Michelle Dunn

Biomimetic Design

4.16.23

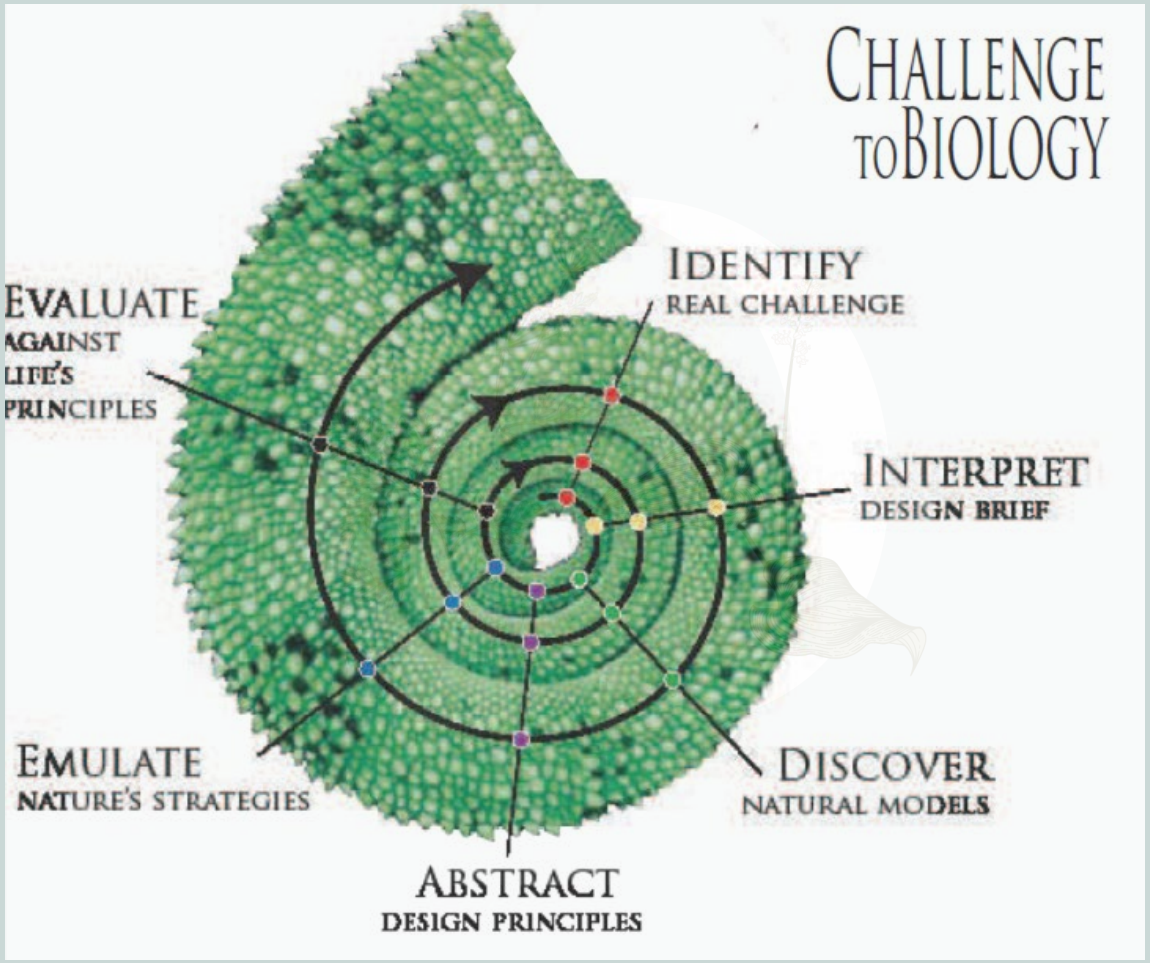
C2B Design Spiral

Outline

Abstract

In this project we aim to find a solution to reducing the use of petroleum-based products in outerwear. Outerwear uses fibers such as polyester and nylon to create water resistant and wind resistance fabrics, as well as make up synthetic insulations for warmth. Polyester and nylon being petroleum-based are therefore using nonrenewable materials, and are not biodegradable. Since outerwear serves as an important functional garment, we aim to find a more sustainable alternative to an important piece of functional clothing.

By turning to nature to find more natural solutions, we can ask, “how does nature…”. Using the C2B design spiral, we take three “laps” through the spiral to identify, translate, discover, and emulate nature’s solutions to solve our design problem. By taking multiple laps through the spiral, we then evaluate and improve our designs. The following slides demonstrate the process and provide a final design result of **a fabric solution for outerwear without the use of petroleum-based fibers**.



