found, we need to take our agar plate to another lab, which is categorized as a biosafety level 2 lab (BSL 2). Here they can help us sequence the RNA or DNA to tell us, if it is safe to continue working with.





Growth phases

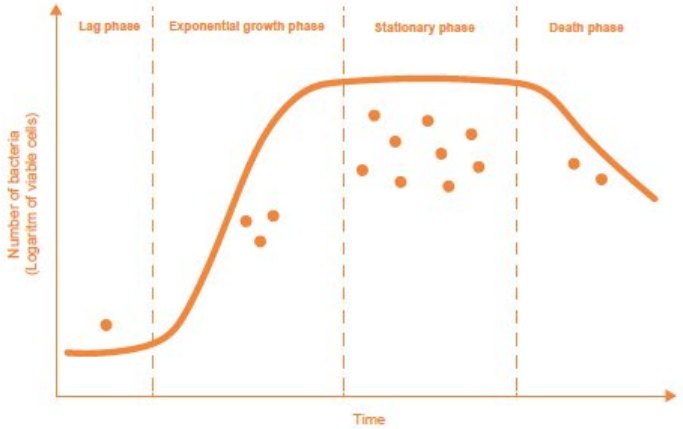
The growth curve
In a closed system or batch culture (no food added, no waste removed) bacteria will grow in a predictable pattern, resulting in a growth curve composed of four distinct phases of growth: the lag phase, the exponential or log phase, the stationary phase, and the death or decline phase.
In the lab we do not work with a 100% closed system, so our growth curves would not look exactly as drawn below, but it can still give an indication of how the bacterial lifecycle works (Wang et al., 2015).

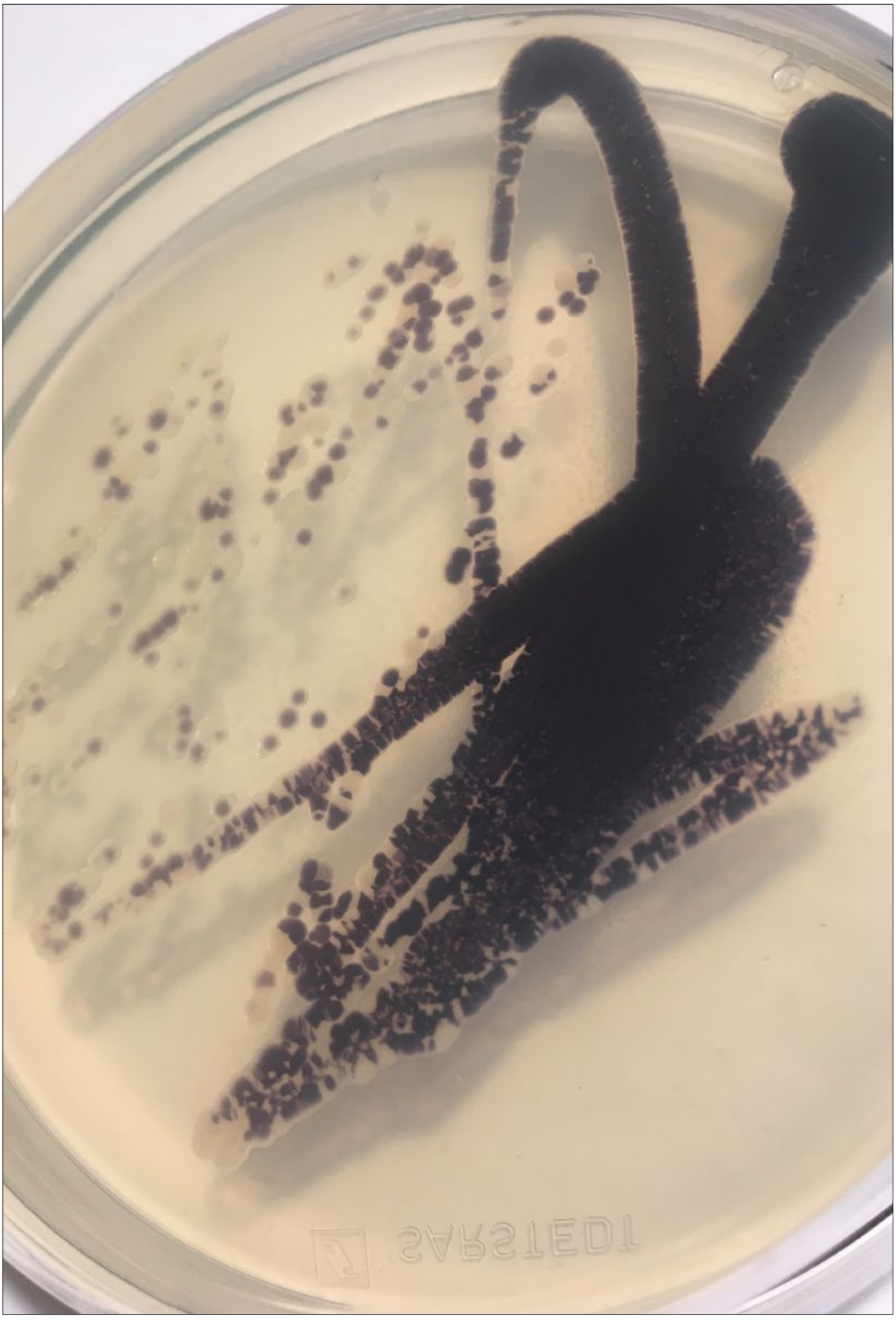
Lag phase
An adaptation period, where the bacteria are adjusting to their new conditions. Cells in the lag period are synthesizing RNA, enzymes, and essential metabolites that might be missing from their new environment (such as growth factors or macromolecules), as well as adjusting to environmental changes such as changes in temperature, pH, or oxygen availability. This phase is also where pigment is generated.

Exponential growth phase
Once cells have accumulated all that they need for growth, they proceed into cell division, where 1 cell become 2 cells, becomes 4, becomes 8 etc. Pigment production can also take place in this phase.

Stationary phase
At some point the bacterial population runs out of an essential nutrient/ chemical or its growth is inhibited by its own waste products or lack of physical space. Pigment production can also take place in this phase.

Death phase
The number of viable cells decreases in a predictable (or exponential) fashion. The steepness of the slope corresponds to how fast cells are losing viability.



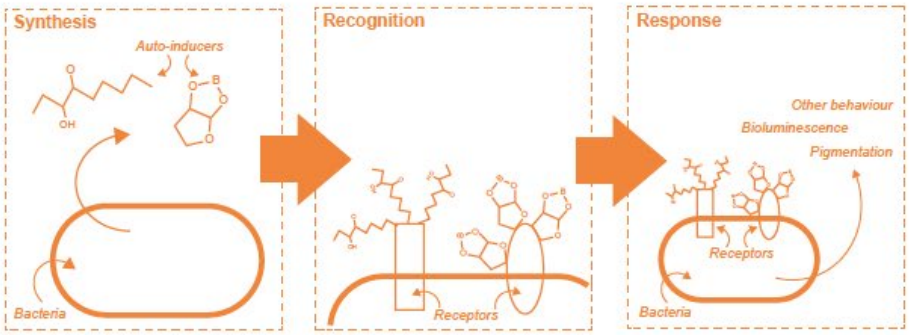

SARSTEDT

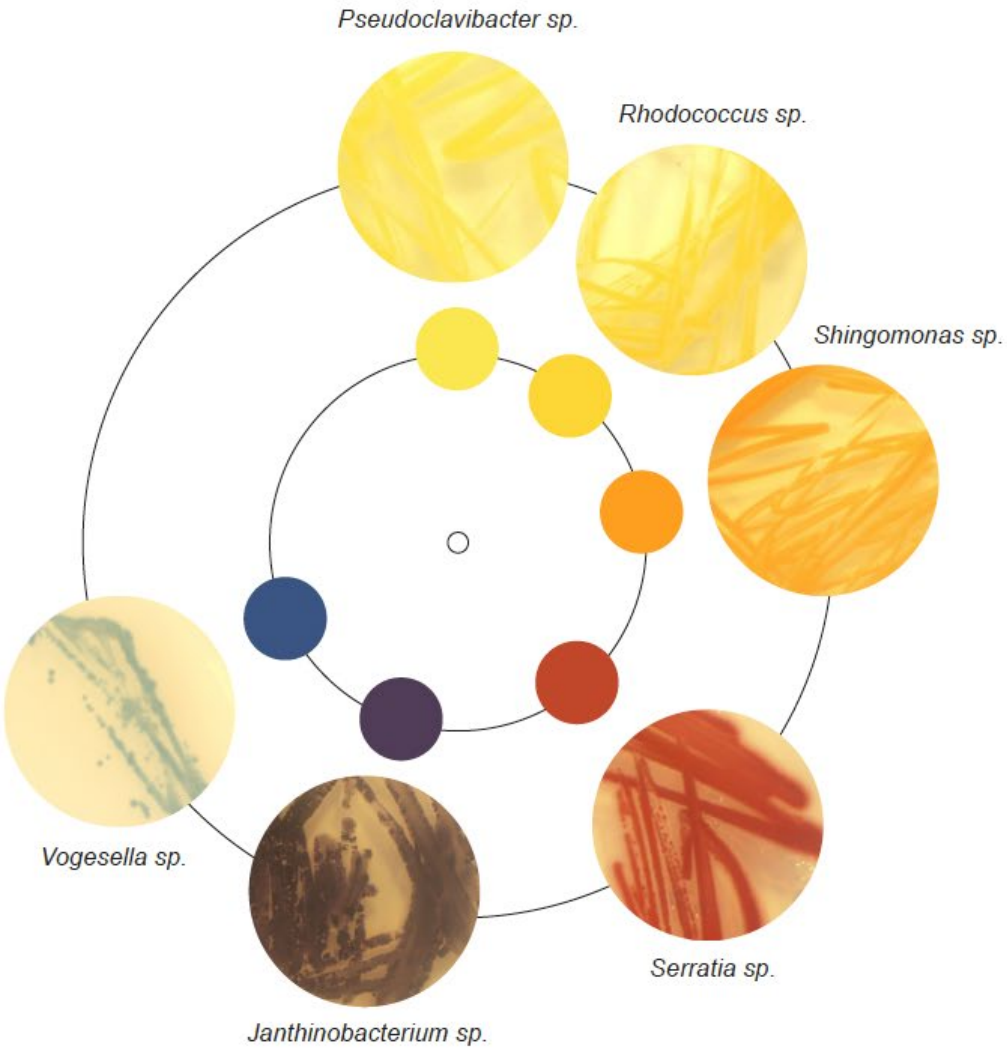
Pigment production

Quorum sensing
The regulation of pigments prodcution is called quorum sensing. Quorum sensing uses signaling molecules (or autoinducers) as a form of communication. In this process bacteria detects and responds to changes in cell population density upon changes in its environment and produce pigment.

Bacteria and their pigment inducing capabilities are not just a form of communication but are indicators of compatibility and of multispecies living. Bacterial pigmentation is a result of an autopoietic system, one that is organized to continuously reproduce its own parts and structure (Mohammadi et al., 2012).

For the bacteria to use quorum sensing, they must possess three characteristics (Rutherford et al., 2012; iGEM, 2021):
Synthesis: to secrete a signaling molecule, an auto-inducer.
Recognition: detect the change in concentration of signaling molecules.
Response: regulate gene transcription as a response.




Pseudoclavibacter sp.
Rhodococcus sp.
Shingomonas sp.
Vogesella sp.
Janthinobacterium sp.
Serratia sp.

28

Bacteria collection

In the biolab we only have microorganism catogorized as BSL-1, thus beeing relatively safe to work with, when taking the right safety precautions.

Janthinobacterium lividum
This bacteria is an aerobic, Gram-negative, soil-dwelling bacterium that has a distinctive dark-violet (almost black) color, due to a compound called violacein. Violacein has antibacterial, antiviral and antifungal properties.
It has an optimal growth temperature for pigment production at 25-30 C⁰ (Oh et al., 2019).

Serratia marcescens
This bacteria is a rodshaped, anaerobic, Gram-negative, soil-dwelling bacterium that has a distinctive red color, due to a compound called prodiogiosin. Prodiogiosin has biological activities including antimalarial, antifungal, immunosuppressant and antibiotic agents.
It has an optimal growth temperature for pigment production at 25-30 C⁰ (Haddix & Shanks, 2018).

Rhodococcus sp.
This bacteria is an aerobic, nonsporulating, nonmotile, Gram-positive, soil-dwelling bacteria that has a distinctive yellow-orange color, due to a compound called carotenoid.
It has an optimal growth temperature for pigment production at 25-30 C⁰ (Cappelletti et al., 2020).

Pseudoclavibacter sp.
This bacteria is a Gram-positive, non-spore-forming, strictly aerobic and non-motile genus, soil-dwelling bacteria that has a distinctive yellow color, due to a compound called carotenoid.
It has an optimal growth temperature for pigment production at 25-30 C⁰ (Oyaert et al, 2013).

Shingomonas sp.
This bacteria is an Gram-negative, rod-shaped, chemoheterotrophic, strictly aerobic bacteria, soil-dwelling bacteria that has a distinctive orange color, due to a compound called carotenoid.
It has an optimal growth temperature for pigment production at 25-30 C⁰ (Feng et al, 2014).

Vogesella indigofera
This bacteria is an aerobic, Gram-negative, soil-dwelling bacterium that has a distinctive blue (dark blue) color, due to a compound called indigoidine.
It has an optimal growth temperature for pigment production at 25-30 C⁰ (Yu et al., 2020).


ML
SM
OTHER

Storing bacteria

Agar stock
Bacteria on an LB agar plate can be stored at 4°C for a few weeks to be sure the bacteria are still alive. The agar plate is wrapped with parafilm around the edge to prevent contamination. We only have a fridge available in the lab, so for now, we store the bacteria here. It is important to mark your plate with name, date and content, othervise it will be removed.

Glycerol stock
In case you want to store bacteria for a longer time, you will need to make glycerol stocks by mixing bacteria, water and glycerol. The addition of glycerol stabilizes the frozen bacteria, preventing damage to the cell membranes and keeping the cells alive. A glycerol stock of bacteria can be stored stably at -80°C for several years. We cannot store glycerol stock at the biolab, so in the case you want to store a microorganism for a longer time, we will have to contact a natural science lab. Contact Monica Hartvigsen if you need help to contact a science lab in regards of making glycerol stocks.


CFH

3 Recipes

33


PROPAN 30 %
230g/410ml
450
BUTANO 70% / PROPANO 30%

Experiment #1: Preparing LB liquid media

Equipment:

- Ethanol
- Gloves
- Mask
- Sterile petri dishes
- Bunsen burner
- LB Broth
- Agar
- Demineralised water
- Pressure cooker
- Fridge
- Paper towel
- Autoclave tape

Prepare LB medium:

1. Measure 20g LB broth powder and 1L demineralised water.
2. Pur in glass container suitable for autoclaving and shake.
3. Put a piece of autoclave tape on the lid of the glass containers.
4. Place in pressure cooker with the lid placed loosely on the top and cook for minimum 30min.
   OBS! Remember to add water to the pressure cooker.
5. Let it cool a bit.
6. Close the lids to make it as airtight as possible.
7. Store until use.

Make sterile LB liquid medium plates:

1. Put on gloves and a mask.
2. Wipe the table surface with ethanol. Wait for the ethanol to evaporate.
3. Turn on the bunsen burner.
4. Pour in sterile petridishes. If you use a bunsenburner, heat the edge of the glass between each pour. You should fill approx. 1/2 of the petri dish.
5. Turn off the bunsen burner.
6. Clean the table surface with ethanol.

Storage:
Keep in fridge. Remember to write name, date and content on your petri dishes e.g. *Monica, 12.05.12, LB*.
If you keep the prepared medium in the fridge, do not place it together with food.


