Biomimetic Design Process

Week 12 | Individual Project - Final

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SD-6610-21-F21 | Biomimetic Design

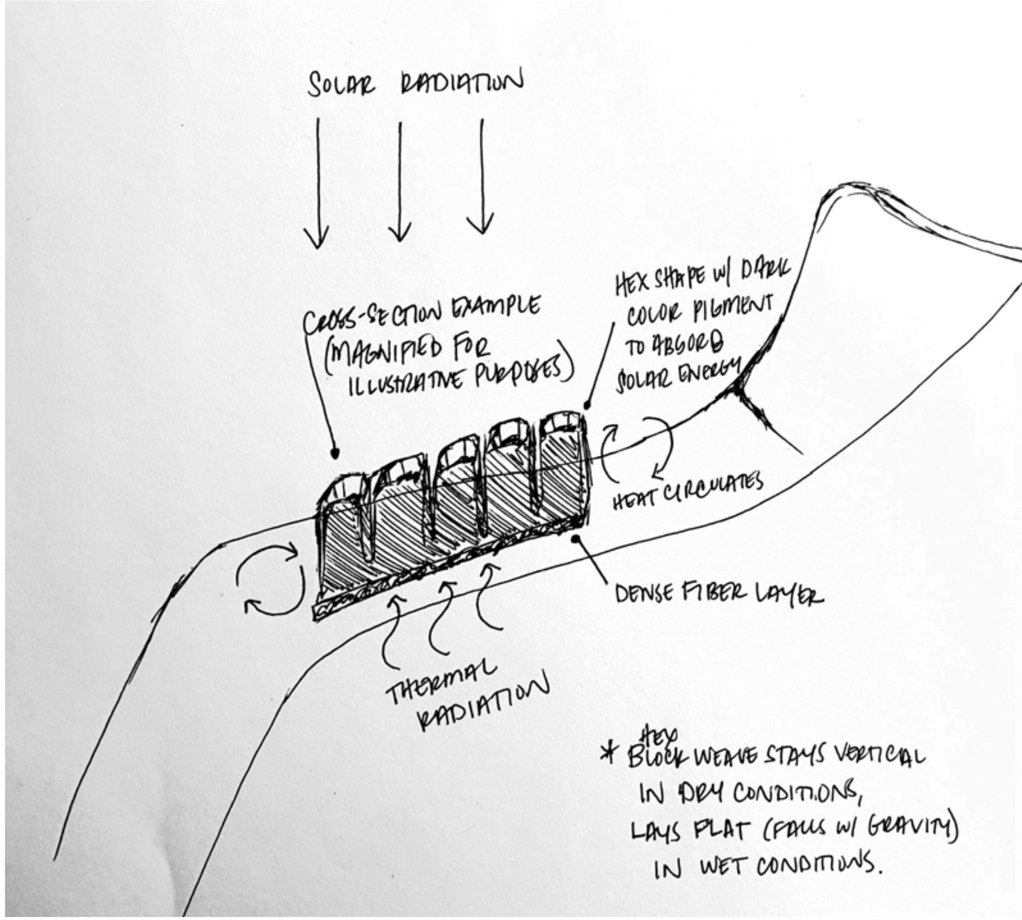
ABSTRACT

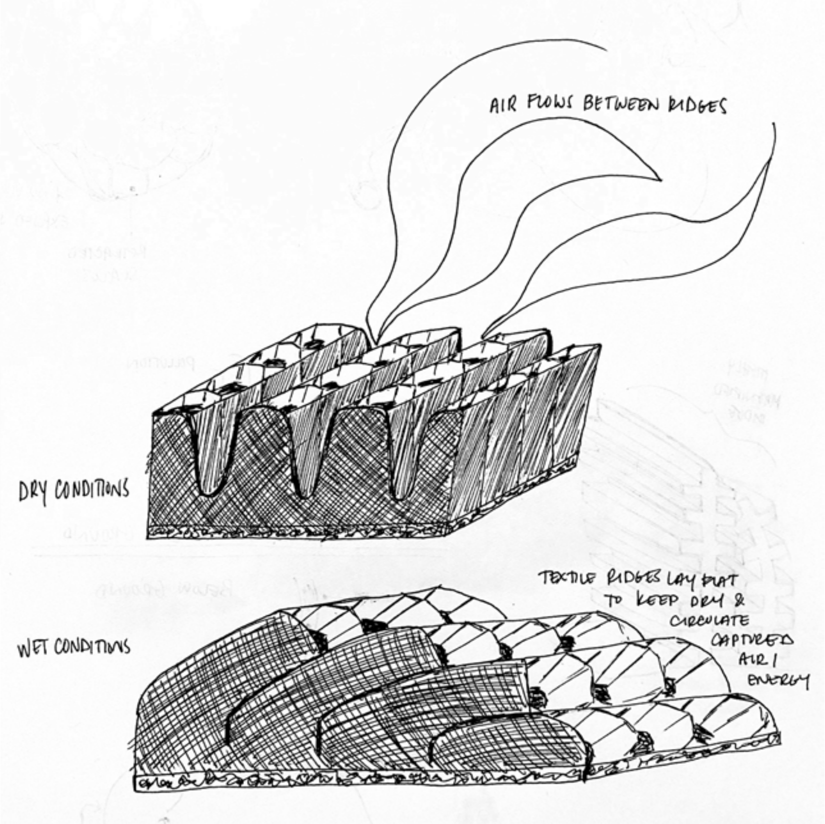
In recent years we have learned of the abundance of microplastics in our environment as a result of synthetic fibers used to make our clothing. Specifiers of the Fast Fashion industry have made it the norm to create disposable clothing, quickly, at a rate much faster than humans can dispose of the waste and at a scale that will take thousands of years to decompose.