Design Spiral Steps

Identify

Translate

Discover

Abstract

Emulate

Evaluate

Spiral Lap 1

Identify Design Challenge Function:

Lap 1

Create outerwear without use of petroleum products

Translations:

1. How does nature **protect from wind?**
2. How does nature **protect from rain?**
3. How does nature **protect from extreme temperature?**
4. How does nature **maintain structural forces against impact?**
5. How does nature **maintain structural forces against tension?**
6. How does nature **chemically break down at the end of its life?**
7. How does nature **store heat?**
8. How does nature **distribute heat?**
9. How does nature **expel liquids?**
10. How does nature **sense temperature?**

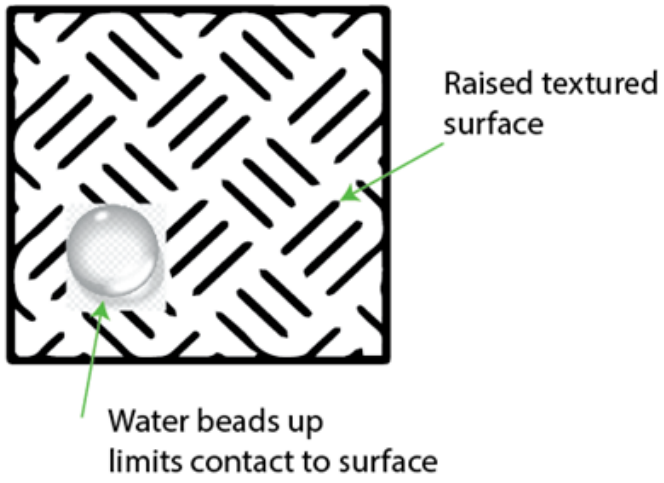
Discovery of Organisms

How Does Nature Protect From Rain?

Garden Nasturtium	Fish Pole Bamboo
Tropaeolum majus	*Phyllostachys aurea*
Ridges on garden nasturtium leaves reduce contact time with water drops by enabling faster drop recoil.	Young leaves of bamboo channel excess water using a combination of hydrophilic and hydrophobic surfaces.

Abstracted Strategies

(Protect from rain)