A20020-500.0
High Gel Strength, Pow
MOLECULAR BIOLOGY GRADE

Experiment #2: Preparing LB agar plates

Equipment:

- Ethanol
- Gloves
- Mask
- Sterile petri dishes
- Bunsen burner
- LB Broth
- Agar
- Demineralised water
- Pressure cooker
- Fridge
- Paper towel
- Autoclave tape

Prepare LB agar:

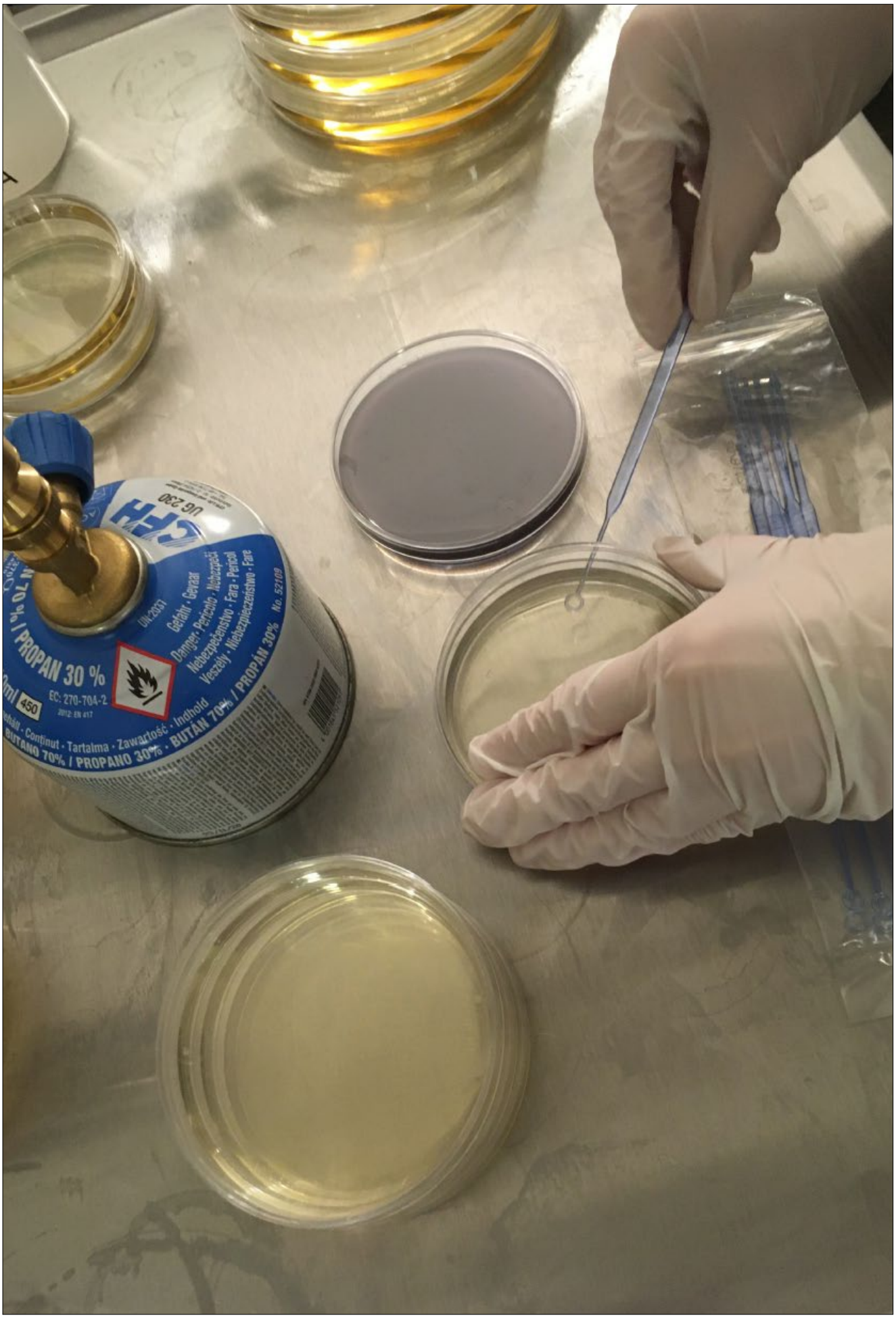
1. Measure 20g LB broth powder, 12-15g agar powder and 1L demineralised water.
2. Pur in glass and stir with a spoon.
3. Put a piece of autoclave tape on the lid of the glass containers.
4. Place in pressure cooker with the lid placed loosely on the top and cook for minimum 30min.
   OBS! Remember to add water to the pressure cooker.
5. Let it cool a bit.
6. Close the lids to make it as airtight as possible.

Make sterile LB agar plates:

1. Put on gloves and a mask.
2. Wipe the table surface with ethanol. Wait for the ethanol to evaporate.
3. Turn on the bunsen burner.
4. Pour in sterile petridishes, when still hot. If you use a bunsenburner, heat the edge of the glass between each pour. You should fill approx. 1/2 of the petri dish.
5. When solidified place the plates upside down in a plastic bag.
6. Turn off the bunsen burner.
7. Clean the table surface with ethanol.

Storage:

Keep the prepared petri dishes in the fridge. Remember to write name, date and content on your bag e.g. *Monica, 12.05.12, LB agar.*
If you keep the petridishes in a fridge, do not place it together with food.


PROPAN 30 %
EC: 270-704-2
Danger · Peligro · Nebezpečí
Nebezpečenstvo · Fara · Perigo
Veszély · Niebezpieczeństwo · Fare
BUTAN 70% / PROPAN 30%

Experiment #3: Bacteria inoculation to LB liquid media

Equipment:

- Ethanol
- Gloves
- Mask
- Sterile petri dishes
- Sterile inoculations loop
- Lighter
- Bunsen burner
- Bacterial sample
- Sterile LB liquid medium
- Paper towel
- Incubator

Bacterial inoculation:

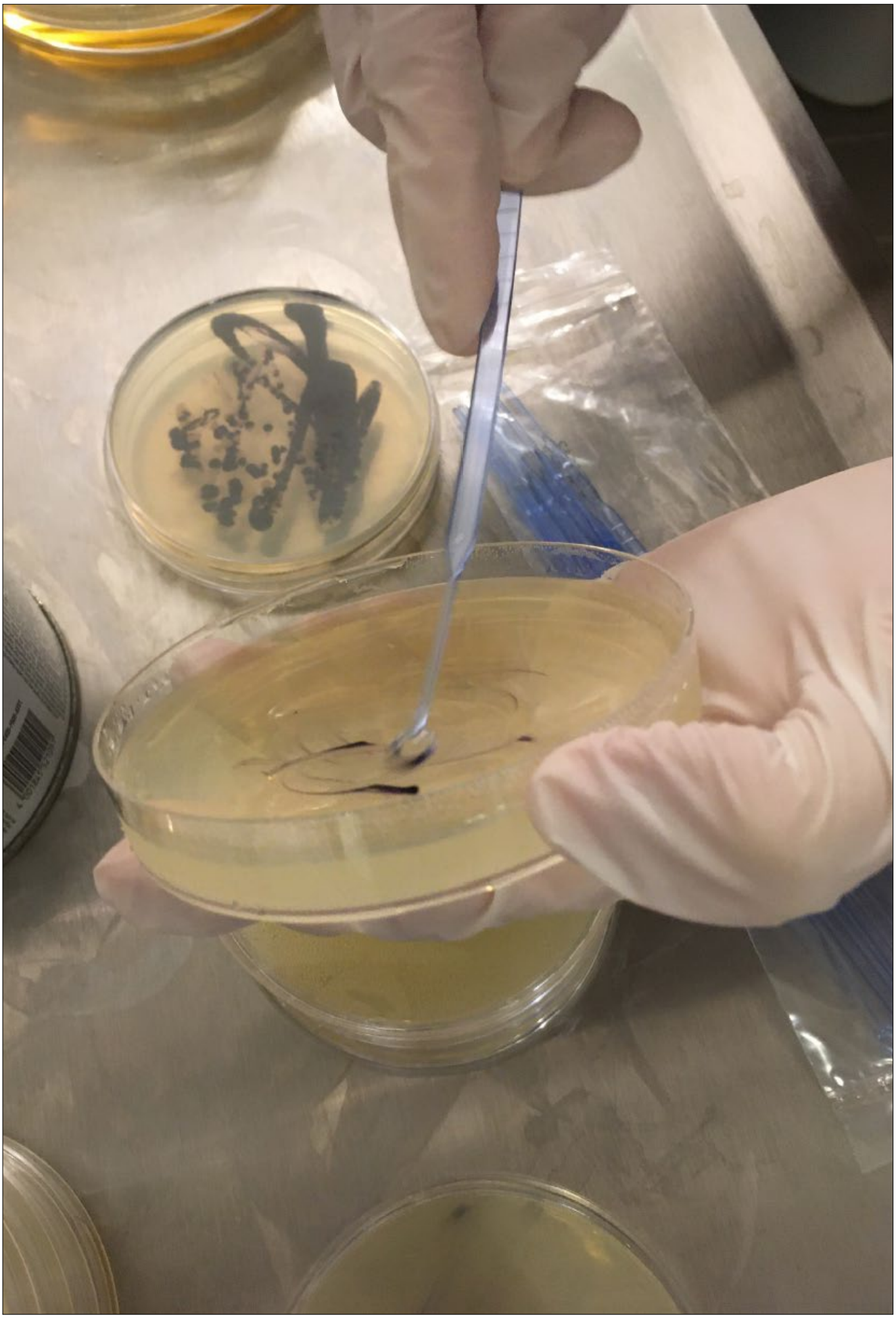
1. Put on gloves and a mask.
2. Wipe the table with ethanol and let it dry.
3. Take your bacterial sample out of the fridge and take it to you sterile workarea.
4. Write name, date and content on the sterile petri dish. E.g. *Monica, 12.05.12, LB, S. Marcescens.*
5. Turn on the bunsen burner.
6. Find your sterile inoculation loop.
7. Take a small sample from the liquid sample and try to keep the lid as closed as possible.
8. Take the sample to your fresh petridish and shake the sterile loop in the liquid LB medium.
9. Turn off the bunsen burner.
10. Clean the table surface with ethanol.

Growth conditions and storage:

1. The newly prepared bacterial samples are stored in the incubator (the white styrofoam boxes placed in the biolab) at room temperature and the light turned on.
2. Check the bacteria specie to find out about the exact growth conditions. The bacteria we have in the biolab grow at room temperature.
3. Leave it to grow for some days (3-5 days).
4. Wrap the bacterial sample in parafilm and store it in the fridge to keep it alive.

Waste management:

5. The gloves should be autoclaved before thrown in the waste bin.
6. Find an autoclave bag and put the gloves in. Close it with a piece of striped autoclaved tape. Cook for 30min. in the pressure cooker



Experiment #4: Bacteria inoculation to LB agar plates

Equipment:

- Ethanol
- Gloves
- Mask
- Sterile petri dishes
- Sterile inoculations loop
- Lighter
- Bunsen burner
- Bacterial sample
- Sterile LB liquid medium
- Paper towel
- Incubator

Bacterial inoculation:

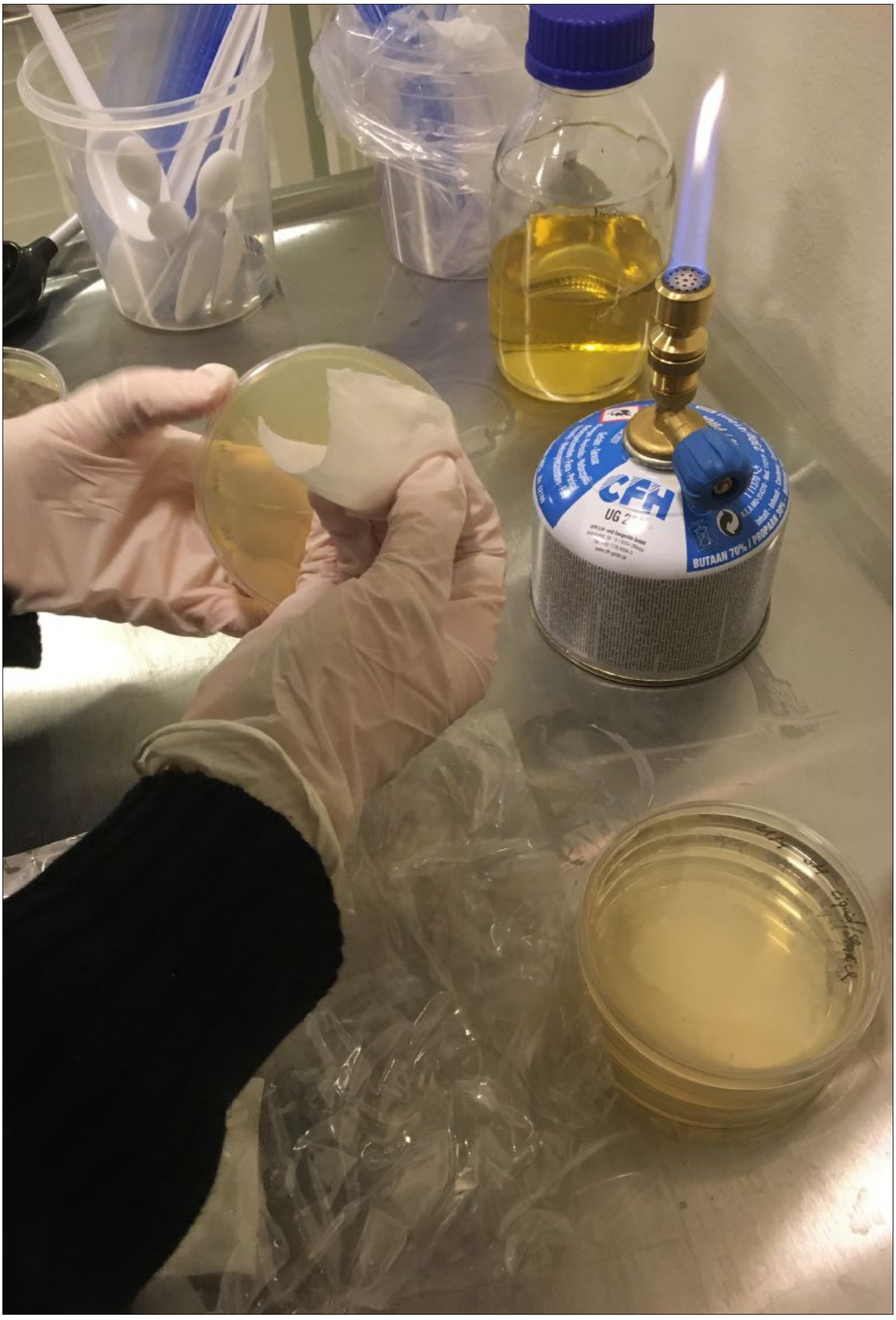
1. Put on gloves and a mask.
2. Wipe the table with ethanol and let it dry.
3. Take your bacterial strain sample out of the fridge and take it to you sterile workarea.
4. Write name, date and content on the sterile LB agar petri dish. E.g. *Monica, 12.05.12, LB agar, S. Marcescens.*
5. Find your sterile inoculation loop.
6. Take a small sample from the liquid sample with the sterile inoculation loop and try to keep the lid as closed as possible.
7. Take the sample to your prepared LB agar plate and smear the sample on to the surface of the plate.
8. Turn off the bunsen burner.
9. Clean the table surface with ethanol.

Growth conditions and storage:

1. The newly prepared bacterial samples are stored in the incubator (the white styrofoam boxes placed in the biolab) at room temperature and the light turned on.
2. Check the bacteria specie to find out about the exact growth conditions. The bacteria we have in the biolab grow at room temperature.
3. Leave it to grow for some days (3-5 days).
4. Wrap the bacterial sample in parafilm and store it in the fridge to keep it alive. Or kill the bacteria using the pressure cooker and autoclave bags.

Waste management:

5. The gloves should be autoclaved before thrown in the waste bin.
6. Find an autoclave bag and put the gloves in. Close it with a piece of striped autoclaved tape. Cook for 30min. in the pressure cooker


CFH
BUTAAN 70% / PROPAAN 30%

Experiment #5: Coloring textile with live bacteria

Equipment:

- Ethanol
- Gloves
- Sterile petri dishes
- Sterile inoculations loop
- Lighter
- Bunsen burner
- Bacterial sample
- Sterile LB liquid medium
- Paper towel
- Incubator
- Textile
- Autoclave bag
- Autoclave tape
- Mask

Prepare textile:

1. Cut the textile in the wanted size.
2. Place the textiles in an autoclave bag.
3. Close the bag with a piece of autoclave tape.
4. Place the autoclave bag in the pressure cooker.
5. Cook for 30min.

Bacterial inoculation:

1. Put on gloves and a mask.
2. Wipe the table with ethanol and let it dry.
3. Take your bacterial strain sample out of the fridge and take it to you sterile workarea.
4. Find your sterile inoculation loop.
5. Take a small sample from the liquid sample with the sterile inoculation loop and try to keep the lid as closed as possible.
6. Take the sample to your prepared LB agar plate or LB medium and smear the sample on to the surface of the plate or into the liquid.
7. **PLACE THE STERILE TEXTILE IN/ON YOUR BACTERIAL SAMPLE.**
8. Turn off the bunsen burner.
9. Clean the table surface with ethanol.

Growth conditions and storage:

1. The prepared bacterial samples **WITH TEXTILE** are stored in the incubator (the white styrofoam boxes placed in the biolab) and the light turned on.
2. The bacteria we have in the biolab grow at room temperature.
3. Leave it to grow for some days (3-5 days).
4. Kill the bacteria, petri dishes, sterile loops and gloves using the pressure cooker and autoclave bags.