I have looked to nature for inspiration to develop more functional clothing and to develop a "super" garment, a garment with superior properties, to promote quality over quantity. In this specific exploration, I seek to create a sweater that retains warmth using life-friendly materials. Understanding how nature's strategies are used to perform various functions is crucial to creating life-friendly clothing. I have explored the possibilities through the Challenge to Biology design spiral and the subsequent steps: Identify, Translate (Interpret), Discover, Abstract, Emulate, Evaluate.

Ultimately, using natural fibers is the answer, but it's uncommon for any single fiber to be the "holy grail" of fibers, or to be able to perform *all* desirable functions. Throughout this exploration, I'll look at functions in nature such as temperature control and moisture regulation to assess how they can be adapted to apparel design.

DESIGN CONCEPT VISUAL





CHALLENGE TO BIOLOGY

LAP 1

IDENTIFY & TRANSLATE

LAP 1

OVERVIEW

One solution to the microplastic problem from clothing is to instead utilize only natural fibers. In order to improve overall product quality and allow for biodegradation at the end of a garments lifecycle, making an article of clothing fully circular.

PURPOSE

1. Source only natural fibers
2. Ensure natural fibers are produced using regenerative agriculture practices
3. Encourage specifiers of the benefits of using natural fibers
4. Encourage consumers to extend garment life
5. Showcase *end of life* disposal and decomposition of naturally-produced apparel

FUNCTION

1. Protect from microbes by utilizing more desirable natural fibers
2. Modify material characteristics to increase fiber integrity
3. Optimize material usage to minimize waste
4. Manage structural forces of mechanical wear
5. Cooperate with other specifiers to encourage the use of natural fiber
6. Foster soil regeneration through sustainable farming methods
7. Optimize water usage
8. Assemble structurally sound and resilient garments
9. Educate specifiers on benefits of natural fibers
10. Collaborate among specifiers to provide better products to consumers

Image Source: Amber Martin via Unsplash

TRANSLATION

Protect from microbes
- How do cicada wings stay clean?
- How do frogs stay fungus-free?

Modify material characteristics
- How do rabbits stay warm in the winter?

Optimize material usage
- How do birds build their nests?
- How do wasps convert honeydew into energy?

Manage structural forces
- How do scales provide strength and protection?
- How does adhesion work under water?

Cooperate with specifiers
- How does cooperative herding attract more food?
- How do juvenile friendships help throughout life?
- How does knowledge sharing help the commons?

Foster regeneration
- How do nurse shrubs promote regeneration?
- How does mycelium connect plant life in an ecosystem?
- How does *deadheading* of coneflower aid in new flower growth?

Optimize water usage
- How do plants optimize water flow during drought?

Assemble sound structures
- How do snakes shed their skin?

Educate specifiers
- How do slime molds share information?

Collaborate
- How do bees collaborate?
- How do ants aid in decomposition?

DISCOVER

LAP 1

Patterns that you notice emerging among your functions:
•Shape and structure are important in material strength and durability
•*Cooperation* among organisms is vital for ecosystems to thrive

What seem to be the most effective strategies?:
•Working systematically together, ie. nurse shrubs + trees, worms + fungi, protein + collagen, mycorrhizal fungi + root systems.
•Organization/optimization of shape and materials

Which strategies might best fit the context of your design challenge?:
•Challenge #1: Honey bees + hexagonal-shaped structures
•Challenge #2: Mycorrhizal fungi + distribution of resources

Any crazy/fun facts you've discovered that don't fit anywhere else?:
•Nitrogen and Phosphorous are found in high levels in both termite mounds and in algae blooms, having an opposite effect on their ecosystems. Termites - aid in foliage growth. Algae blooms - reduction in oxygen for other organisms to thrive.

Anything else you've learned by delving deep into these biological strategies?:
I'm continuously aware of the theme of cooperation in nature and organisms emphasizing symbiosis rather than competition and rivalry. Each organism in an ecosystem exists because of the conditions and events prior, always evolving to suit a need and become repurposed for food or energy elsewhere. This true circularity and the concept of "no waste in nature" gets more and more interesting each time I read more.