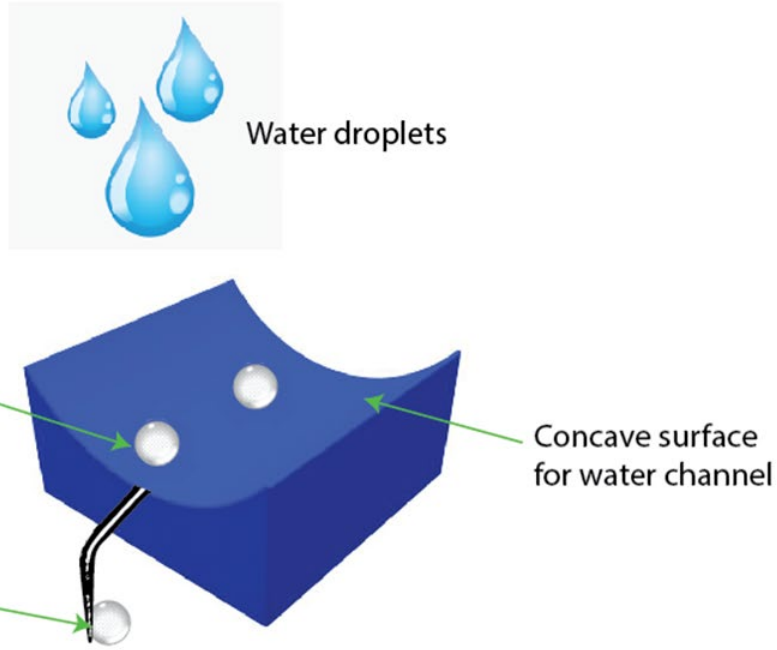


Reduce water contact time

Garden Nasturtium

Water channeling

Fish Pole Bamboo

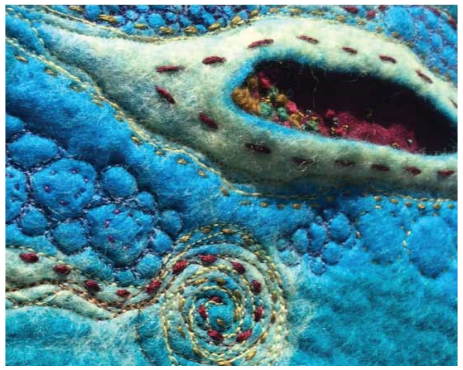


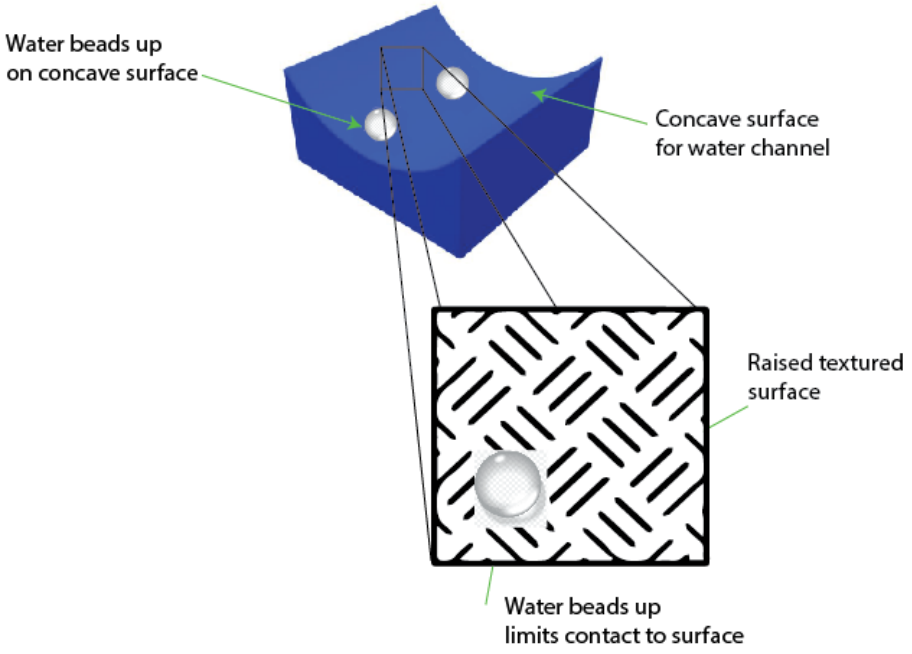
Stamp shape will create a rigid surface to limit contact time of water to fabric, as well as have a concave shape to channel water away from the surface.

Emulated Design

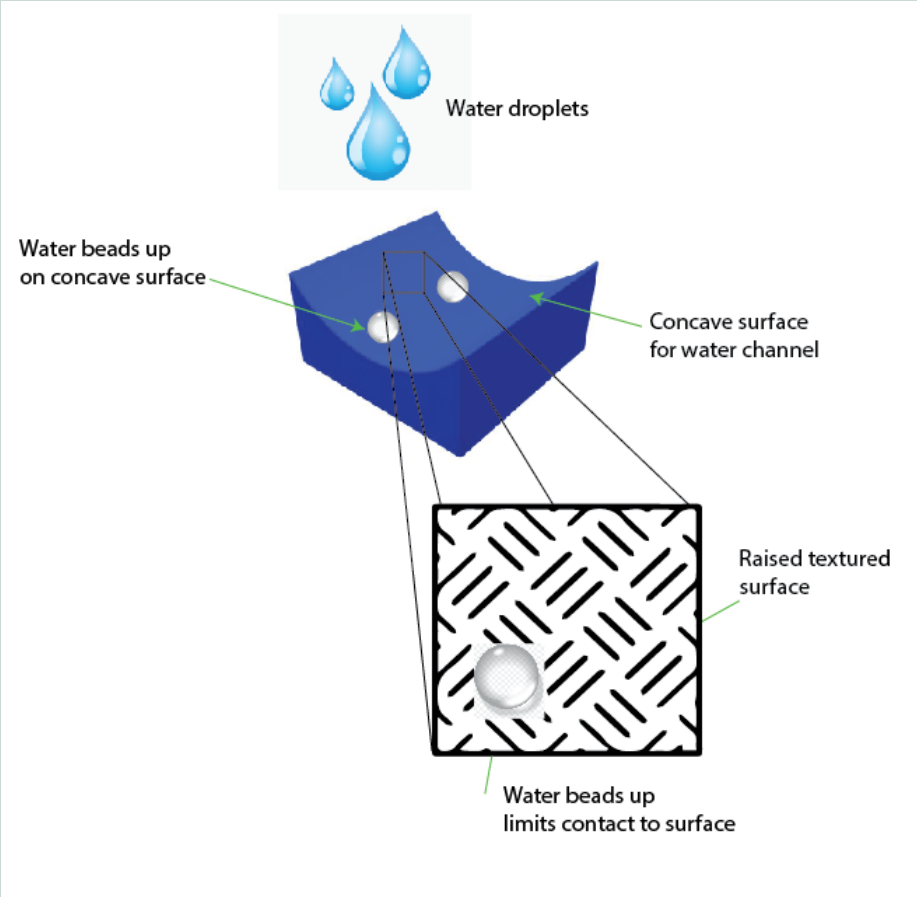
Lap 1

A fabric texture stamp device can be 3D printed to create the textured surface when fabric is wet felted.





*Note, the design itself is the fabric technology, but here we also outline how this can be achieved via a stamping device



Yes=9/16
No=5/16
Partial=2/16

Evaluate Against Life's Principles & Improve

1. Is the design resourceful? *Yes, because it uses renewable resources*

2. Does it leverage feedback loops? *Yes, because the shape can be altered based on needs*

3. When it uses materials are the materials locally available and abundant? *No, because wool is not naturally available every where, and still needs to be grown.*

4. Are the processes cyclical? *Yes, because wool can be sheared then regrown*

5. Does it integrate feedback loops? *Yes, because the design can be altered based on needs*

6. Can it withstand disturbance while maintaining function? *No because it is only water resistant, and not fully water proof.*

7. Does it heal after disturbance? *Yes, it can be easily repaired*

8. Are there opportunities to cross pollinate and mutation? *Yes, this moldable design can be integrated with other design features to achieve different functions.*