Experiment #6: Coloring BIG pieces of textile with live bacteria

Equipment:

- Ethanol
- Gloves
- Sterile petri dishes
- Sterile inoculations loop
- Lighter
- Bunsen burner
- Bacterial sample
- Sterile LB liquid medium
- Paper towel
- Incubator
- Textile
- Autoclave bag
- Autoclave tape
- Mask

Prepare textile:

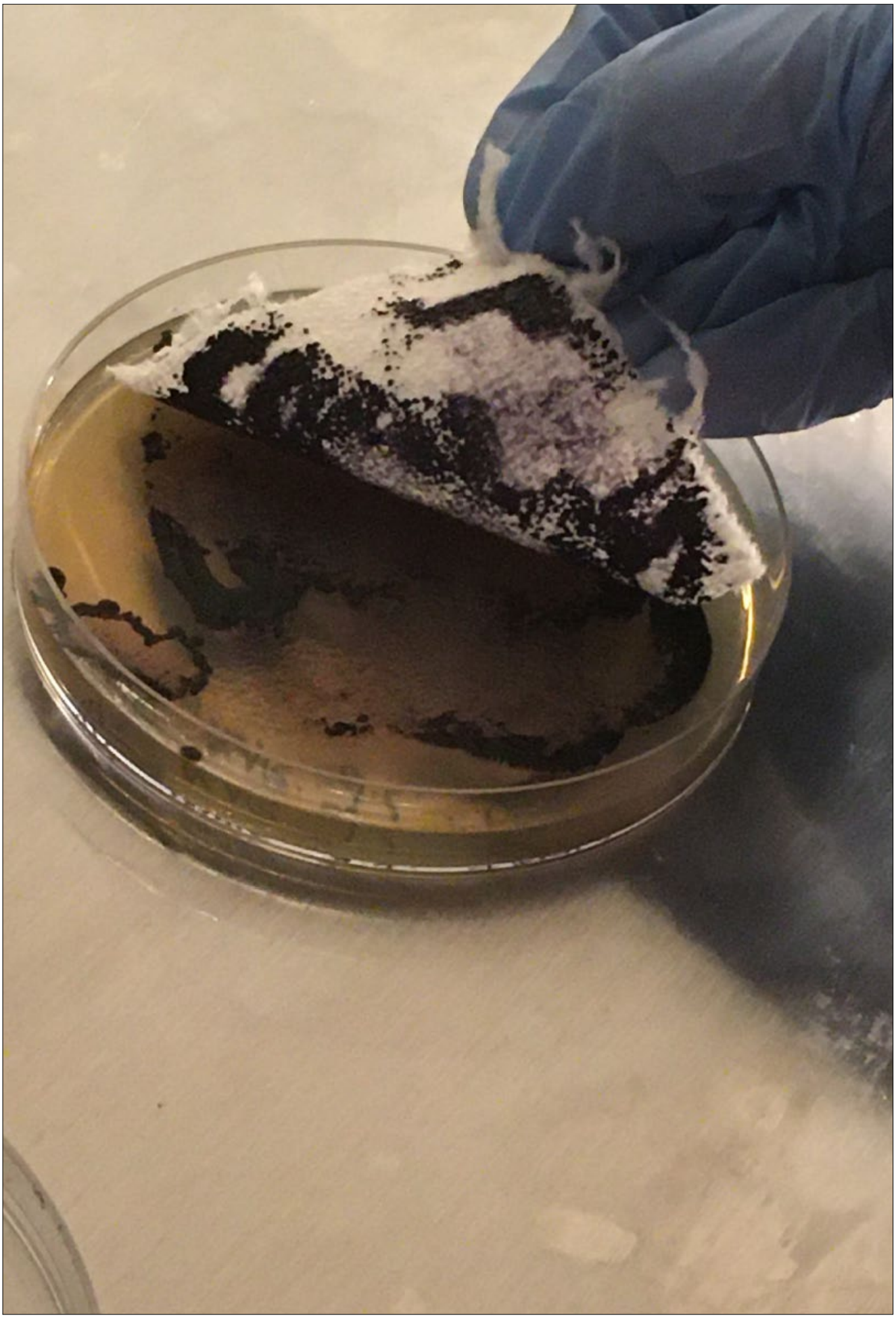
1. Cut the textile in the wanted size.
2. Place the textiles in an autoclave bag.
3. Close the bag with a piece of autoclave tape.
4. Place the autoclave bag in the pressure cooker.
5. Cook for 30min.

Bacterial inoculation:

1. Put on gloves and a mask.
2. Wipe the table with ethanol and let it dry.
3. Take your bacterial strain sample out of the fridge and take it to you sterile workarea.
4. Find your sterile inoculation loop.
5. Take a small sample from the liquid sample with the sterile inoculation loop and try to keep the lid as closed as possible.
6. **Find your bag with the sterilized textile.**
7. Open the bag as close to the busen burner as possible.
8. Add some sterile LB liquid medium to the bag.
9. Take a small bacteria sample with the sterile inoculation loop and shake in the bag.
10. Turn off the bunsen burner.
11. Clean the table surface with ethanol.

Growth conditions and storage:

1. The newly prepared bacterial samples **WITH TEXTILE** are stored in the incubator (the white styrofoam boxes placed in the biolab) at room temperature and the light turned on
2. The bacteria we have in the biolab grow at room temperature.
3. Leave it to grow for some days (3-5 days).
4. Kill the bacteria, petri dishes, sterile loops and gloves using the pressure cooker and autoclave bags.



Experiment #7: Stamping pieces of textile with live bacteria

Equipment:

- Ethanol
- Gloves
- Sterile petri dishes
- Sterile inoculations loop
- Lighter
- Bunsen burner
- Bacterial sample
- Sterile LB liquid medium
- Paper towel
- Incubator
- Textile
- Autoclave bag
- Autoclave tape
- Mask

Stamping on to textile:

1. Cut the textile in the wanted size.
2. Put on gloves and a mask.
3. Wipe the table with ethanol and let it dry.
4. Take you bacterial strain sample to your sterile workarea.
5. Place the textile on top of the bacteria grown on the LB agar plate.
6. Use your fingers to transfer pigment from the plate to the textile.
7. Gently remove the textile.

Fixating pigment to the textile:

1. Place the textiles in an autoclave bag. As well as petri dishes, sterile loops and gloves.
2. Close the bag with a piece of autoclave tape.
3. Place the autoclave bag in the pressure cooker.
4. Cook for 30min.
   OBS! Remember to add water to the pressure cooker.
5. Clean the table surface with ethanol.

Experiment #8: Coloring textile with harvested pigment

Equipment:

- Ethanol
- Gloves
- Sterile petri dishes
- Sterile inoculations loop
- Lighter
- Bunsen burner
- Bacterial sample
- Sterile LB liquid medium
- Paper towel
- Incubator
- Textile
- Autoclave bag
- Autoclave tape
- Mask

Prepare textile:

1. Cut the textile in the wanted size.

Killing bacteria to harvest pigment:

1. Put on gloves and a mask.
2. Wipe the table with ethanol and let it dry.
3. Take you bacterial samples, which have produced pigment in the liquid media, to your sterile workarea.
4. Put the liquid into a glass container.
5. Place the glass container in the pressure cooker.
6. Cook for 30min.
7. Clean the table surface with ethanol.

Dyeing with the harvested pigment:

1. Find the amount of glass containers you need.
2. Place the prepared textiles into glass containers.
3. Add the harvested pigment from the previous step.
4. Place the glass containers in the pressure cooker. As well as petri dishes, sterile loops and gloves.
5. Cook for 30min.
   OBS! Remember to add water to the pressure cooker.
6. Clean the table surface with ethanol.

Experiment #9: Coloring biomaterials with harvested pigment

Equipment:

- Ethanol
- Gloves
- Sterile petri dishes
- Sterile inoculations loop
- Lighter
- Bunsen burner
- Bacterial sample
- Sterile LB liquid medium
- Paper towel
- Incubator
- Textile
- Autoclave bag
- Autoclave tape
- Mask

Prepare material:

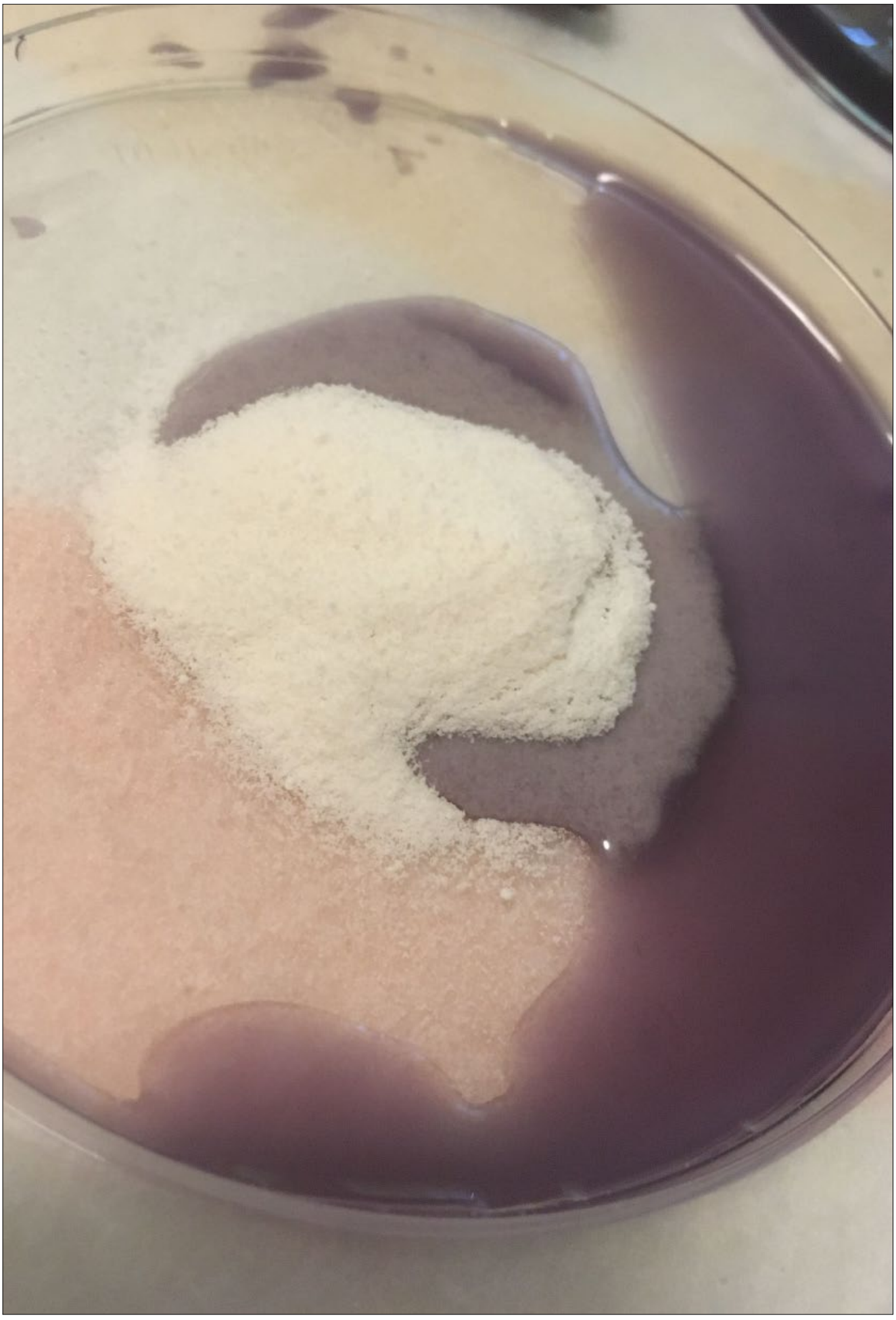
1. Find the material you want to dye e.g. PLA filament.

Killing bacteria to harvest pigment:

1. Put on gloves and a mask.
2. Wipe the table with ethanol and let it dry.
3. Take you bacterial samples, which have produced pigment in the liquid media, to your sterile workarea.
4. Put the liquid into a glass container.
5. Place the glass container in the pressure cooker.
6. Cook for 30min.
7. Clean the table surface with ethanol.

Dyeing with the harvested pigment:

1. Find the amount of glass containers you need.
2. Place the material(s) into glass containers.
3. Add the harvested pigment from the previous step.
4. Place the glass containers in the pressure cooker.
5. Cook for 30min.
   OBS! Remember to add water to the pressure cooker.
6. Clean the table surface with ethanol.



Experiment #10: Printing on textile with harvested pigment

Equipment:

- Ethanol
- Gloves
- Sterile petri dishes
- Sterile inoculations loop
- Lighter
- Bunsen burner
- Bacterial sample
- Sterile LB liquid medium
- Paper towel
- Incubator
- Textile
- Autoclave bag
- Autoclave tape
- Mask
- Binder (Gummi arabicum)

Prepare textile:

1. Cut the textile in the wanted size.

Killing bacteria to harvest pigment:

1. Put on gloves and a mask.
2. Wipe the table with ethanol and let it dry.
3. Take you bacterial samples, which have produced pigment in the liquid media, to your sterile workarea.
4. Put the liquid into a glass container.
5. Place the glass container in the pressure cooker.
6. Cook for 30min.
7. Clean the table surface with ethanol.

Printing with the harvested pigment:

1. Add a binder to you harvested pigment e.g. gummi arabicum.
2. Mix it together to get a homogen paste.
3. Use the print paste to print your textile in your wanted pattern.

Fixating the print to the textile:

1. Use a heat iron to fixate the print onto the textile. **THIS IS DONE IN THE BIOLAB** and **NOT IN THE TEXTILE WORKSHOP**.
2. Place the textiles in a pressure cooker and cook for 30min. to make sure all the bacteria are killed.
   OBS! Remember to add water to the pressure cooker.
3. Clean the table surface with ethanol.


WASCO

Experiment #11: Waste management

Equipment:

- Pressure cooker
- Textile
- Autoclave bag
- Autoclave tape
- Gloves
- Mask
- Bacterial samples
- Ethanol
- Paper towel
- Glass container

Waste management:
Since you are working with biological material, it is important to kill the bacteria before throwing anything, that has been in contact with the living bacteria, in the trash.

Safely kill bacteria:

1. Put on gloves and a mask.
2. Seperate the textile and the petri dishes from each other.
3. Put the textiles in one autoclave bag
4. Put the petridishes, used sterile loops and gloves in another autoclave bag. If you have used anything else, when working with the bacteria, this should also be autoclaved.
5. Remeber to open the petri dishes otherwise a vacuum can form and the petri dishes can explode in the pressure cooker.
6. If you have any liquid, put it in a glass container and place it in the pressure cooker as well.
7. Place the autoclave bags in the pressure cooker.
8. Cook for 30min.
   OBS! Remember to add water to the pressure cooker.
9. The waste is now safe to throw out in the normal trash bins.
10. The textile is also safe to touch without gloves.
11. Clean the workspace with ethanol.