Design Concept	Function	Organism	Strategy Used	Source
Use life-friendly materials. (challenge #1)	Optimize material usage to minimize waste.	Honey Bees	The hexagonal shape of the honeycomb allows for maximum volume of storage with the most efficient quantity of materials.	Ask Nature NPR.org Nature.com
Use life-friendly materials. (challenge #1)	Optimize material usage to minimize waste.	Coral Reefs	Proteins, collagens, and other organic molecules assemble to create durable structures.	Ask Nature Iisd.org PNAS.org
Use life-friendly materials. (challenge #1)	Optimize material usage to minimize waste.	Banana Leaves	Banana leaves structure allows them to twist rather than bend, maintaining their structure and providing extra strength.	Ask Nature American Journal of Plant Sciences ProMusa.org
Consider the end of life of a garment early in the design process to ensure full circularity. (challenge #2)	Foster decomposition.	Common Brandling Worm	Earthworms, along with fungi, work together to break down cellulose.	Ask Nature Frontiersin.org nrcs.usda.gov
Consider the end of life of a garment early in the design process to ensure full circularity. (challenge #2)	Foster decomposition.	Nurse Shrubs	Decomposing bio-matter, protected by the shade of nurse shrubs, secrete potassium (K) for further regeneration and tree growth.	Ask Nature Fs.fed.us
Consider the end of life of a garment early in the design process to ensure full circularity. (challenge #2)	Foster decomposition.	Mycorrhizal Fungi	Distributes resources for the well-being of root systems in an ecosystem.	Pnas.org Ask Nature

ABSTRACT

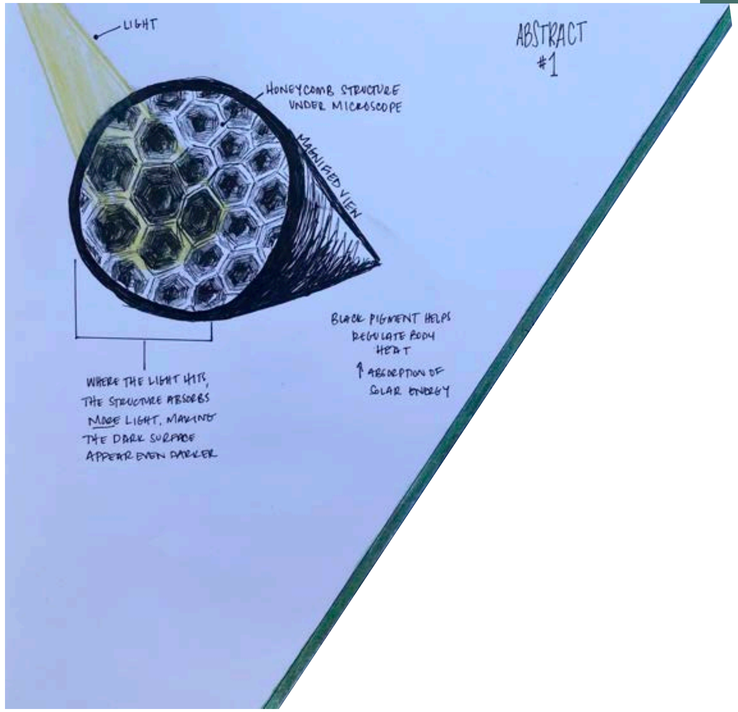
LAP 1

DESIGN CHALLENGE

Design a cold-weather sweater that uses life-friendly materials in order to retain warmth.

FUNCTION: Regulate temperature during environmental changes.

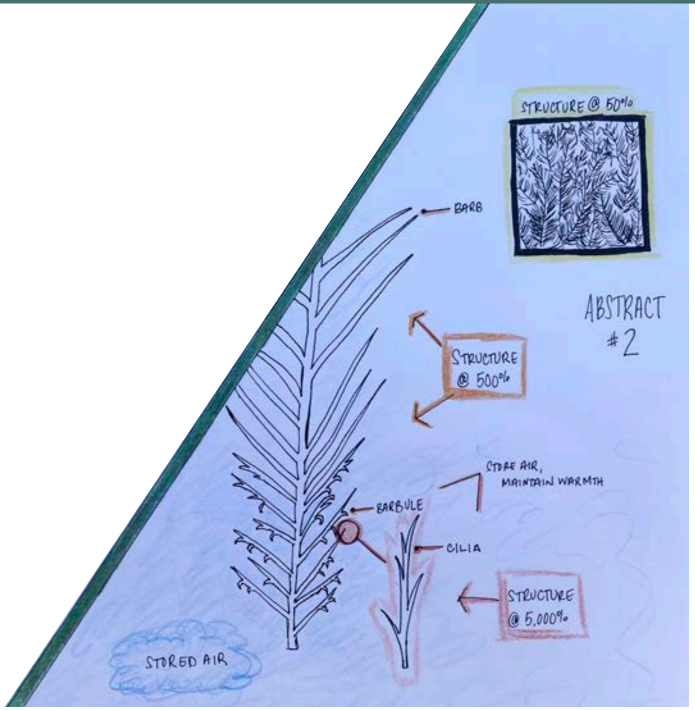
Note: My exploration shifted from a systemic solution to a product-based solution. Because of this, I researched new functions specific to the updated "Design Challenge" which you see beginning in this step.