9. Does the design integrate multiple functions? *No, currently its only function is water resistance*

10. Does it recycle all materials? Is it recyclable? *Partially, it cannot be recycled but it is biodegradable*

11. Does it perform functions with minimal materials and energy? *No, in order to achieve this design, it will require water*

12. Is it made from life friendly materials? *Yes, wool is a natural resource*

13. Is the chemistry done in water? *Yes, wool felting only needs water to make its shape*

14. Is the process done at ambient (local) pressures and temperatures? *No, requires hot water for the felting process*

15. Does it foster symbiotic, cooperative, community based relationships? *Yes, it does not extract more petroleum, and wool is easy to grow*

16. Does it foster emergent relationships? *Partially, will still require resources to raise the sheep, which requires land space, and shepherds to raise the sheep.*

Spiral Lap 2

Identify Design Challenge Function:

Lap 2

Give the design multiple functions

Translations:

1. How does nature **protect from wind?**
2. How does nature **protect from extreme temperature?**
3. How does nature **maintain structural forces against impact?**
4. How does nature **maintain structural forces against tension?**
5. How does nature **store heat?**
6. How does nature **distribute heat?**
7. How does nature **sense temperature?**

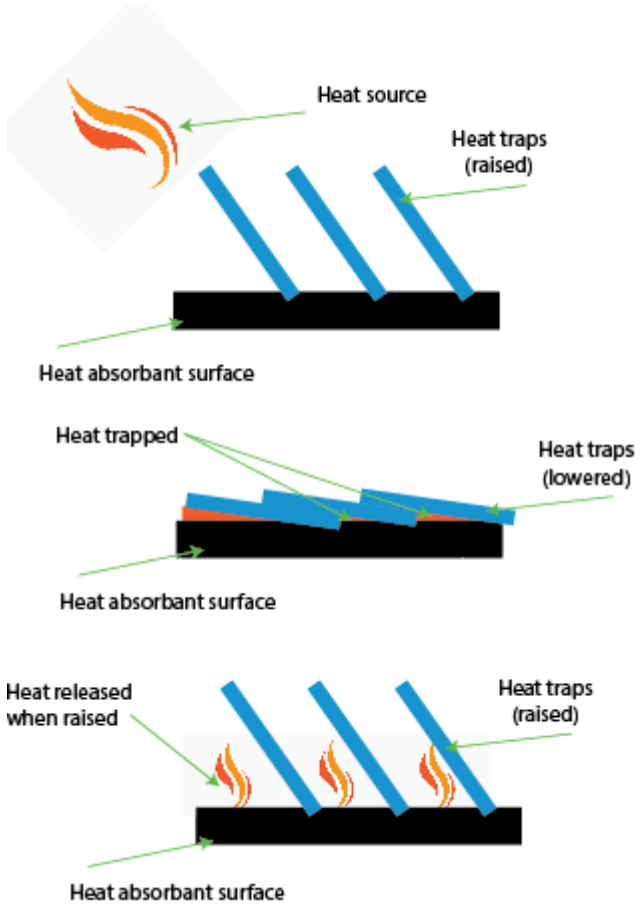
Discovery of Organisms

How Does Nature Store Heat?

Numbat	Merino Sheep
Myrmecobius fasciatus	*Ovis aries*
By making their hairs stand up, numbats expose more skin to the sun and create an insulating layer of air to reduce heat loss.	The wool of Merino sheep forms an insulating layer via underhair that creates hundreds of trapped air pockets.

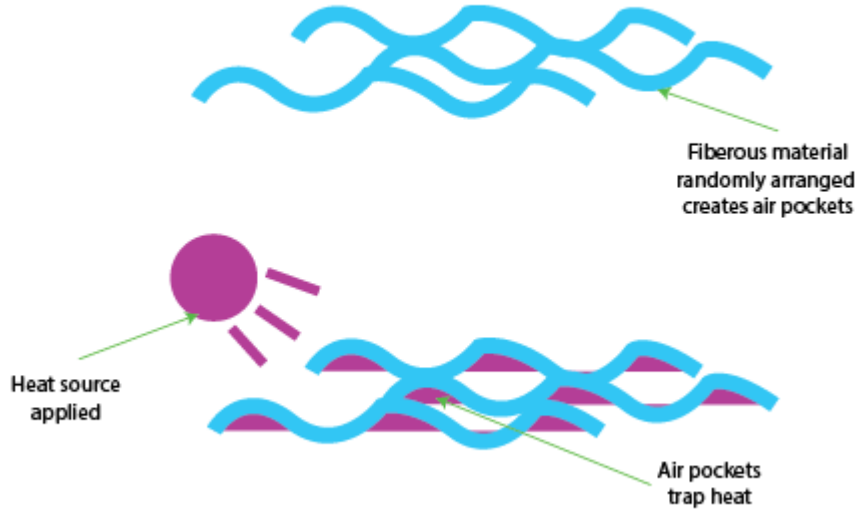
Abstracted Strategies

(Store Heat)