PARAFILM "M"
LABORATORY FILM
Bemis
PM-996
PARAFILM "M"

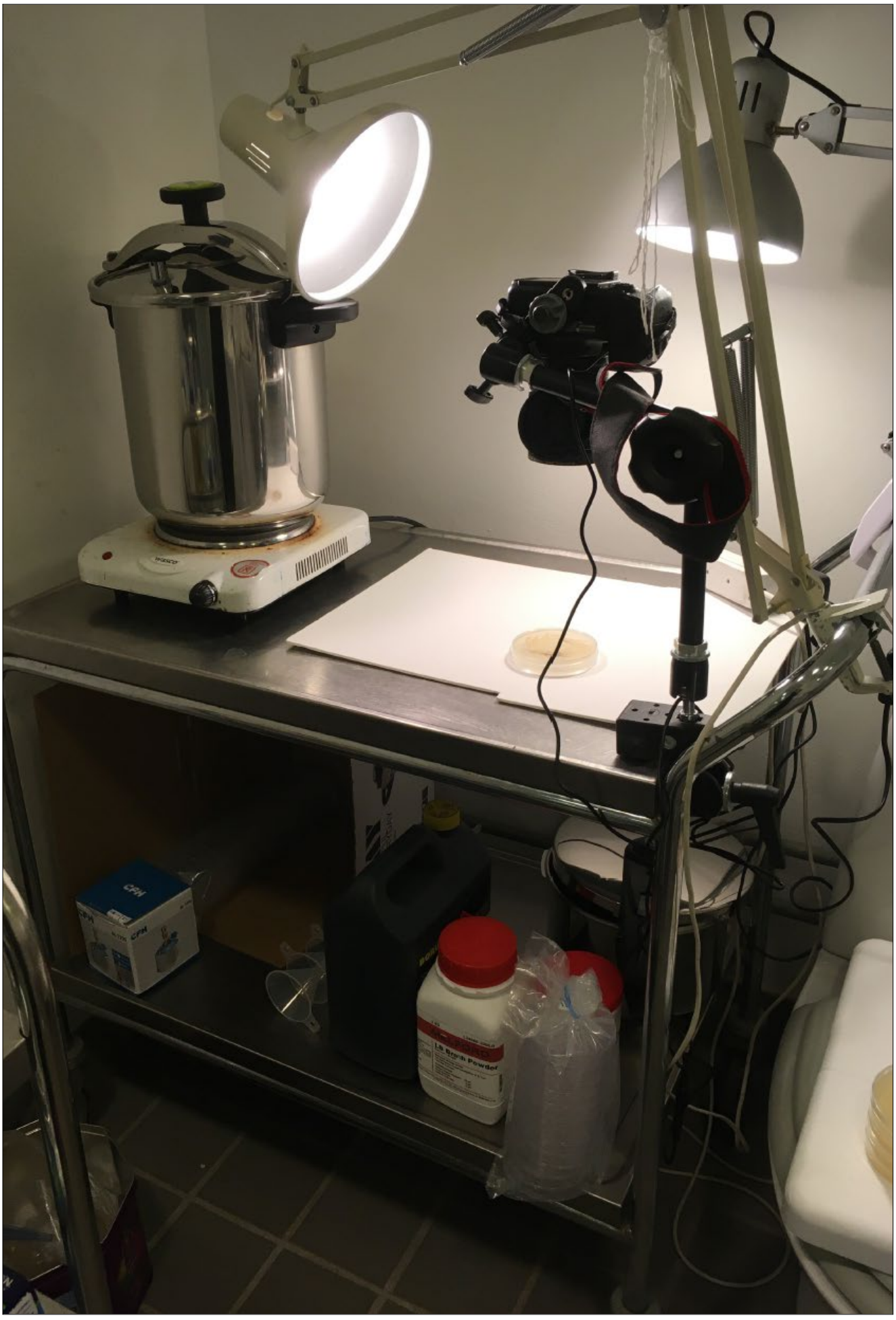
Experiment #12: Storing bacteria - parafilming

Equipment:

- Pressure cooker
- Textile
- Autoclave bag
- Autoclave tape
- Gloves
- Mask
- Bacterial samples
- Ethanol
- Paper towel
- Glass container

LB agar plates stock:

1. Put on gloves.
2. Cut a piece of parafilm.
3. Wrap it around the petri dish streching the parafilm to reach all the way aound the plate.
4. Put the parafilmed petri dish in the fridge.
5. Remember to mark the petri dish with date, content and name.


CPH
Lb Broth Powder

4 Video tutorials

Preparing LB liquid media
LINK TO VIDEO

Preparing LB agar plates
LINK TO VIDEO

Bacteria inoculation to LB liquid media
LINK TO VIDEO

Bacteria inoculation to LB agar plates
LINK TO VIDEO

Coloring textile with live bacteria
LINK TO VIDEO

Stamping textile with live bacteria
LINK TO VIDEO

Coloring with harvested pigment
LINK TO VIDEO

Printing textile with harvested pigment
LINK TO VIDEO

Parafilming
LINK TO VIDEO

Waste management
LINK TO VIDEO

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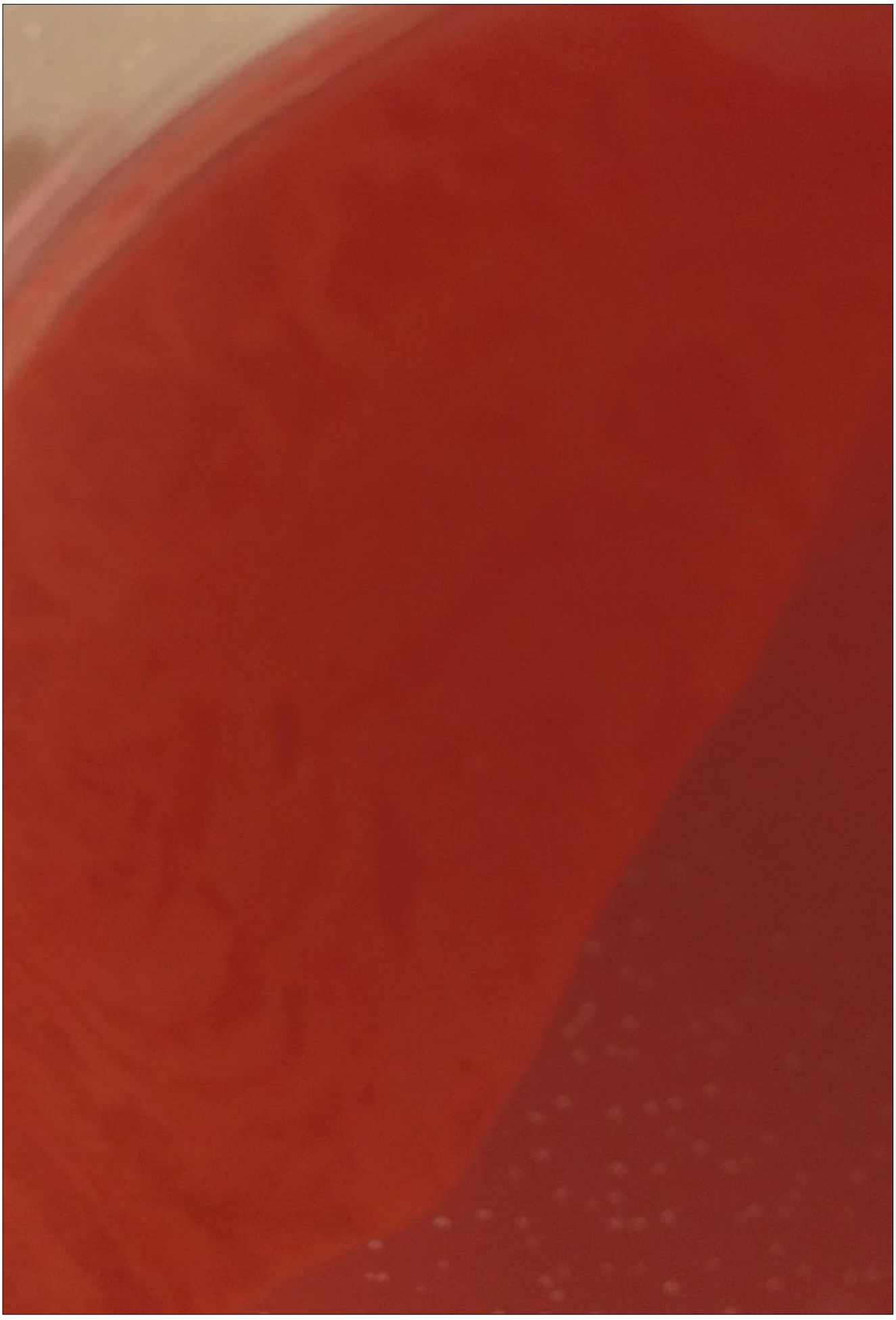

5 Glossary

Aerob: an organism (such as a bacterium) that lives only in the presence of oxygen.

Anaerob: an organism (such as a bacterium) that lives in the absence of free oxygen.

Agar: a gelatinous colloidal extract of a red alga (as of the genera Gelidium, Gracilaria, and Eucheuma) used especially in culture media or as a gelling and stabilizing agent in foods.

Agar plate: a Petri dish that contains a growth medium solidified with agar, used to culture microorganisms. Sometimes selective compounds are added to influence growth, such as antibiotics.

Aseptic: preventing infection or free or freed from pathogenic microorganisms.

Autoclave bag: Autoclave or sterilisation bags are supplied for the secure containment of items intended for autoclaving, steam sterilisation, disposal or incineration.

Autopoesis: the property of a living system (such as a bacterial cell or a multicellular organism) that allows it to maintain and renew itself by regulating its composition and conserving its boundaries.

Bacteria: Microscopic single-celled organisms lacking a distinct nucleus are known as bacteria. They may be shaped like spheres, rods, or spirals. They inhabit virtually all environments, including soil, water, organic matter, and the bodies of animals.

Biosafety level: or pathogen/protection level, is a set of biocontainment precautions required to isolate dangerous biological agents in an enclosed laboratory facility. The levels of containment range from the lowest biosafety level 1 (BSL-1) to the highest at level 4 (BSL-4).

Carbohydrate: are the main source of energy for the body. They are the sugars, starches, and dietary fiber that occur in plant foods and dairy products. Carbohydrates are mainly found in plant foods. They also occur in dairy products in the form of a milk sugar called lactose.

DNA: Deoxyribonucleic Acid (DNA) is the chemical name for the molecule that carries genetic instructions in all living things. The DNA molecule consists of two strands that wind around one another to form a shape known as a double helix. Each strand has a backbone made of alternating sugar (deoxyribose) and phosphate groups. Attached to each sugar is one of four bases--adenine (A), cytosine (C), guanine (G), and thymine (T). The two strands are held together by bonds between the bases; adenine bonds with thymine, and cytosine bonds with guanine. The sequence of the bases along the backbones serves as instructions for assembling protein and RNA molecules.

Endorgonic reaction: (also called a heat absorbing nonspontaneous reaction or an unfavorable reaction) is a chemical reaction in which the standard change in free energy is positive, and an additional driving force is needed to perform this reaction.

Enzyme: a substance that acts as a catalyst in living organisms, regulating the rate at which chemical reactions proceed without itself being altered in the process.

Ethanol: (also called ethyl alcohol, grain alcohol, drinking alcohol, or simply alcohol) is an organic chemical compound.

Exergonic reaction: is a chemical reaction where the change in the free energy is negative (there is a net release of free energy).

Fermentation: is a metabolic process that produces chemical changes in organic substrates through the action of enzymes. In biochemistry, it is narrowly defined as the extraction of energy from carbohydrates in the absence of oxygen.

Genetically Modified Organism: (GMO) can be defined as organisms (i.e. plants, animals or microorganisms) in which the genetic material (DNA) has been altered in a way that does not occur naturally by mating and/or natural recombination.

Gram-positive bacteria: bacteria with thick cell walls.

Gram-negative bacteria: bacteria with thick cell walls.

Growth media: or culture medium is a solid, liquid, or semi-solid designed to support the growth of a population of microorganisms or cells via the process of cell proliferation or small plants like the moss Physcomitrella patens. Different types of media are used for growing different types of cells.

Incubator: an apparatus with a chamber used to provide controlled environmental conditions especially for the cultivation of microorganisms or the care and protection of premature or sick babies.

Inoculation: to introduce (something, such as a microorganism) into a suitable situation for growth.

Inorganic compound: any substance in which two or more chemical elements (usually other than carbon) are combined, nearly always in definite proportions.

LB Broth: is a nutritionally rich medium primarily used for the growth of bacteria.

Metabolism: is a term that is used to describe all chemical reactions involved in maintaining the living state of the cells and the organism.

Nutrients: a nutrient is a substance used by an organism to survive, grow, and reproduce.

Organic compound: any of a large class of chemical compounds in which one or more atoms of carbon are covalently linked to atoms of other elements, most commonly hydrogen, oxygen, or nitrogen.

Oxidative agent: a substance that oxidizes something especially chemically (as by accepting electrons).

Parafilm: is a semi-transparent, flexible film composed of a proprietary blend of waxes and polyolefins. It is a ductile, malleable, non-toxic, tasteless and odorless, and self-sealing thermoplastic.

Petri dish: a Petri dish (alternatively known as a Petri plate or cell-culture dish) is a shallow transparent lidded dish that biologists use to hold growth medium in which cells can be cultured, originally, cells of bacteria, fungi and small mosses.

Pigment: A particle or substance that has a specific colour. a powdered substance that is mixed with a liquid in which it is relatively insoluble and used especially to impart color to coating materials (such as paints) or to inks, plastics, and rubber.

Protein: any of various naturally occurring extremely complex substances that consist of amino-acid residues joined by peptide bonds, contain the elements carbon, hydrogen, nitrogen, oxygen, usually sulfur, and occasionally other elements (such as phosphorus or iron), and include many essential biological compounds (such as enzymes, hormones, or antibodies).

Protocol: a detailed plan of a scientific or medical experiment, treatment, or procedure.

RNA: ribonucleic acid (RNA), complex compound of high molecular weight that functions in cellular protein synthesis and replaces DNA (deoxyribonucleic acid) as a carrier of genetic codes in some viruses. RNA consists of ribose nucleotides (nitrogenous bases appended to a ribose sugar) attached by phosphodiester bonds, forming strands of varying lengths. The nitrogenous bases in RNA are adenine, guanine, cytosine, and uracil, which replaces thymine in DNA.

Sterile: completely clean and free from dirt and bacteria.

Streaking: is a technique used to isolate a pure strain from a single species of microorganism, often bacteria. Samples can then be taken from the resulting colonies and a microbiological culture can be grown on a new plate so that the organism can be identified, studied, or tested.

Substrate: the surface or material on or from which an organism lives, grows, or obtains its nourishment or the substance on which an enzyme acts.

Reducing agent: a substance that reduces a chemical compound usually by donating electrons.

Tissue: any of the distinct types of material of which animals or plants are made, consisting of specialized cells and their products.

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6 Suggested readings

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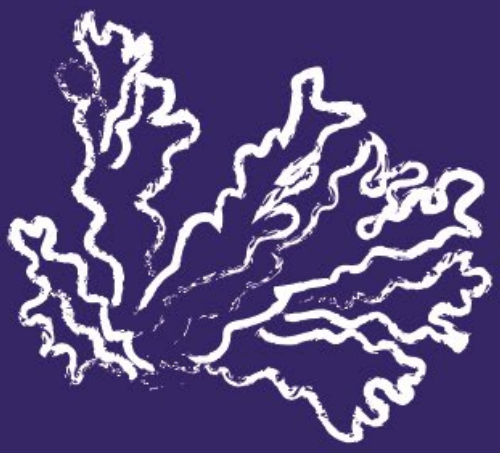
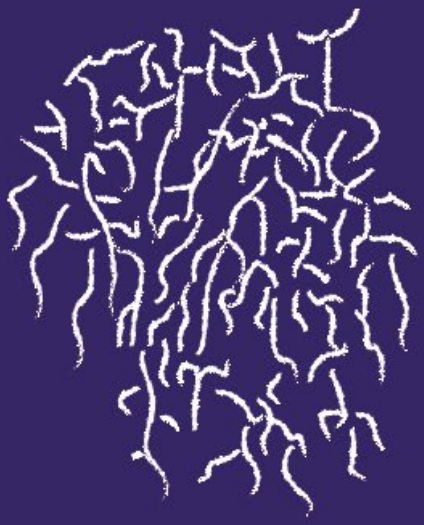
Bio Cards





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Bio Cards

This tool comprises 21 cards, each providing a brief introduction to a specific aspect of the biomaterial world. It is designed to inspire designers by sparking curiosity about microorganisms and serves as an educational resource for sharing knowledge about biomaterials and biocolours.

The cards present selected algae, bacteria, and fungi, along with the biocolours or biomaterials they produce.

An overview of the cards is provided below.

Algae

Biomaterial	Biocolour
Spirulina	Phycocyanin
Alginate	Phycoerythrin
Agar	Luciferin

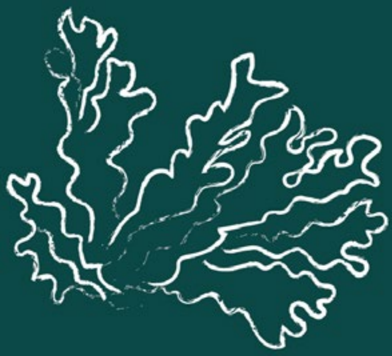
Bacteria

Biomaterial	Biocolour
Bacterial cellulose	Violacein
Calcium carbonate	Indigoidine
Polyhydroxy-alkanoate (PHA)	Prodiogiosin
	Carotenoid
	Structural colour

Fungi

Biomaterial	Biocolour
Chitin	Xylindein
Chitosan	Bisorbicillinol
Mycelium	Azaphilone
Mycelium leather	

Algae



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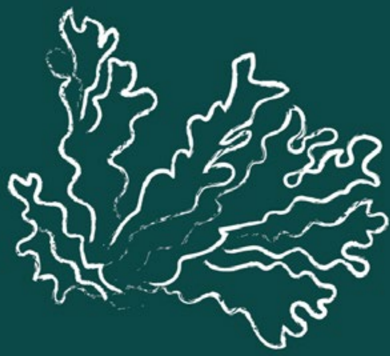
Algae



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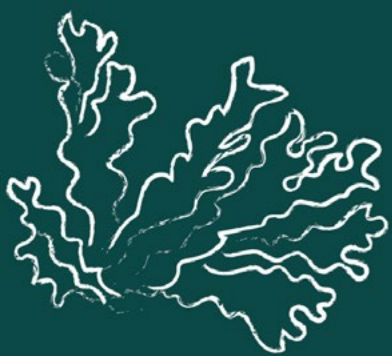

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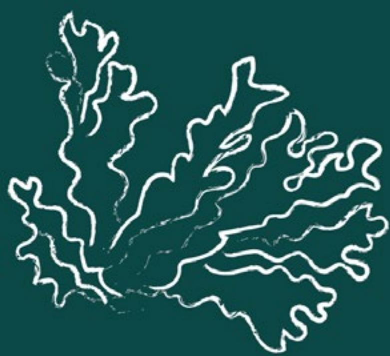
Algae



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Spirulina

Who grew this?