ORGANISM Green Birdwing Butterfly

DESCRIPTION

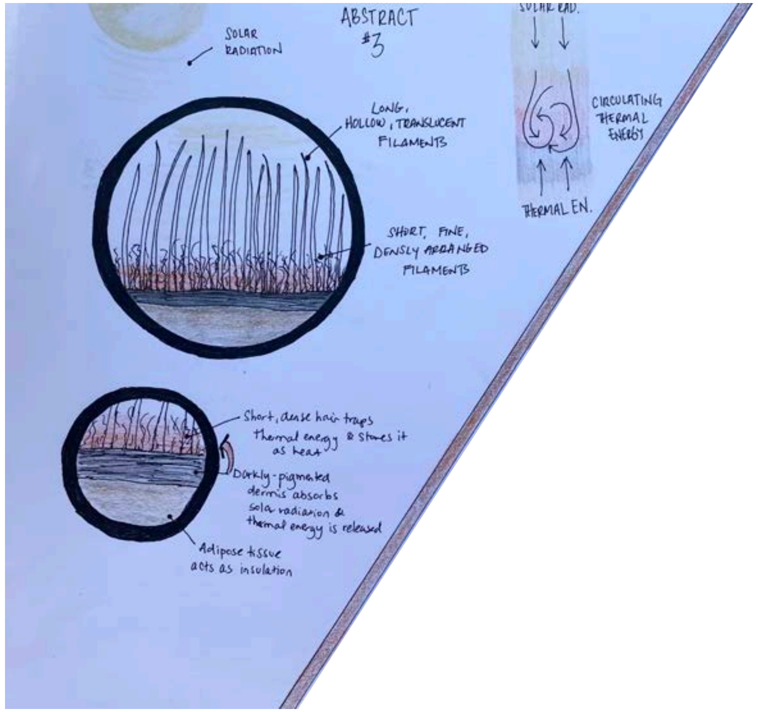
An arrangement of rigid hexagonal plates that absorb photons at a greater rate than less-textured outer layers of an organism. Inverted ridges minimize reflection while the absorbed solar light results in deeper pigments and heat retention.



ORGANISM Emperor Penguin

DESCRIPTION

Epidermal growths provide a layered outer covering that allows air to be trapped by filaments to be heated for temperature regulation. These growths are made up of two layers that are both short and stiff. The under layer is comprised of tiny branches that end with barbs, these barbs contain hundreds to thousands of barbules, and barbules contain cilia which act as a mechanism for movement and stored air for warmth.



ORGANISM Polar Bear

DESCRIPTION

Protein filaments grow from follicles of the dermis of mammals, long and transparent filaments make up the outer layer, while the inner layer is comprised of short and dense filaments. The transparent filaments absorb infrared radiation expelled from the mammalian body. This process acts as insulation and absorptivity precisely at the exact wavelengths that thermal energy is expended from the mammal in order to maximize its survival in extremely cold temperatures.

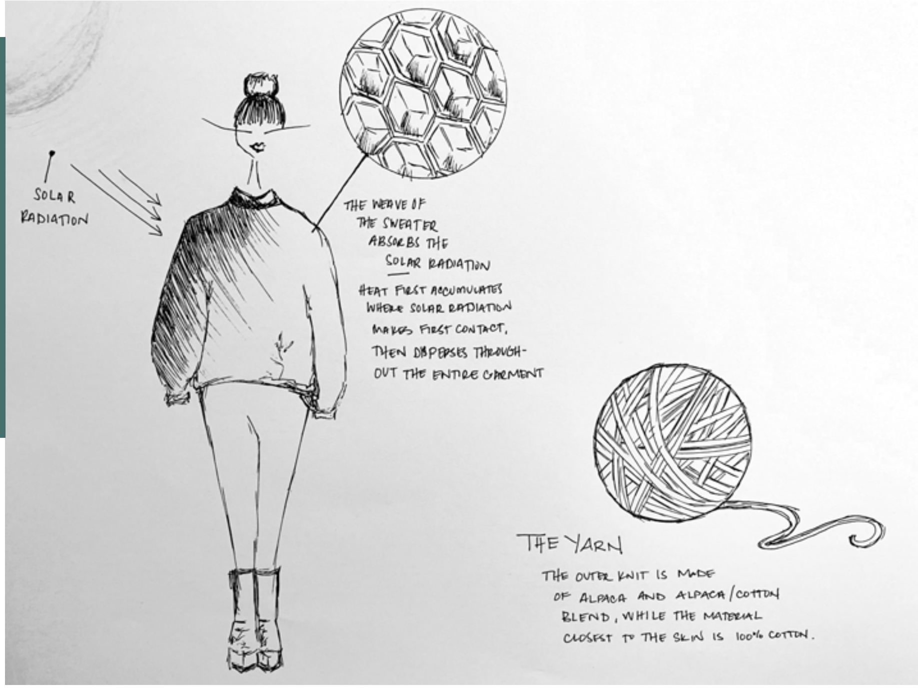
● Indicates organisms/functions chosen for further exploration