Absorb, Store, & Release Heat

Numbat



Air Pockets Store Heat

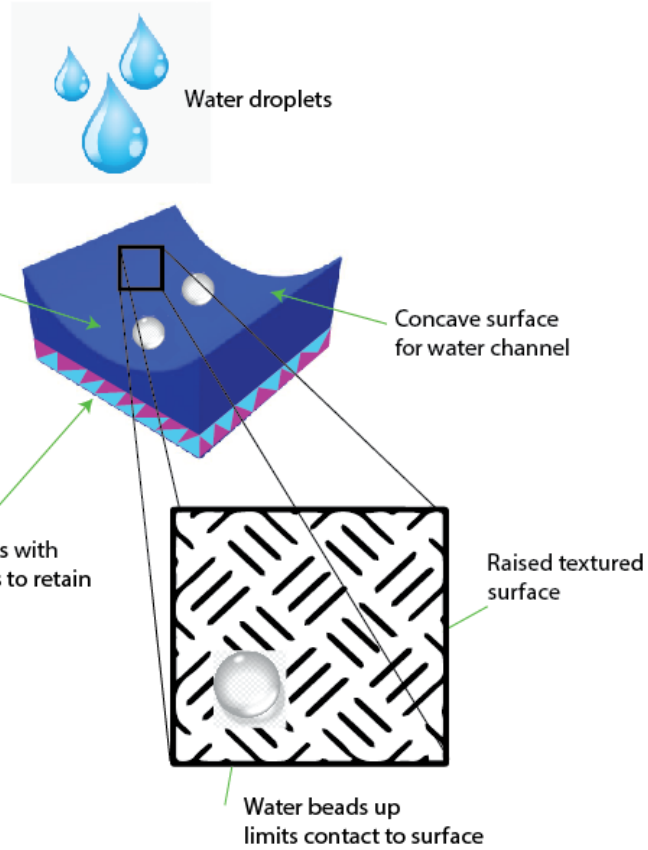
Merino Sheep

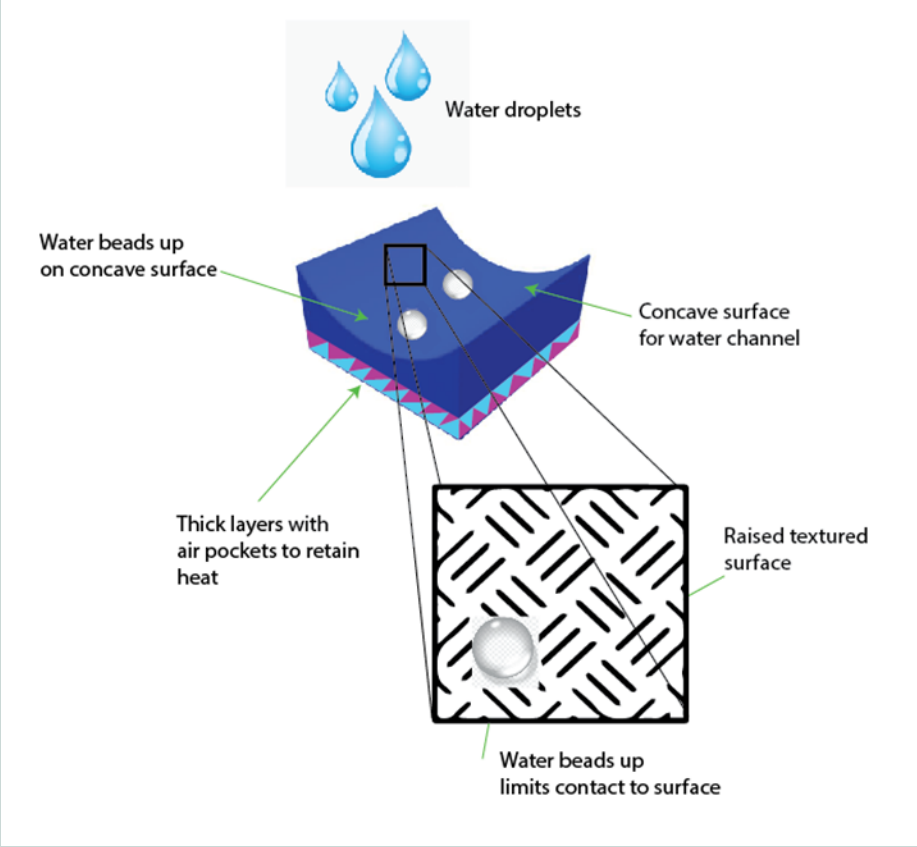
Updated design now has a layer of fibers with air pockets that retain body heat. Similar to that of a knit blanket

Emulated Design

Lap 2
Design Revised

These air pockets can be developed also using the stamping technology mentioned in lap 1





Yes=10/16
No=3/16
Partial=3/16

Evaluate Against Life's Principles & Improve

1. Is the design resourceful? *Yes, because it uses renewable resources*

2. Does it leverage feedback loops? *Yes, because the shape can be altered based on needs*

3. When it uses materials are the materials locally available and abundant? *No, because wool is not naturally available every where, and still needs to be grown.*