Spirulina, a type of blue-green algae, is one of the oldest known species on Earth. It is rich in various nutrients, including fat-soluble vitamins (A, E, and K), essential fatty acids (DHA and EPA), beta carotene, and a range of minerals.

Biomaterial

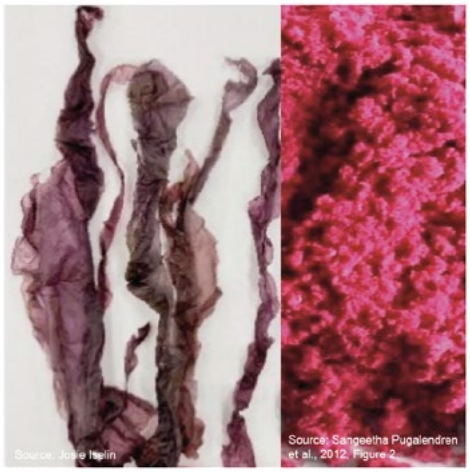
Phycocyanin

Who grew this?

Phycocyanin, a phycobiliprotein, is found in cyanobacteria, a type of blue-green algae that obtains its energy through photosynthesis. It plays an important ecological role as an indicator of cyanobacteria blooms.

Biocolour

Phycoerythrin



Who grew this?

Phycoerythrin, a phycobiliprotein, is found in red algae (Cyanobacteria), Rhodophyta, Glaucocystophyta, and Cryptophyta. It plays a crucial role in photosynthesis.

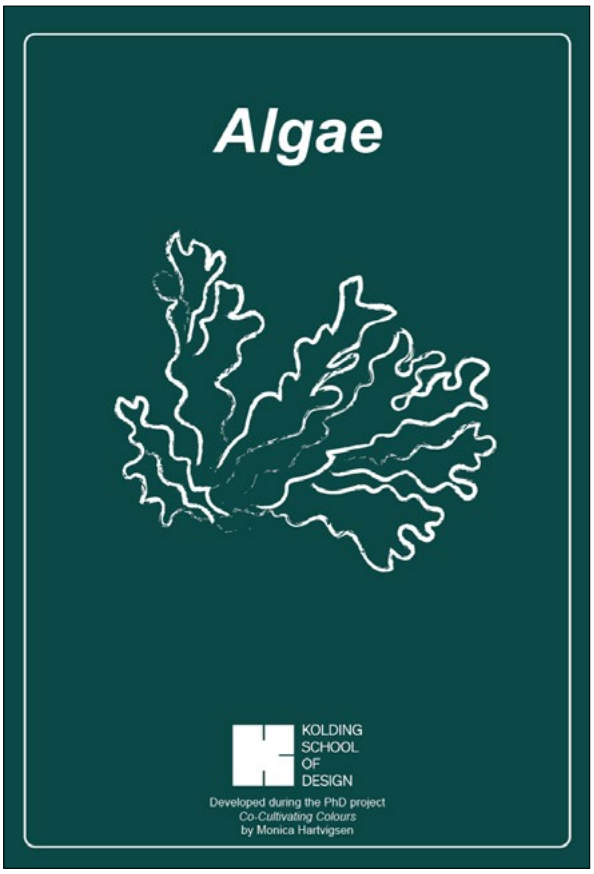
Biocolour

Alginate

Who grew this?

Alginate, a polysaccharide derived from the cell walls of brown algae, has the ability to form a gel.

Biomaterial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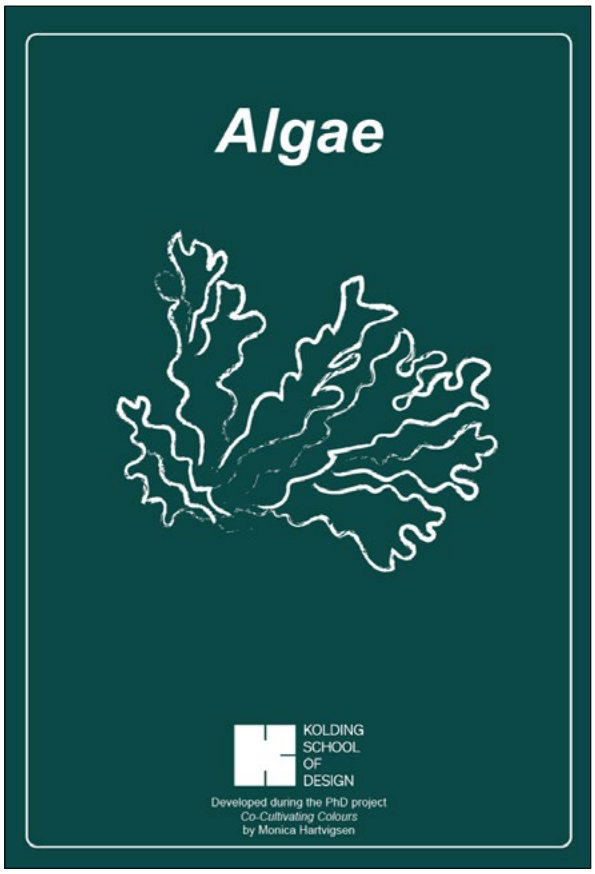
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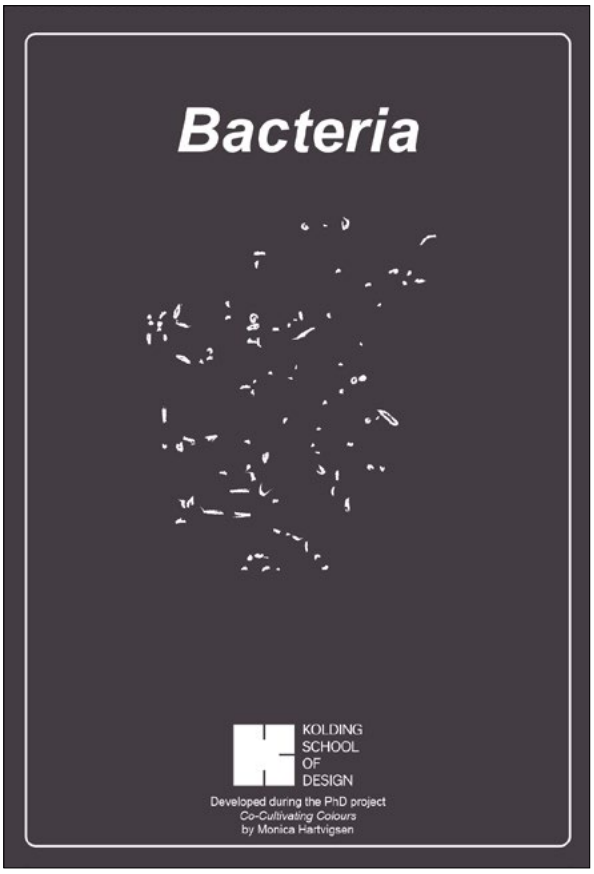
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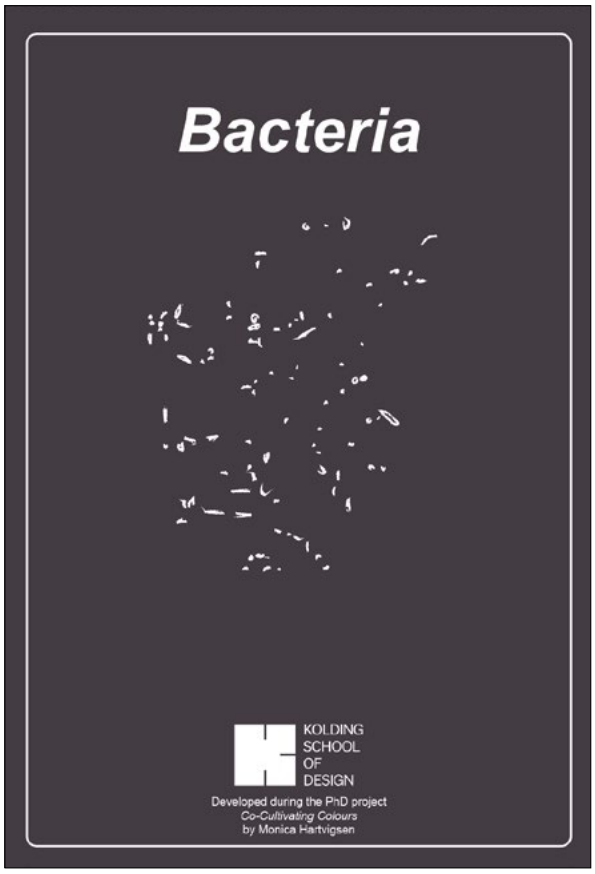
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Agar

Who grew this?

Agar, derived from the cell walls of certain species of red algae, is composed of a mixture of two polysaccharides: agarose and agaropectin, with agarose accounting for approximately 70% of the mixture. It possesses the ability to form a gel.

Biomaterial

Luciferin

Who grew this?

Bioluminescent algae, most commonly dinoflagellates, produce light through the interaction of the enzyme luciferase and the compound luciferin. Luciferin is a complex molecule that generates light, while luciferase is an enzyme that accelerates the chemical reaction, resulting in the emission of light.

Biocolour

Violacein

Who grew this?

Violacein is a purple pigment produced by the bacterium Janthinobacterium lividum.

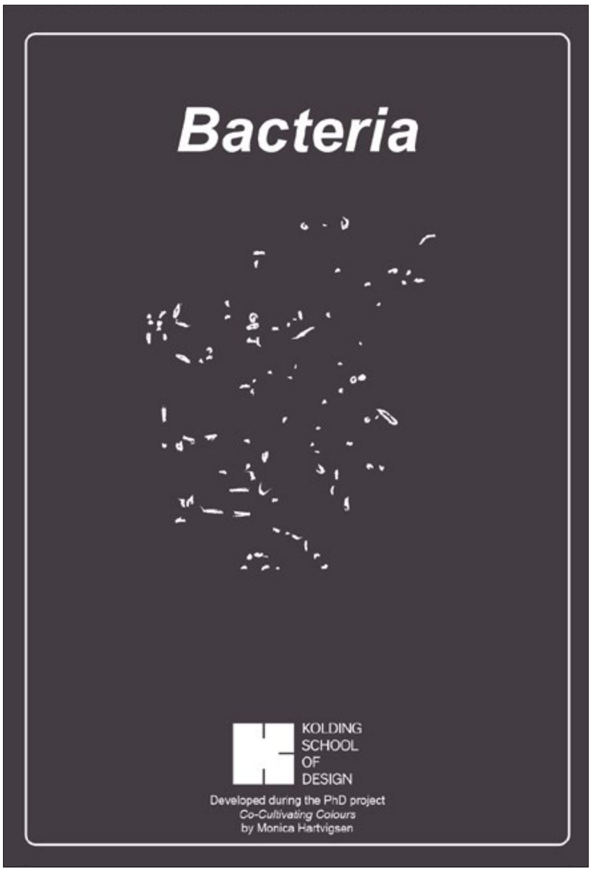
Biocolour

Carotenoid

Who grew this?

The orange or yellow pigment known as carotenoid is produced by various bacteria, such as Sphingomonas sp. or Micrococcus luteus, the latter being a common bacterium found on human skin.

Biocolour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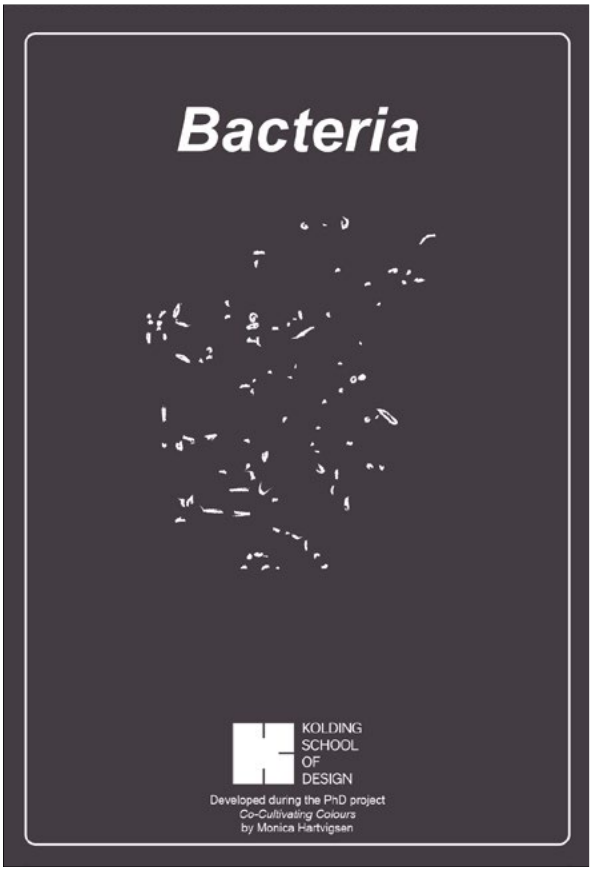
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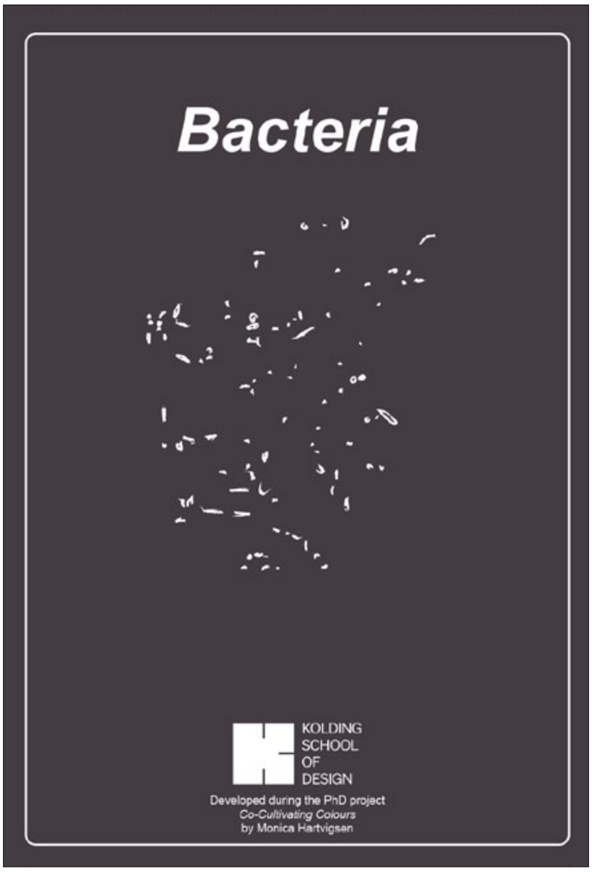
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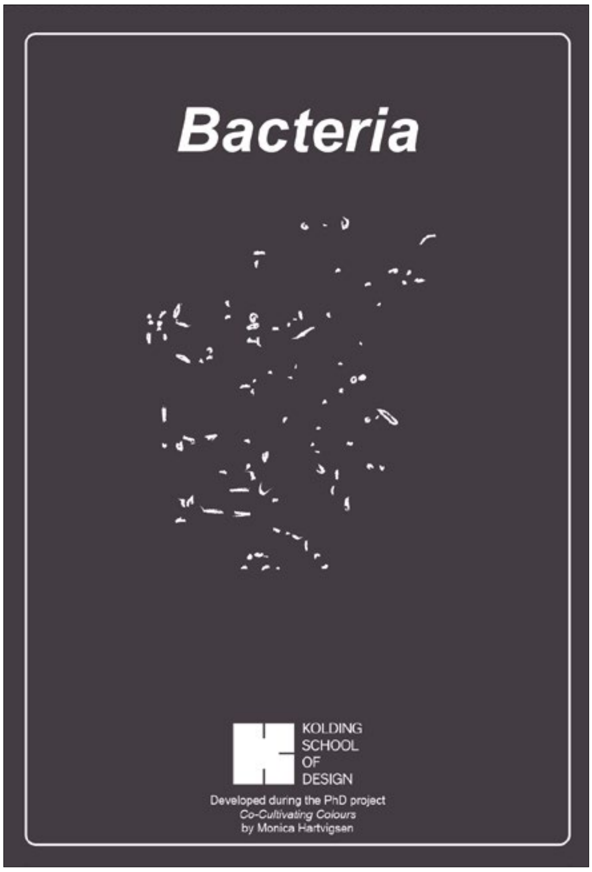
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Polyhydroxyalkanoat

Who grew this?
Polyhydroxyalkanoate (PHA) is a bioplastic comparable to PLA. It is produced by various bacteria, such as Cupriavidus necator, Aspergillus eutrophus, and Rhodobacter sphaeroides.