EMULATE

LAP 1

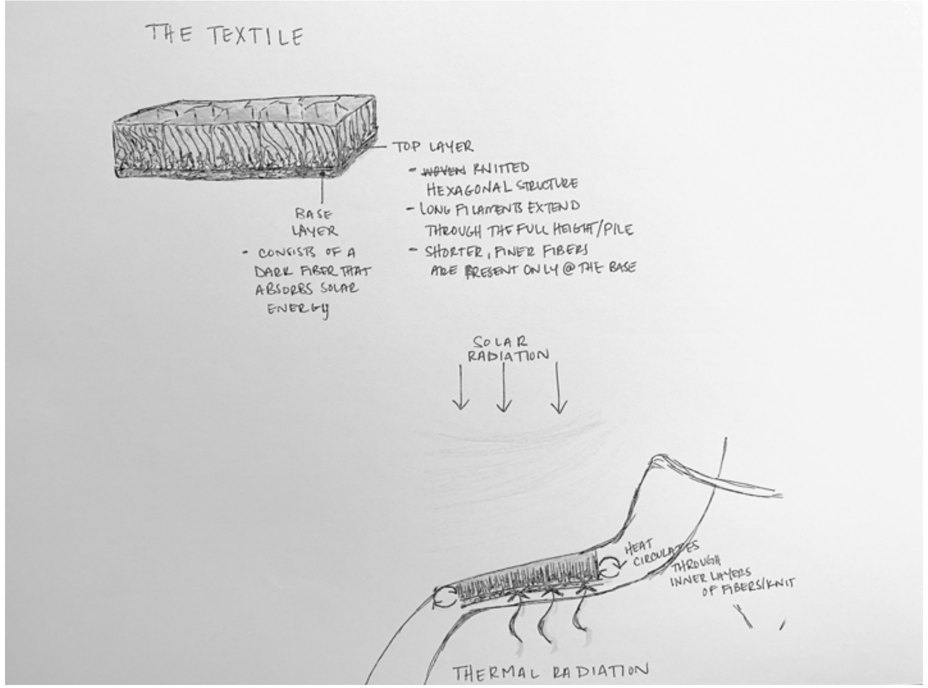
DESIGN CHALLENGE
Design a cold-weather sweater that uses life-friendly materials in order to retain warmth.

FUNCTION
Regulate temperature during environmental changes



DESCRIPTION

Solar and thermal radiation are the primary heat sources for this garment, but it's the knit that maintains and circulates the heat. Natural fibers, alpaca and cotton, maintain warmth while also circulating trapped air to ensure the wearer keeps warm in cold conditions, but also is cool enough when the temperatures rise. Alpaca fiber is naturally moisture-wicking, so dryness will ensure regulated temperatures and comfort.



DESCRIPTION

The cross-section of the textile shows two layers of structure. The top layer has a waffle-like appearance from the top, but from the side view you can see that there are two different types of fibers knitted together. Entirely alpaca fiber on the top and the finer fibers are a combination of both alpaca and cotton at the base. The bottom layer is made up of cotton with a dark pigment. This pigments absorbs solar energy, which combined with thermal energy, circulates through the alpaca/cotton layer.

The heat is stored as long as thermal radiation is also circulating, keeping the wearer warm even in low-light or cloudy days.

EVALUATE

LAP 1

PURPOSE

To strengthen a design solution by assessing it using Life's Principles. A design may be strengthened by making changes to be more sustainable, innovative, and/or higher performing.

In this evaluation, I will be taking a closer look at a new sweater design that was created to better regulate temperature for the wearer during changes in the environment.

As a reminder, Life's Principles are as follows:

- **Does the design adapt & evolve?**
    - Is the design locally attuned & responsive?
    - Does the design integrate cyclic processes?
    - Is the design resilient?
- **Does the design create conditions conducive to life?**
    - Does the design optimize rather than maximize?
    - Does the design use benign manufacturing?
    - Does the design leverage its interdependence in the system?

Life's Principles and how this design meets or fails to meet them are outlined on the next page.

EVALUATE

LAP 1

LOCALLY ATTUNED & RESPONSIVE

Is the design resourceful?
This design utilizes shape and information in tandem with material to create energy. Its shape is part of what makes it function at a higher level than other knit garments.

Does it leverage feedback loops?
The design responds to solar energy to trap and circulate heat with the addition of thermal energy, maintaining homeostasis for longer.

When it uses materials, are the materials locally available and abundant?
This garment is made by natural fibers (cotton and alpaca) that are both grown and harvested domestically.

INTEGRATE CYCLIC PROCESSES

Are processes cyclical?
The fibers used in this garment have desirable properties that adapt to changing conditions: moisture-wicking, naturally antimicrobial, etc. It however is not designed for disassembly or reuse. At this stage, it does not utilize recycled materials, however it may be reintroduced back into nature and may biodegrade at end of life.

Does it integrate local feedback loops?
This design does respond to feedback, both through the thermal energy developed by the wearer, and in response to environmental changes.

RESILIENT

Can it withstand disturbance while maintaining function?
Yes, the weave of this garment if functional and moves with the wearer. The hexagonal shape can expand, and contract based on sensory inputs from solar and thermal energy.

Are there opportunities for cross-pollination and mutation?
This design does not cross-pollinate or mutate.

OPTIMIZE VS. MAXIMIZE

Does it integrate multiple functions?
Yes! This design both absorbs solar energy and retains solar and thermal energy to maintain optimal temperature. The natural properties of the fibers also work together to maintain the comfort of the garment.

Does it recycle all materials/is it recyclable?
This design is not made of recycled materials, but the fiber may be reused for other purposes, however not in their original form.

Does it perform functions with minimal material and energy?
This design is currently manufactured in a traditional way using existing processes that require water and energy.

USE BENIGN MANUFACTURING

Is it made from life-friendly materials?
Yes, the sweater is made from cotton and alpaca fiber and it can be reincorporated into nature's cycles at the garments end of life.

Is chemistry done in water?
Water is used both in growth and manufacturing, but the garment is not self-assembled. The knit is however built to shape through the hexagonal pattern.