4. Are the processes cyclical? *Yes, because wool can be sheared then regrown*

5. Does it integrate feedback loops? *Yes, because the design can be altered based on needs*

6. Can it withstand disturbance while maintaining function? *No because it is only water resistant, and not fully water proof.*

7. Does it heal after disturbance? *Yes, it can be easily repaired*

8. Are there opportunities to cross pollinate and mutation? *Yes, this moldable design can be integrated with other design features to achieve different functions.*

9. Does the design integrate multiple functions? *Yes, it now also has the ability to retain heat*

10. Does it recycle all materials? Is it recyclable? *Partially, it cannot be recycled but it is biodegradable*

11. Does it perform functions with minimal materials and energy? *Partially, as it can use one's own body heat to retain heat, but still needs water to make felt*

12. Is it made from life friendly materials? *Yes, wool is a natural resource*

13. Is the chemistry done in water? *Yes, wool felting only needs water to make its shape*

14. Is the process done at ambient (local) pressures and temperatures? *No, requires hot water for the felting process*

15. Does it foster symbiotic, cooperative, community based relationships? *Yes, it does not extract more petroleum, and wool is easy to grow*

16. Does it foster emergent relationships? *Partially, will still require resources to raise the sheep, which requires land space, and shepherds to raise the sheep.*

Spiral Lap 3

Identify Design Challenge Function:

Lap 3

Withstand disturbance while maintaining function

Translations:

1. How does nature **maintain structural forces against impact?**
2. How does nature **maintain structural forces against tension?**
3. How does nature **protect from wind?**
4. How does nature **protect from excess liquids?**
5. How does nature **expel/distribute liquids?**

Discovery of Organisms

How Does Nature Protect From Excess Liquids?

Poplar Spiral Gall Aphid

Myrmecobius fasciatus

Powdery wax secreted by aphids makes sticky honeydew waste manageable by coating it and creating non-stick “liquid marbles”.