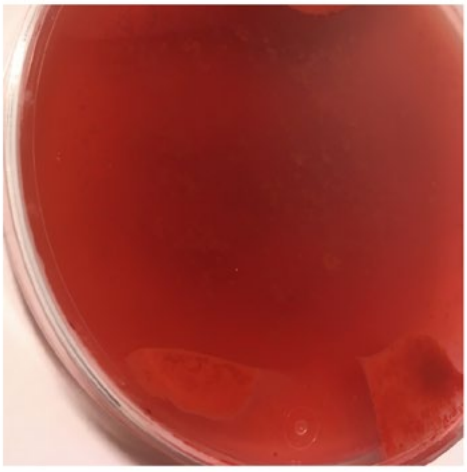
Biomaterial

Calcium carbonate

Who grew this?
Biomineralization is the process by which ureolytic bacteria, utilizing urea, produce calcium carbonate biominerals.

Biomaterial

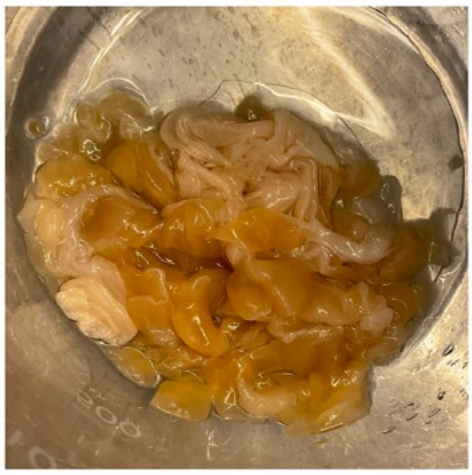
Prodiogiosin



Who grew this?
The red pigment, prodigiosin, is produced by the bacterium Serratia marcescens.

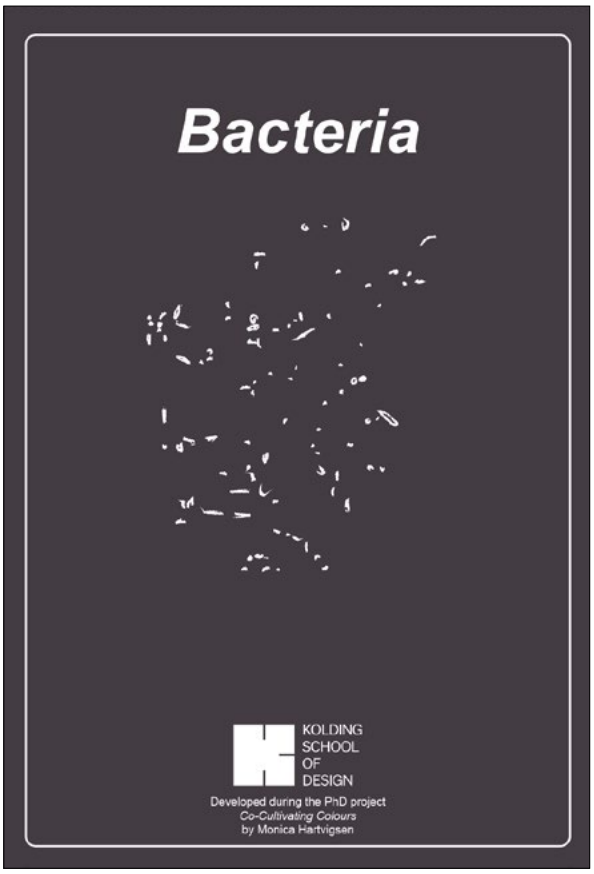
Biocolour

Bacterial cellulose



Who grew this?
Bacterial cellulose is produced by various types of bacteria, such as Komagataeibacter xylinus, which utilize different forms of agricultural waste as nutrients for cultivation. It can also be generated by a symbiotic consortium of yeast and bacteria, known as SCOBY.

Biomaterial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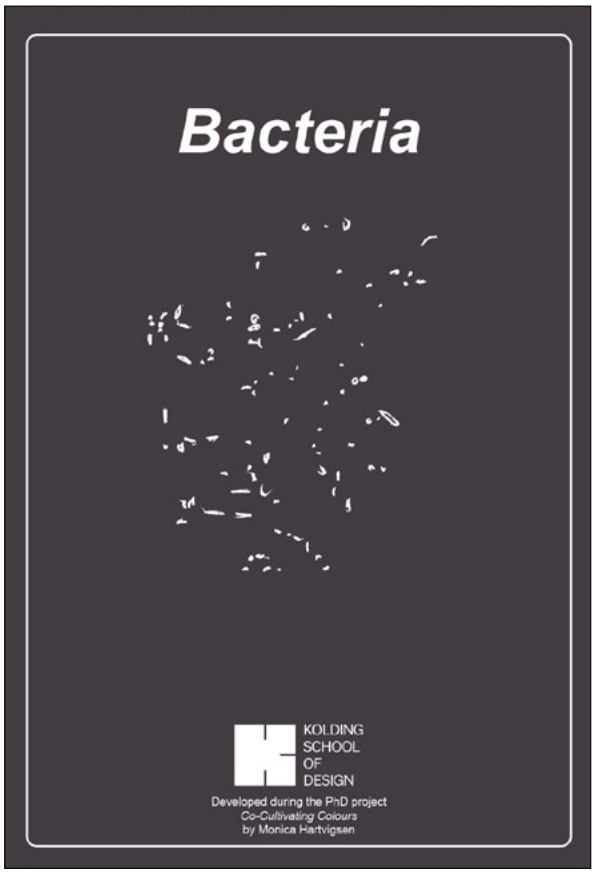
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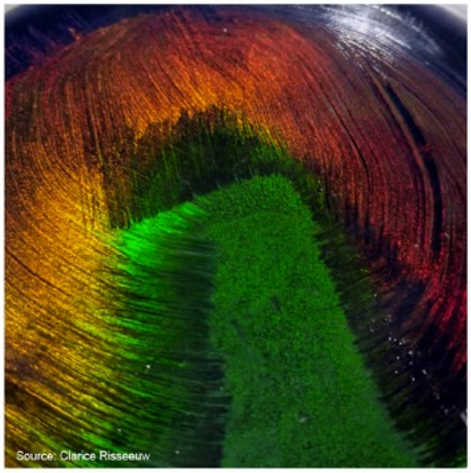
Structural colour

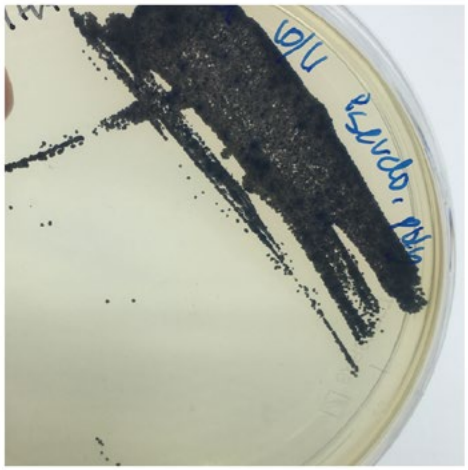


Who grew this?

Some bacteria, such as Flavobacteria sp., produce structural color by arranging themselves into nanostructures that reflect specific wavelengths of light, resulting in the creation of various colors.

Biocolour

Indigoidine



Who grew this?

The blue pigment, indigoidine, can be produced by various bacterial strains, including Vogesella indigofera and Pseudoanthrobacter polychromogenes.

Biocolour

Mycelium leather

Who grew this?

Mycelium leather is derived from the root-like network of fungi, known as mycelium. Various types of fungi can be utilized for this process, such as Trametes versicolor, which digests lignocellulose and forms a dense mycelium network suitable for producing mycelium leather.

Biomaterial

Chitosan

Who grew this?

Chitosan is a derivative of chitin. It is produced by partially removing acetyl groups from chitin through a process known as deacetylation, which makes it soluble in aqueous acetic acid. Chitin is commonly found in the cell walls of filamentous fungi.

Biomaterial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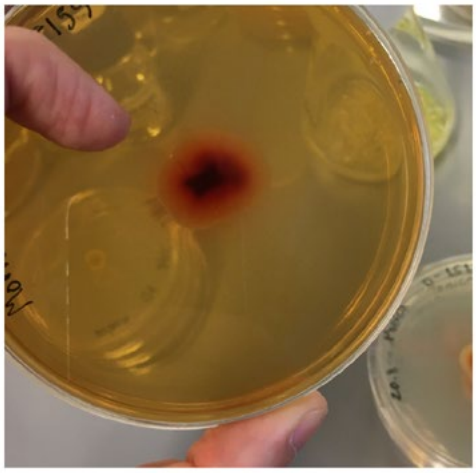
Chitin

Who grew this?

Chitin, the second most abundant polymer after cellulose, is present in the cell walls of filamentous fungi.

Biomaterial

Azaphilone

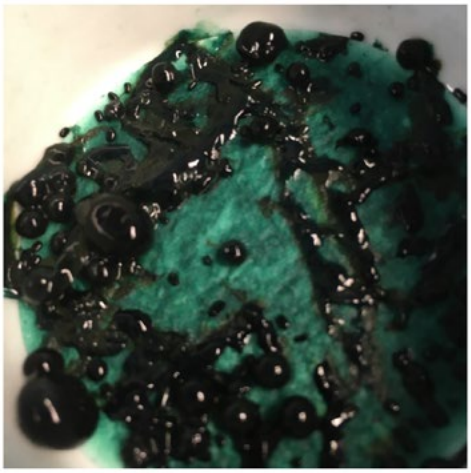


Who grew this?

The fungus Penicillium purpurogenum produces a red pigment belonging to the azaphilone molecular structure.

Biocolour

Xylindein



Who grew this?

The fungus Green Elf Cup (Chlorociboria aeruginascens) produces a green pigment known as xylindein. This fungus thrives on decaying wood, coloring it green as it grows.

Biocolour

Mycelium

Who grew this?

Mycelium, derived from the root network of fungi, can act as a natural "glue," binding various sources of biomass together to form a biocomposite material. During this process, it digests part of the biomass as it develops its root-like structure.

Biomaterial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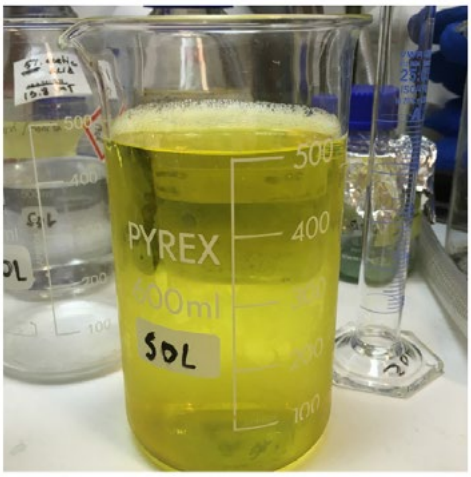
Bisorbicillinol



Who grew this?

The fungus Trichoderma reesei produces a yellow pigment known as bisorbicillinol. It thrives on various carbon sources and has been utilized for large-scale industrial production.

Biocolour

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by Monica Hartvigsen

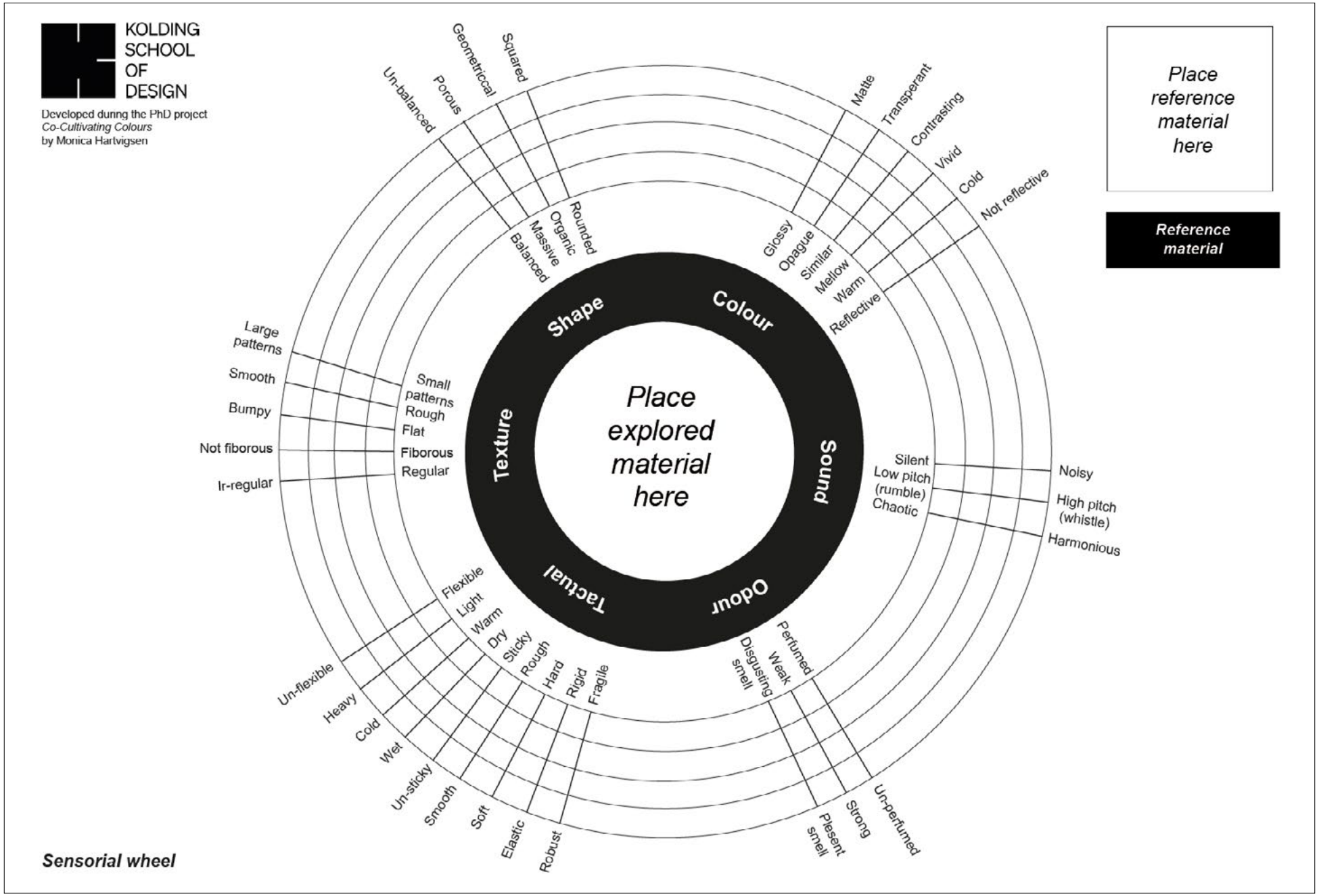
The **Sensuous Tool** is a set of three wheels designed to assist designers in exploring materials, facilitating discussions and reflections by comparing material qualities, and communicating material choices throughout the design process. While the three wheels are intended to be used together as a series, they can also be used individually when a designer wishes to explore a specific aspect of a material. These tools are suitable for both group and individual use and can be utilized either physically or digitally. It is recommended to use them physically if the material is available for hands-on interaction.

The **Sensorial Wheel** helps examine materials by evaluating them based on contrasting qualities. To use it, place the material being assessed in the centre and the reference material in the top right corner. Next, fill in each word pair grouped by qualities (colour, sound, odour, tactility, texture, and shape) by marking the line between the two words. For example, if the material in the centre feels rough compared to the reference material, the mark should be placed closer to “rough” than “smooth.” These marks create a visual comparison, which is useful when comparing multiple materials to the same reference material. This tool can aid in selecting materials during a design process or understanding material differences. Additional word pairs can be added to further describe the material.

The **Visual Wheel** explores the characteristics of selected materials by using samples or photographs to illustrate them. This process also involves comparing the chosen material to a reference material. When used in conjunction with the Sensorial Wheel, these samples or photos can align with the descriptive word pairs to explore the understanding of materials and highlight similarities or differences.

The **Impact Wheel** examines how materials evolve over time with use. Selected attributes are marked to show how various factors affect the material as it ages, grouped by themes. Additional attributes can be added to provide a more detailed description of the material’s changes over time.