Are processes done at ambient pressure and temperatures?
Chosen fibers are naturally antimicrobial, thus self-cleaning and are processed with minimal energy derived from solar. Heat and pressure are not used.

LEVERAGING INTERDEPENDENCE

Does it foster symbiotic, cooperative, and community-based relationships?
Yes, this product creates opportunity rather than competition in the apparel space.

Does it foster emergent relationships?
This design is not a self-organizing system, nor does it take the energy path of least resistance.

EVALUATE

LAP 1

How human-made solutions reflect Life's Principles

COMPARED TO WEEK 4's EXPLORATION

The design concept has evolved slightly over the weeks, but much of what I looked at earlier on in the course was like this new design challenge. For example, in the week 4 assignment, I looked at Patagonia's efforts to utilize natural and recycled fiber options and how they related to Life's Principles. I discovered that this approach is good, in general, but could be modified for improvements.

While Patagonia's efforts are excellent, they touch on only part of the issue of apparel manufacturing: fiber choice. The innovative weave of the hexagonal shape in my design, plus the layering of fibers to trap and circulate air to improve functionality add another element of function to what a lot of apparel designs are lacking, particularly those in fast fashion.

My design will struggle in the same way that Patagonia's do – are they accessible and scalable to several SKUs required to run a successful business? Despite this, my design is functional and like Patagonia, uses life-friendly materials.

Week 4's Exploration

DESIGN CHALLENGE	MEETS	VIOLATES	IMPROVEMENT
Use of only natural materials in apparel production to improve garment function, durability, and biodegradation at the end of a garments lifecycle. Current Solution - Specifiers choosing to manufacture with more earth-friendly materials, like Patagonia's efforts to include more natural and recycled fiber options.	Locally attuned & responsive: Consider limitations and accessibility of manufacturing clothing at scale across many skus. Optimize vs. maximize: Designers aim to encourage functionality in garments. Benign manufacturing: Some forms, ie. utilizing "life-friendly" materials and materials already in existance (recycled). Leverage interdependence: Designs are leaning closer to interdependence within the system with more close relationships to material vendors and more innovative concepts.	Cyclical processes: Most garments are not made to be disassembled or reconfigured. However, some Patagonia products are made from recycled materials. Resilient: Garments are not made for resiliency, despite Patagonia's efforts to encourage proper care and repair.	Numbat Function/Strategy: Thin pelts allow numbats to absorb more solar heat while reducing heat lost when they erect their pelts. Inspired Solution: The insulating properties of the numbat fur can inspire other materials that can keep the wearer warm in cool temperatures and cool in warm temperatures as it responds to the temperature of the wearer, increasing adaptability and functionality of the garments [resiliency].

Image Source: Amber Martin via Unsplash

EVALUATE

LAP 1

How can my design be modified to better reflect life's principles?

1. Integrate cyclic processes

To set this design apart, it would be fully biodegradable, but also nutrient rich. The ultimate goal would include an "end of life" plan for the sweater, where it can be incorporated into the soil and provide nutrients for new growth. Maybe even include some seed that is activated by the conditions found in soil.

Rather than throwing out the garment, it could be planted in a garden or mixed with compost to provide feed for crops, whereas most other apparel ends up in a landfill and takes decades, if not centuries, to decompose.

2. Resilient

A really cool opportunity here would be to offer a simple, modular repair solution to anyone who owns a sweater. Simply remove the damaged hexagon and replace it with a new one. Providing solutions for easy maintenance will encourage longer use!

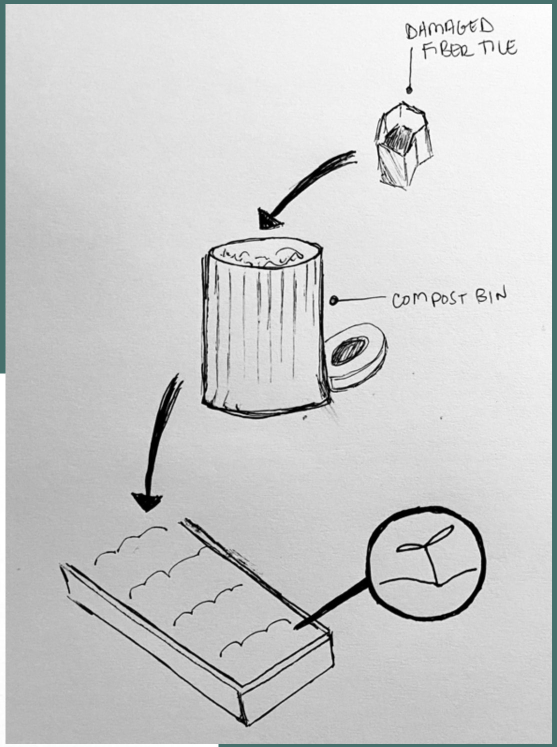
Plus, we could incorporate the design solution from "integrate cyclic processes" into this modular feature – once a piece of the sweater is damaged, it can be removed and placed back into a garden to act as a nutrient-rich fertilizer for regrowth. Often with sweaters, if a thread comes loose, if not repaired it could damage the entire garment and may not be reparable at all. This would offer a simple solution for increasing the longevity of a garment.