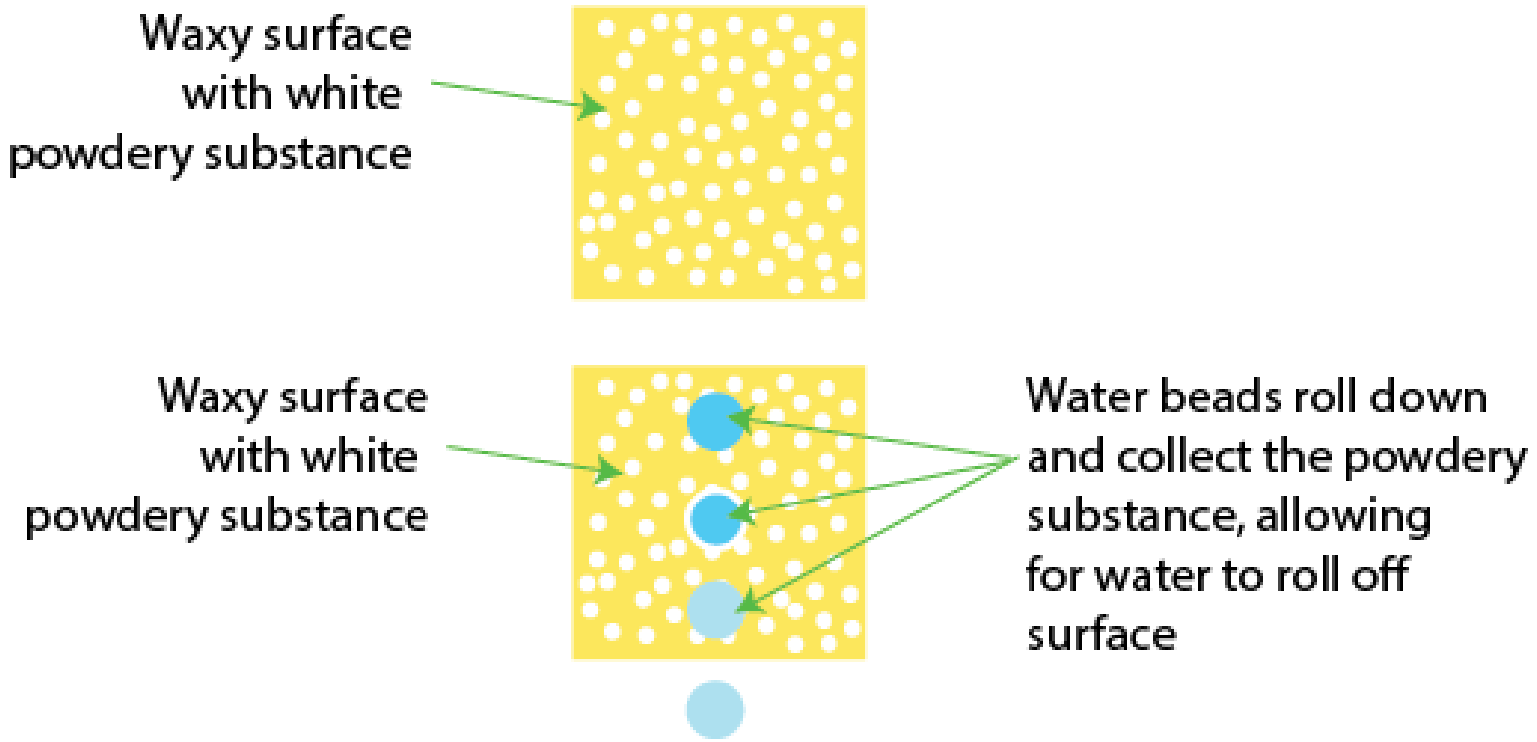
Gannets

Morus capensis

A closeable gap in the beak of a gannet, instead of open nostrils, prevent water from rushing in during high speed dives.

Abstracted Strategies

(Protect from Excess Liquids)



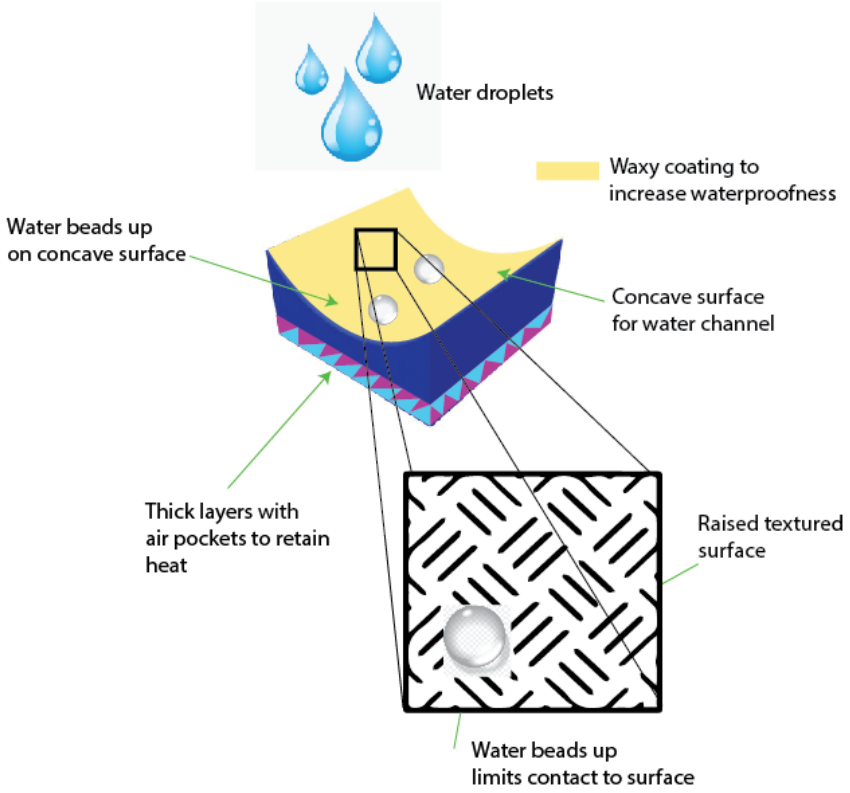
Water Gathers in Powdery Substance

Poplar Spiral Gall Aphid

Final design has an all natural waxy coating to increase waterproofness.