Explainer


KOLDING SCHOOL OF DESIGN
Developed during the PhD project
Co-Cultivating Colours
by Monica Hartvigsen
Place reference material here
Reference material
Place explored material here
Shape
Colour
Sound
Odour
Tactual
Texture
Rounded
Organic
Massive
Balanced
Squared
Geometrical
Porous
Un-balanced
Matte
Transparent
Contrasting
Vivid
Cold
Not reflective
Glossy
Opague
Similar
Mellow
Warm
Reflective
Silent
Low pitch (rumble)
Chaotic
Noisy
High pitch (whistle)
Harmonious
Perfumed
Weak
Disgusting smell
Un-perfumed
Strong
Plesent smell
Flexible
Light
Warm
Dry
Sticky
Rough
Hard
Rigid
Fragile
Un-flexible
Heavy
Cold
Wet
Un-sticky
Smooth
Soft
Elastic
Robust
Small patterns
Rough
Flat
Fiborous
Regular
Large patterns
Smooth
Bumpy
Not fiborous
Ir-regular
Sensorial wheel

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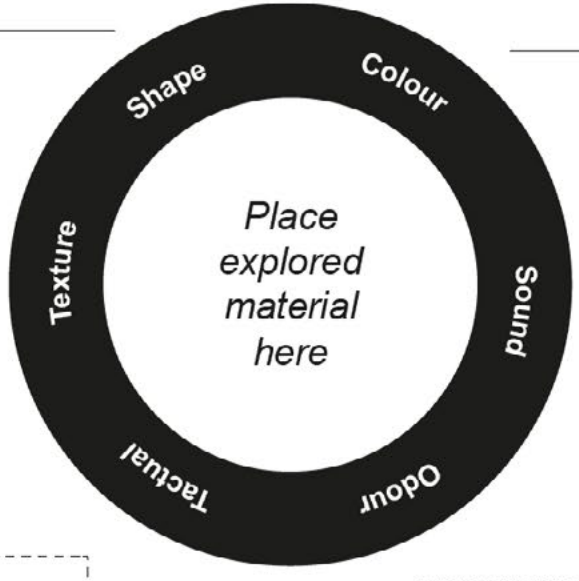

Visual wheel

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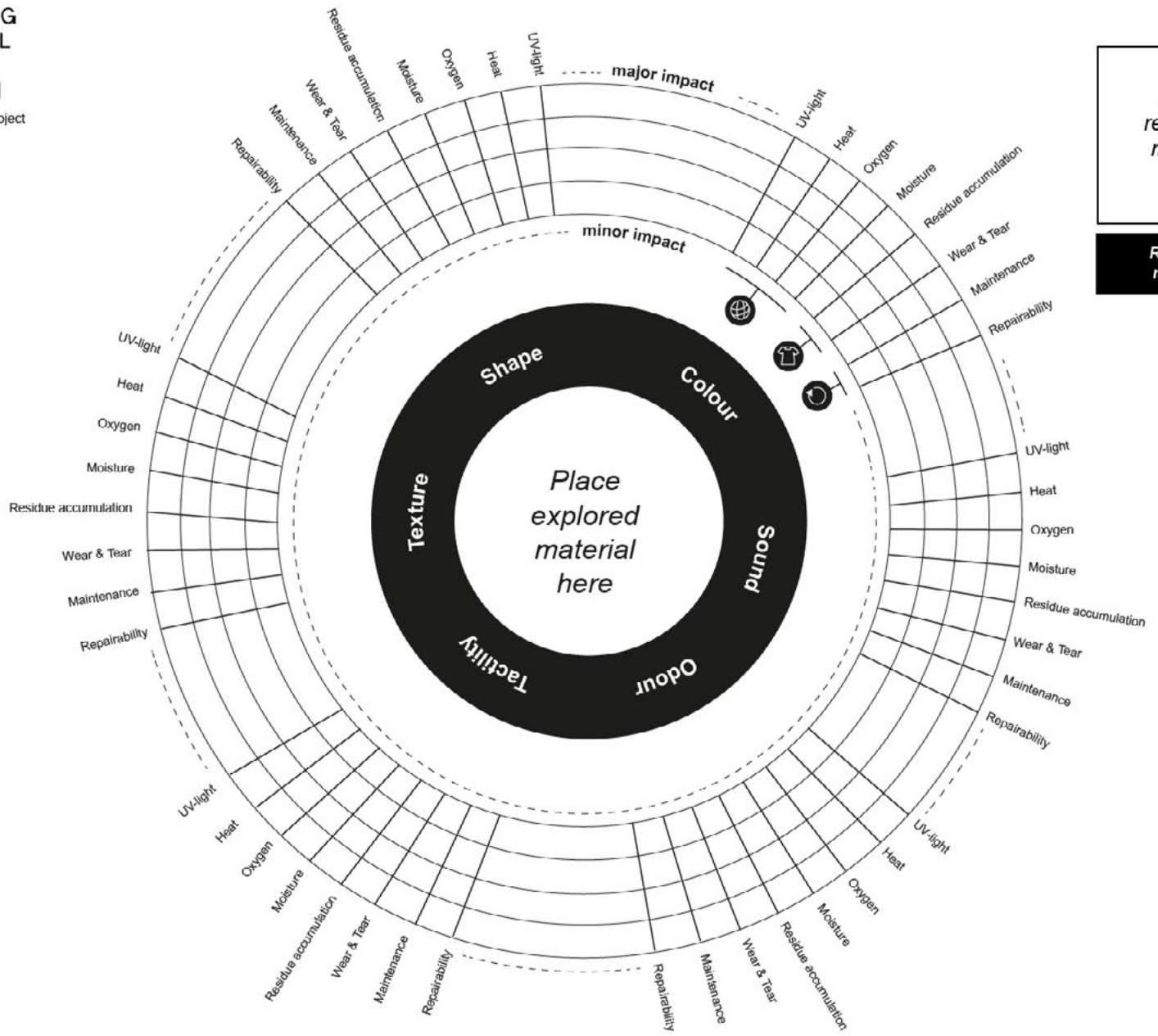
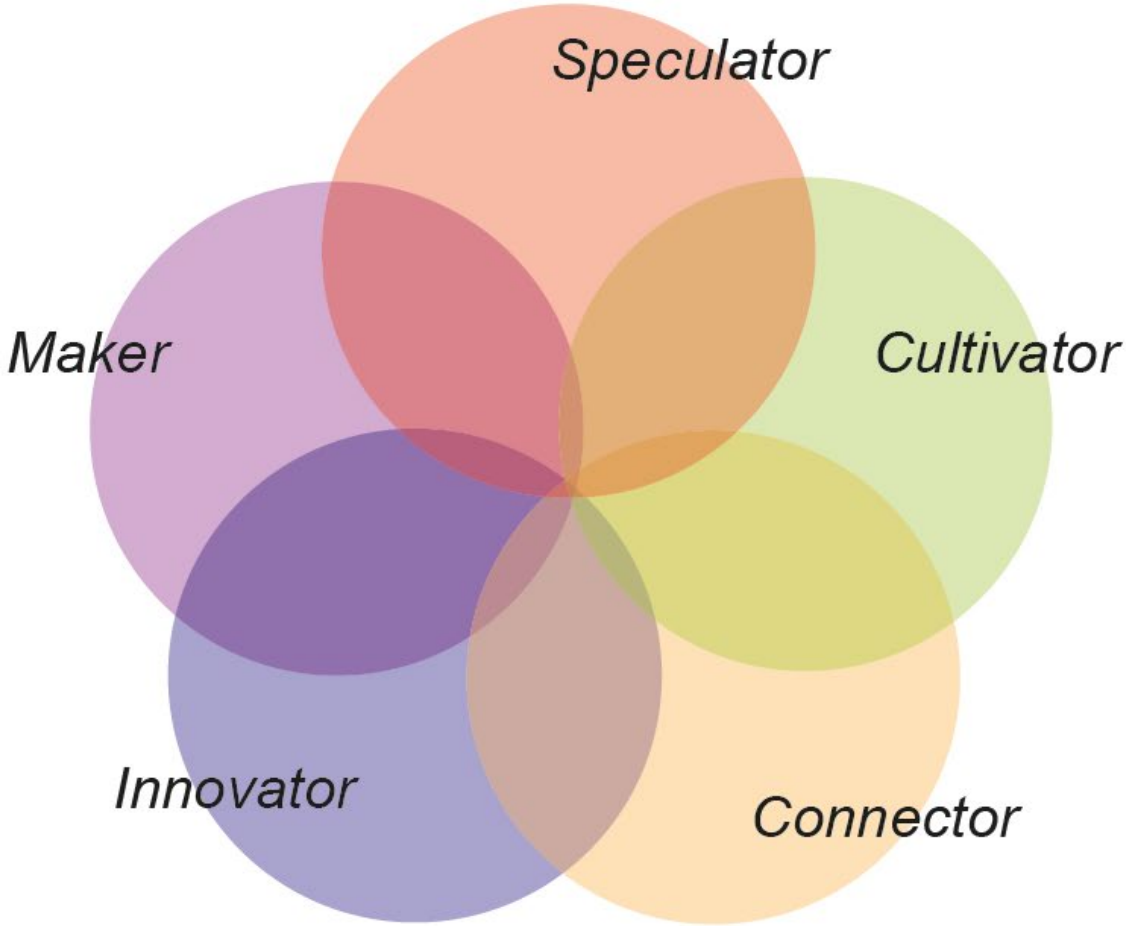


Impact wheel

Biodesigner Roles



Cards

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The Cards

Introduction to the Biodesigner Roles Cards

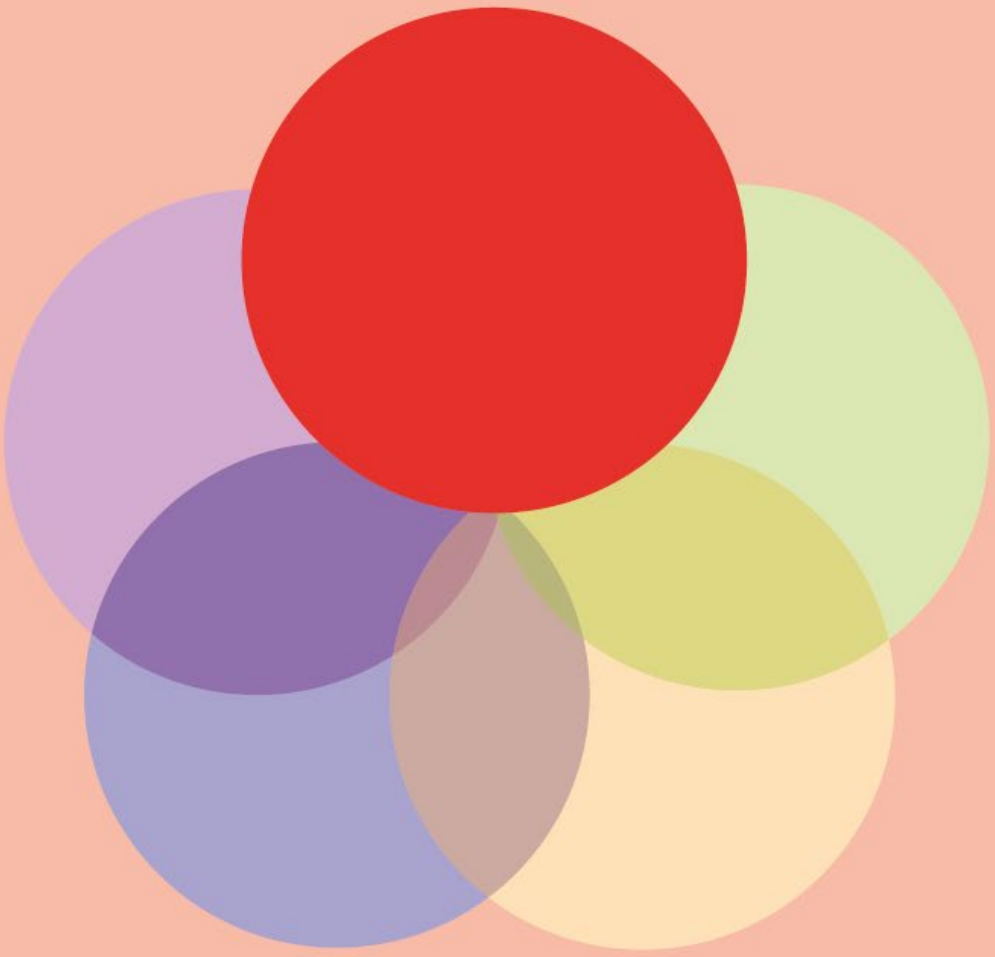
The five cards serve as a tool to reflect on selected aspects of biodesigner roles identified during the PhD project "Co-cultivating Colours" and inspired by Serena Camere and Elvin Karana's 2018 article "Fabricating Materials from Living Organisms: An Emerging Design Practice."

Each card outlines a role through three key dimensions: Knowledge, Skills, and Competences.

The purpose of these cards is to introduce designers to the various roles of a biodesigner, provide insight into their practices, and explore how these roles can collaborate and interact in project work. Ultimately, the cards encourage designers to reflect on their own individual design practices.

I hope you enjoy exploring the cards and find them both inspiring and useful.

The Speculator



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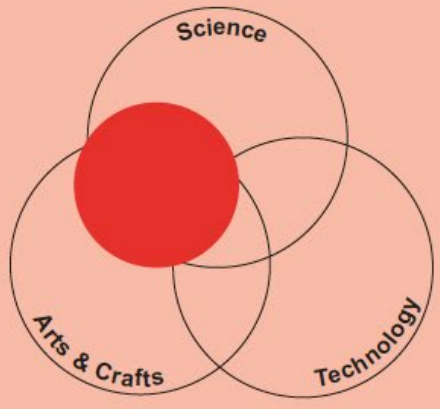
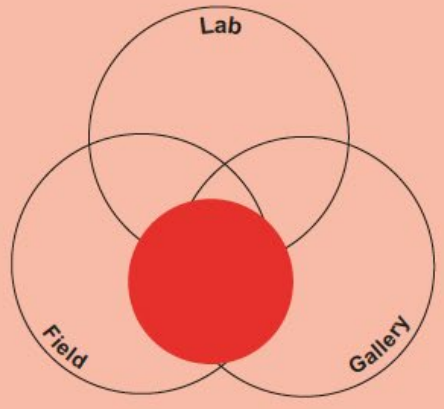
The Speculator

Knowledge:
- Has a basic understanding of microorganisms.

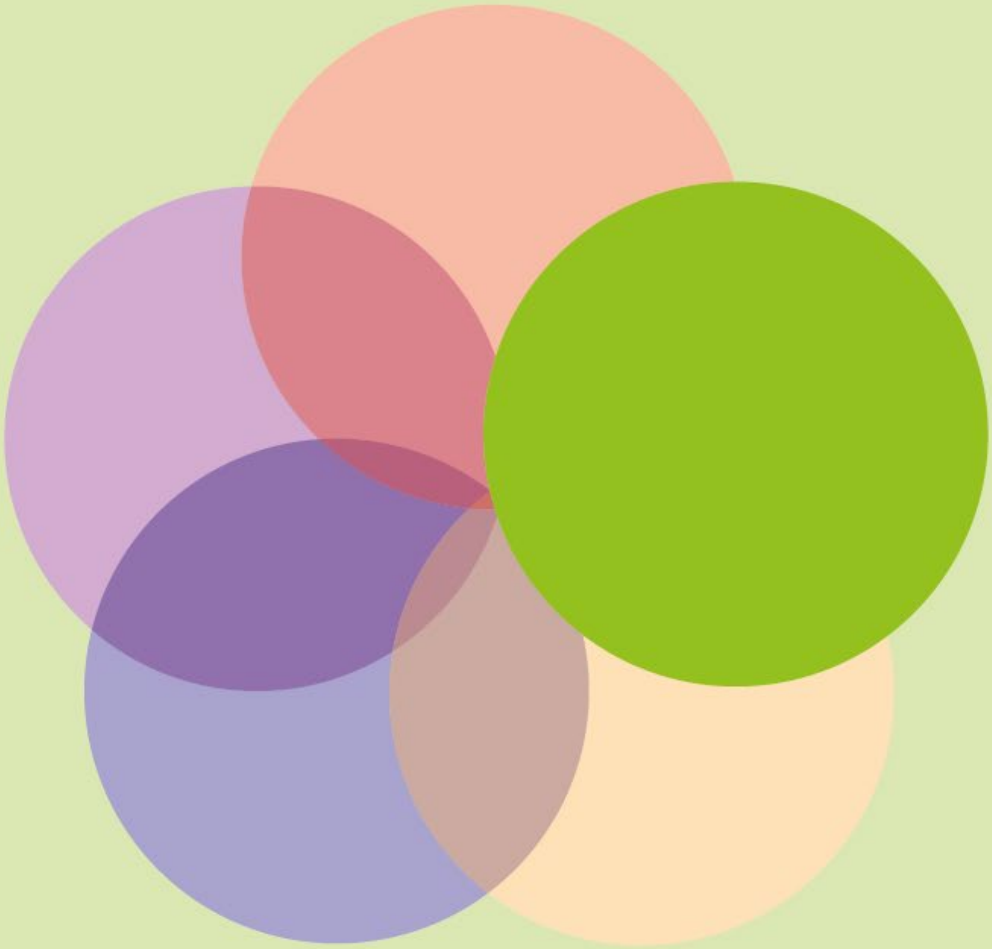
Skills:
- Be able to reflect on elements of future scenarios and imaging "what could be", while comparing it to relevant sources.
- Be able to observe and do notations of reflective conversations on experiences e.g. exhibition experiences or workshop activity experiences.
- Be able to apply a sensuous approach to workshop activities and develop tools which use our senses.