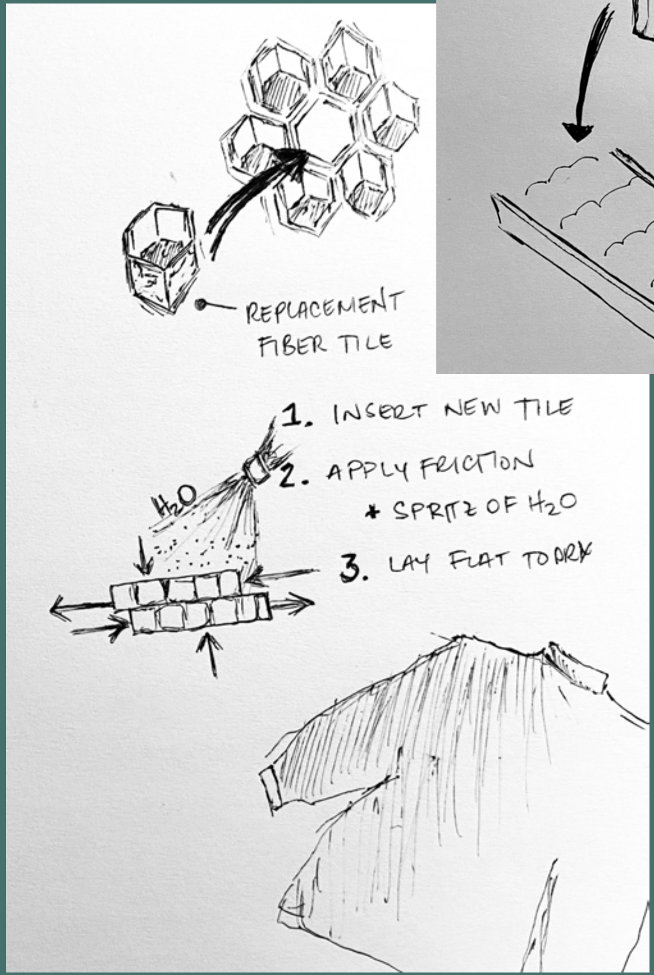
3. Use benign manufacturing

One of the most difficult challenges will be to ensure that the textiles can be developed in a way that does not require high heat or temperature and can be self-assembled. Can fibers be processed differently that isn't necessarily knit by gigantic energy-sucking machines? I think reimagining the process entirely may aid in making this sweater even more innovative.

One of the most wasteful processes of manufacturing apparel comes from the off-cuts of materials. Could we utilize some sort of machine that can create the hexagonal shaped knit in a method like bees building their hive? Each piece is formed individually, then bound together through friction or another naturally occurring method?

Incorporating this new processes of assembly for a system of grading (accommodating a range of sizes) would also eliminate the masses of waste that traditional manufacturing acquires.





CHALLENGE TO BIOLOGY

LAP 2

IDENTIFY | TRANSLATE | DISCOVER

LAP 2

OVERVIEW

Beginning once again at the Identify step of the Challenge to Biology design spiral, I took another look at the purpose of a sweater. Why do we wear sweaters? What are the functions a sweater performs?

Once I identified the functions, I began to interpret them in a biological sense, with the goal of being able to translate them to a biological function in nature.

PURPOSE

Provides warmth
Provides modesty
Fits the wearer
Is reusable
Is washable
Holds tools
Breathable
Moisture-wicking

FUNCTION & TRANSLATION

Stores heat
- How do otters keep water out and heat in?
- How do polar bears absorb light to store heat?

Manages forces
- How are glass skeletons tough yet flexible?
- How do elephant trunks twist and twirl?
- How do fish scales minimize drag?

Filters air
- How do spider webs filter water from air?

Maintains temperature
- How do ants maintain temperature and humidity?
- How does the shape of cacti aid in temperature regulation?

Conforms to shapes
- How does seaweed change shape to avoid damage?
- How do sea anemones change shape?

Protects from cold
- How do wooly hairs protect leaves?
- How does a dense covering protect from cold?

Indicates organisms/functions chosen for further exploration

Image Source: Jean Wimmerlin via Unsplash

SEA ANEMONE

The body of a sea anemone is made up of two layers separated by mesoglea, which provides structure to the organism. The central cavity of a sea anemone is filled with water by ciliary pumps. This flow of water in and out allows the organism to change shape from a low sphere to a tall cylinder.

Image Source: Dejan Zakic via Unsplash

TORCH CACTUS

Cooling ribs of the torch cactus protect the plant from solar radiation by shading different areas of the cactus throughout the day. These ribs provide rising and falling air currents improving radiation. When the sun is at its highest point only the smallest surface area of the cactus is touched by the light.

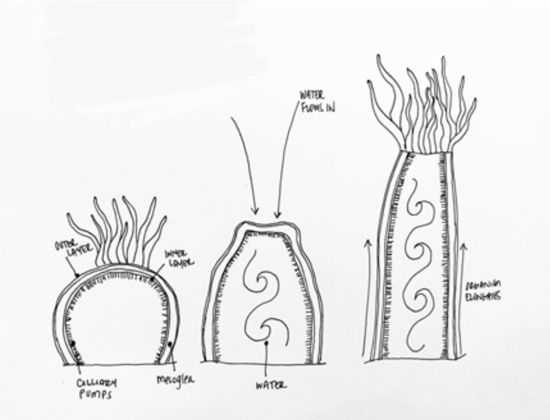
Image Source: Jean Wimmerlin via Unsplash

SPIDER WEBS

Cribellate spiders spin webs that can transport and store water captured from the air. They do this by utilizing cilia on their legs to tangle their silk, weaving their silk in such a way that alternates tangles with straight sections that in turn aid in channeling water along the path. The water pools in specific areas, while the silk remains dry in others.