Emulated Design

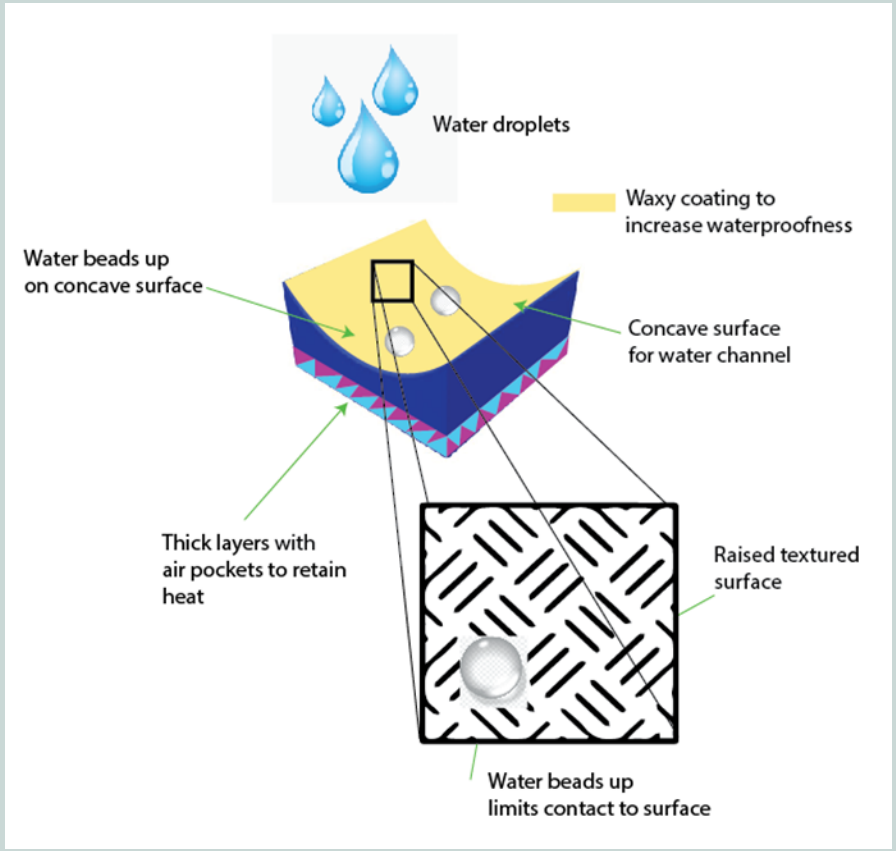
Lap 3
Final Design



There is also an opportunity here for this waxy coating to be reapplied periodically thought the lifetime of the product to increase longevity sold as a separate product or service

This final design offers a fabric technology for apparel companies to purchase and integrate into their garments.

Final design is a textured wool fabric that can even be integrated into the pattern of the garment (such as a plaid)



Yes=10/16
No=2/16
Partial=4/16

Evaluate Against Life's Principles & Improve

1. Is the design resourceful? *Yes, because it uses renewable resources*

2. Does it leverage feedback loops? *Yes, because the shape can be altered based on needs*

3. When it uses materials are the materials locally available and abundant? *No, because wool is not naturally available every where, and still needs to be grown.*

4. Are the processes cyclical? *Yes, because wool can be sheared then regrown*

5. Does it integrate feedback loops? *Yes, because the design can be altered based on needs*

6. Can it withstand disturbance while maintaining function? *Partially, it is now mostly water-proof, but still not fully*

7. Does it heal after disturbance? *Yes, it can be easily repaired*

8. Are there opportunities to cross pollinate and mutation? *Yes, this moldable design can be integrated with other design features to achieve different functions.*

9. Does the design integrate multiple functions? *Yes, it now also has the ability to retain heat*

10. Does it recycle all materials? Is it recyclable? *Partially, it cannot be recycled but it is biodegradable*

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The Result

Pros:

This new **proposed design meets 10 out of 16 of the Life's Principles**, and partially meets 4 of the Life's principles, offering a more sustainable solution that the current offerings. In summary, this design is made of an easily accessible renewable resource, and is biodegradable.

Cons:

Although this design offers a more sustainable alternative, as it stands currently, it will likely still not function as well as petroleum based products for waterproofness and wind proofness. Additionally, this material will require a large amount of hot water to achieve the process, which is still a scarce resource.

A More Sustainable Future

Reflection

- *What did you learn in this process?*
  - In this process I learned how cool it was to keep evaluating the design idea and building off of it to improve
- *What surprised you?*
  - I was surprised that I got into the groove of the process and it clicked in my mind as an effective way to design
- *Could you have predicted your design solution?*
  - No I wouldn't have expected my design to be a fabric design!
- *What was your favorite part?*
  - My favorite part was the Abstracting phase. I enjoyed taking a biological function and turning it into an engineering one.

Potential

- *What's possible for this design at large scale adoption?*
  - For large scale adoption, would be that the outerwear industry moves to this being the normal fabric for usage instead of what is currently being used. Customers will expect this
  - Large companies that are known for sustainability such as Patagonia can be the leaders in the adoption of this product, causing others companies to follow suit to compete.

Limitations

- *What are some current limitations to this design?*
  - This design still may not perform as well as petroleum based products in its waterproofness and windproofness
- *Next steps?*
  - Further R&D, partnering with big name companies
- *Obstacles to overcome?*
  - To get both design companies and consumers on board with a fabric that is different from what is know to be tried and true. Getting over that mental block
- *Unknown factors to consider?*
  - If the demand for wool increases, to be mindful that land that could have been used for growing crops is not now instead used for raise sheep to make wool.

Thank You

References

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https://asknature.org/strategy/beak-protects-during-dives/
https://asknature.org/strategy/fur-absorbs-infrared-radiation-to-prevent-heat-loss/
https://asknature.org/strategy/thinner-fur-keeps-numbats-warmer/
https://asknature.org/strategy/underhairs-provide-insulation/
https://asknature.org/strategy/unique-antifreeze-protects-from-extreme-cold/

Change Log

First Draft to Final

- Reduce number of slides, removing elements that were brainstorms and did not move forward with in the spiral process (not all but most), including additional functions, organisms, abstracted strategies, and designs.
- Added image of the C2B spiral
- Further explanation to the Abstract as to why we need to find an alternative to petroleum based fibers.
- Added more detail to the discovery of organisms slides
- Added explanations to the yes/no/partial to meeting the LP's
- Added a tally to the LP's
- Added a final LP/result slide with why this is better than the alternative
- Added an image as an example for the final design
- Remade video with new presentation and shortened time