Competences:
- Be able to facilitate workshop activities focused on speculation and creating future scenarios based on biocolours including microbial colourants.
- Be able to create tools for speculative and sensuous reflection.
- Be able to curate an exhibition on bacterial colouring, where semi-structured interviews is conducted with the visitors, initiating reflection on their experience.





The Cultivator



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The Cultivator

Knowledge:

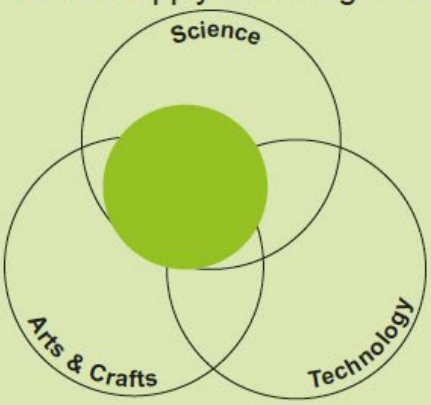
- Has an in depth understanding of microorganisms, how they grow and divide, what they produce, and how they die.
- Has an understanding of the safety guidelines and cleaning required in a laboratory.
- Has an understanding of the requirements and functionality of a DIY biolab.

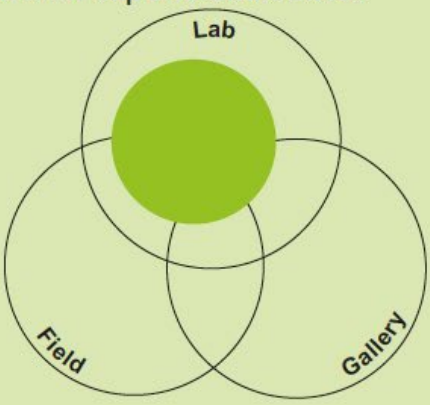
Skills:

- Be able to locate, isolate and cultivate various microorganism producing colourants by following biological protocols and associated laboratory practices.
- Be able to follow experiment protocols, observe and document the results.
- Be able to use a range of different laboratory equipment, including: bioreactor, flow-bench, centrifuge and precision scale.
- Be able to source equipment for and setup a DIY biolab.
- Be able to collaborate with experts from the natural science field.

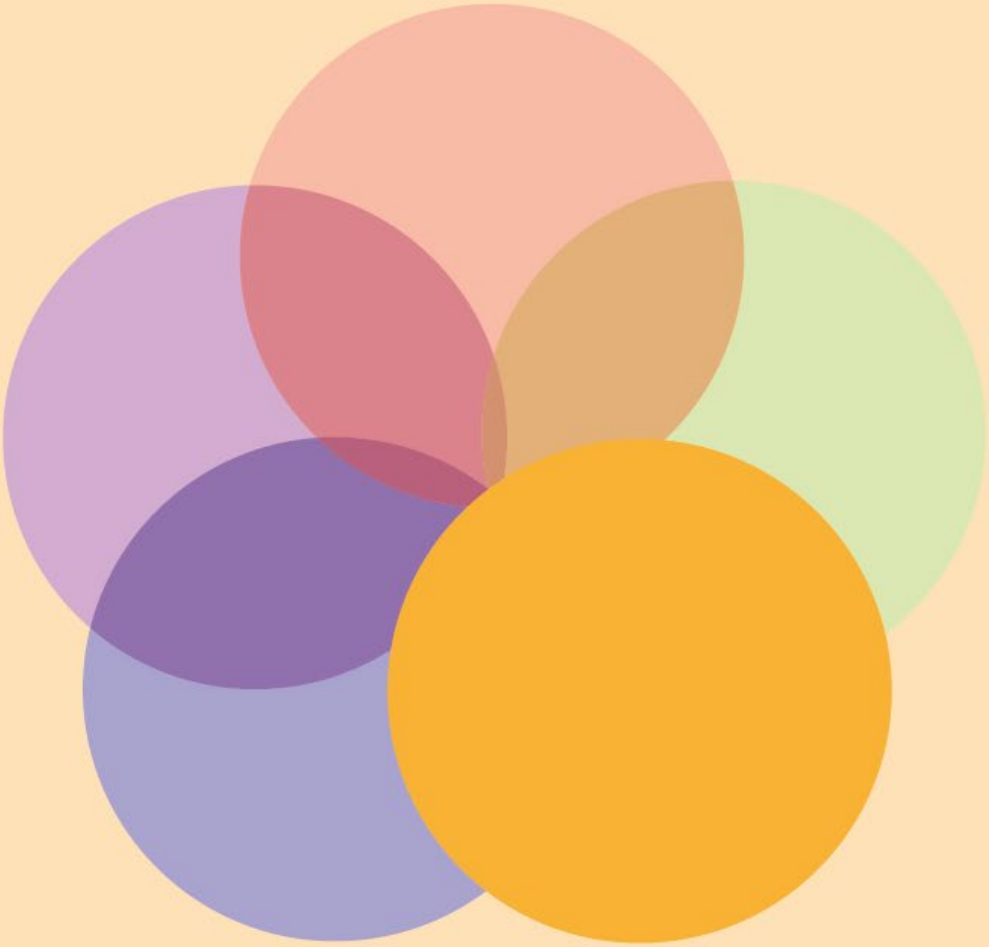
Competences:

- Be able to cultivate pigment from microorganisms, and potentially extract and refine that pigment for future applications.
- Be able to work safely with GMO practices and laboratories.
- Be able to use a bioreactor to cultivate a larger number of microorganisms
- Be able to collaborate with natural science experts, to plan and execute experiments to produce a large amount of microbial pigment.
- Be able to apply knowledge from interviewed experts and source





The Connector



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The Connector

Knowledge:

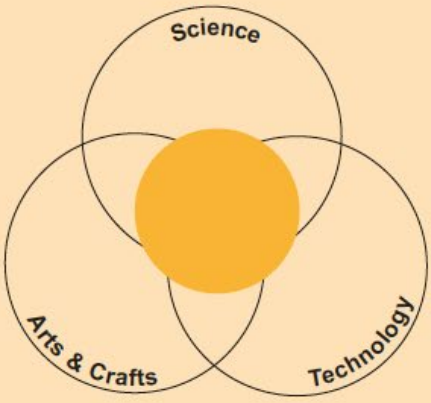
- Has a basic understanding of natural science methods and approaches.
- Has an understanding of the similarities and differences between design and natural science.

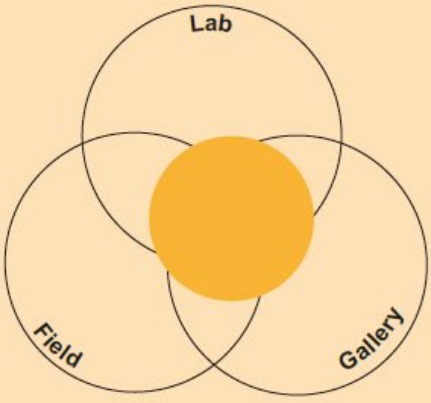
Skills:

- Be able to present samples and knowledge, with a 'high degree' of finish and clear direction, assisting as a link between scientific discoveries and commercial applications.
- Be able to apply different design approaches to topics outside of design, using them to apply new insight to e.g. a scientific topic.
- Be able to initiate and maintain connections with people and organisations within different domains, e.g. scientists, students, curators, institutions.
- Be able to explain, guide and inspire others, creating opportunities for mutual learning.

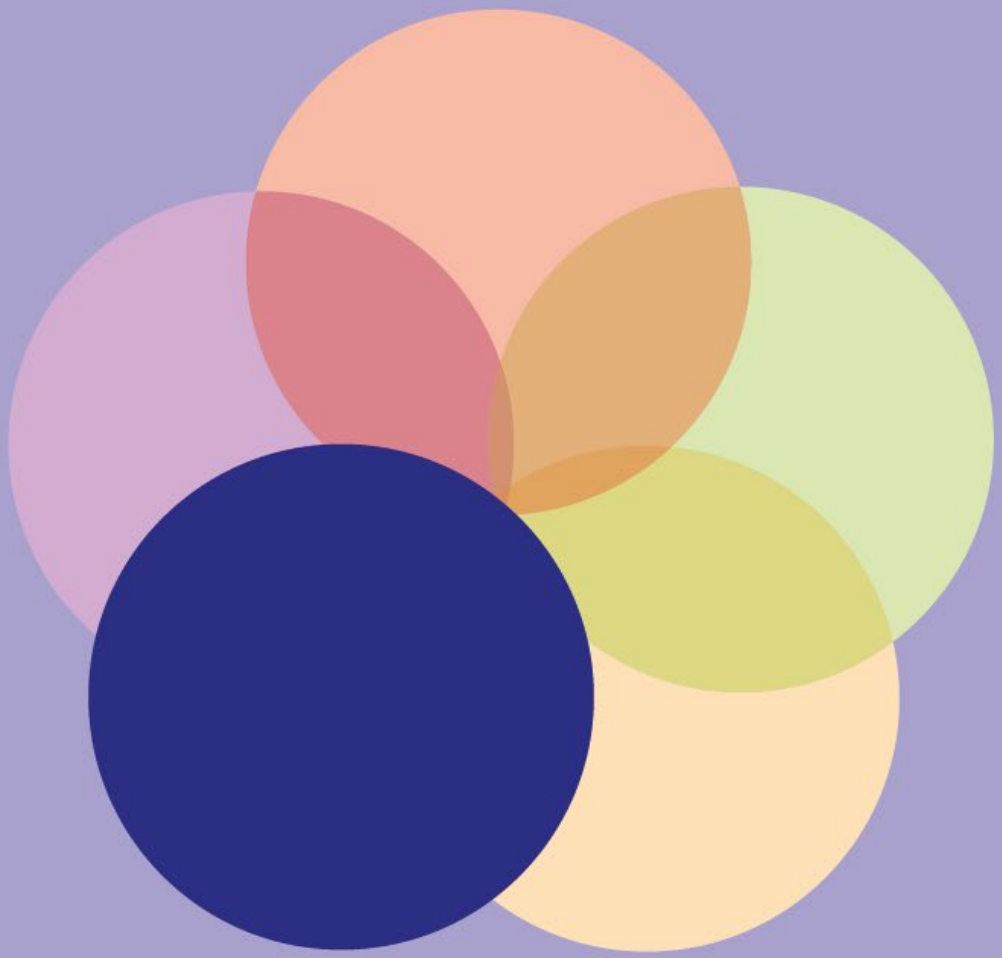
Competences:

- Be able to form relations with industrial partners, gaining knowledge on challenges of scaling and commercialisation.
- Be able to facilitate meetings between different domains.
- Be able to connect design students to relevant biological methods for cultivating microbial colourants and associated natural science laboratory practices.





The Innovator



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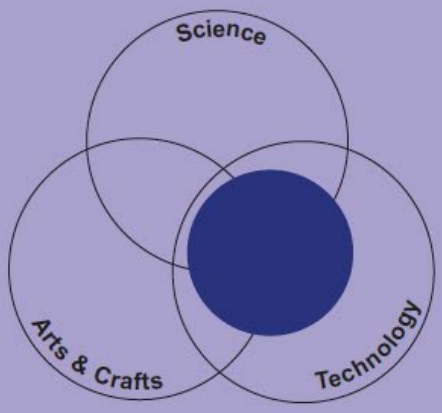
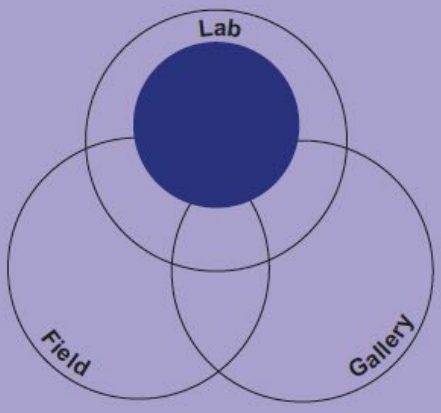
The Innovator

Knowledge:
- Has a basic understanding of textile engineering.
- Has an understanding of dying technologies.

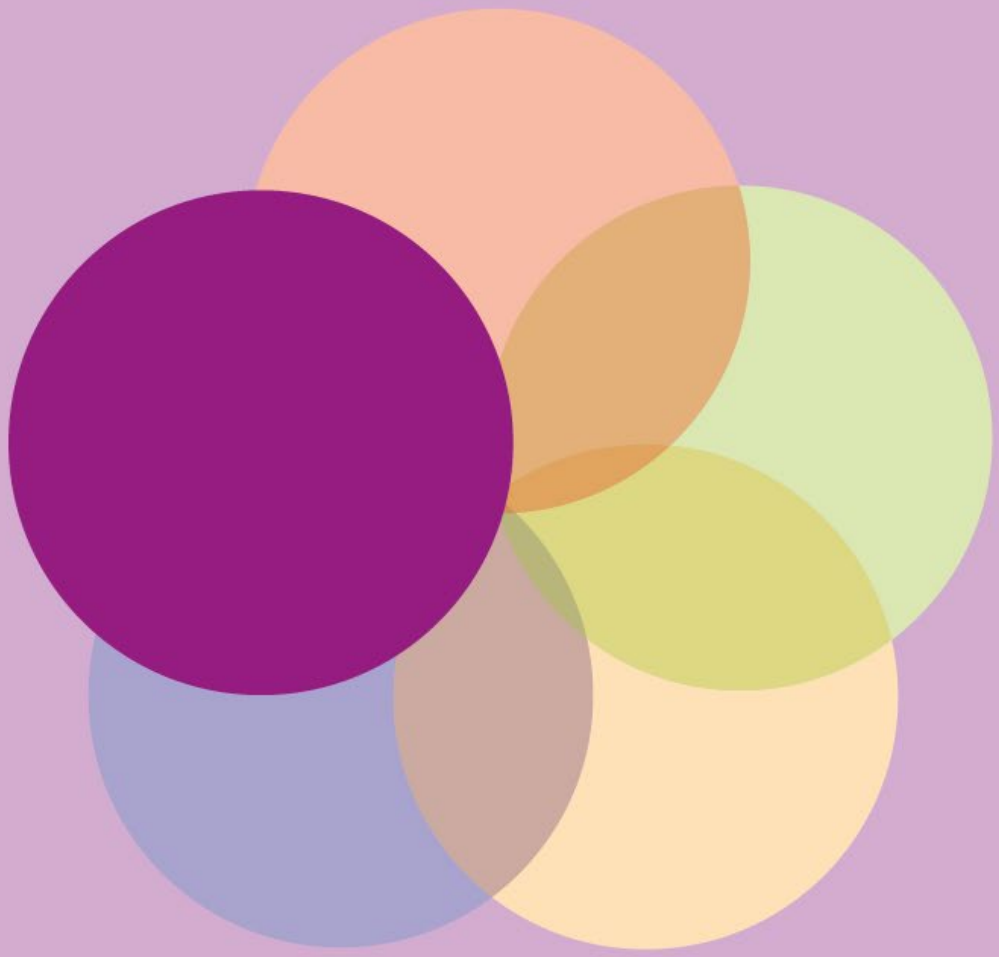
Skills:
- Be able to work with natural science methods and use laboratory protocols to write down processes and findings.
- Be able to apply current textile fibre technologies, such as melt spinning and wet spinning.
- Be able to apply an optimisation approach, inspired from engineering, where one parameter is tested at a time.
- Be able to collect knowledge from industrial application experts within biocolour or textiles.

Competences:
- Be able to conduct experiments to improve the technical performance of textiles and pigment.
- Be able to measure reproducible results of experiments with colour light fastness, exploring if colourants could meet commercial performance criteria.
- Be able to use knowledge on microbial colourants and the newest technologies to develop innovative colour applications.
- Be able to be a part of an innovation team, discussing experimental findings with research employees from other fields.





The Maker



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The Maker

Knowledge:

- Has an understanding of testing and making prototypes through a hands-on experiential process, where learning-by-doing is central.
- Has an understanding of textile disciplinary knowledge and the making of textile products.

Skills:

- Be able to explore new concepts through sensuous, hands-on approaches combining creative thinking and structured experimentation.
- Be able to apply traditional textiles skills in a creative practice, working with the material properties and experiential qualities of the materials e.g. printing and dyeing techniques.

Competences:

- Be able to use hands-on approach to explore new technologies.
- Be able to iterate on different visual expressions of materials, and get inspired during the experiments.
- Be able to explore acceptance of coloured textiles.
- Be able use the hands-on approach to introduce other designers to biodesign.
- Be able to produce visual results of experiments, to make them more concrete and assist in communicating them.