ABSTRACT | EMULATE

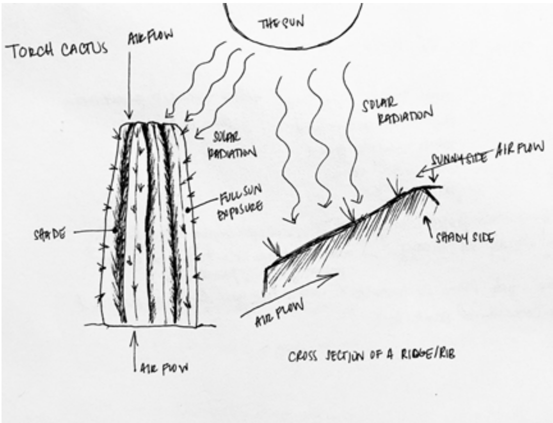
LAP 2



ORGANISM Sea Anemone

DESCRIPTION

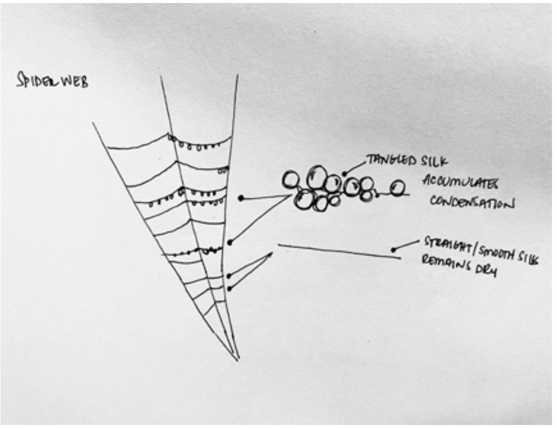
The physical structure of the organism is derived from two layers of matter separated by a gelatinous substance, that provides structure to the organism. The central cavity is filled with seawater by ciliary pumps. This flow of water in and out allows the organism to transform from globus to a cylindrical form.



ORGANISM Torch Cactus

DESCRIPTION

Linear projections (crest) of the organism protect the plant from solar radiation by shading different areas of the structure throughout the day. These ribs provide rising and falling concentrated areas of winds that facilitate radiation.



ORGANISM Cribellate Spider

DESCRIPTION

Webs of strong silk are strung and tangled to both transport and store condensation captured from the air. Short filaments on the appendages of the organism are used to weave the silk in different arrangements for different purposes, encouraging pooling in some areas and movement in others.

Indicates organisms/functions chosen for further exploration

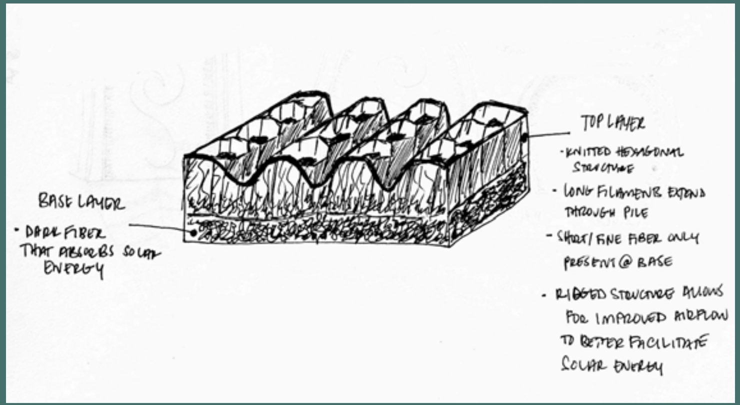
EMULATE

DESIGN CHALLENGE

Design a cold-weather sweater that uses life-friendly materials in order to retain warmth.

FUNCTION

Regulate temperature during environmental changes



DESCRIPTION

The improved design of the fiber weave is shown above. A detailed cross-section of the fibers shows that with the addition of the ridges, there is more opportunity to absorb solar energy while the valleys of the ridges encourage air flow for temperature maintenance. The hexagonal pattern remains, as does the dark fiber base layer for solar energy absorption.

The fiber make-up of this textile is entirely alpaca fiber on the top layer and a combination of baby alpaca and cotton in the base layer. The combination here is important to to be anti-microbial as it's in close contact with the wearer's skin, and facilitate the exchange of air and heat to maintain the garment's warmth through circulation of solar energy, thermal energy, and the flow of air.

EVALUATE

LAP 2

A design may be strengthened by assessing it against Life's Principles. Below, I explore which changes could make my design more sustainable, innovative, and/or higher performing. How could this new sweater design better regulate temperature for the wearer during changes in the environment?

LOCALLY ATTUNED & RESPONSIVE

Is the design resourceful?
This design utilizes shape, color, and solar and thermal energy in order to maintain homeostasis. The shape is part of what makes it function at a higher level than other knit garments.

Does it leverage feedback loops?
The design responds to solar energy to trap and circulate heat with the addition of thermal energy, maintaining homeostasis for longer.

When it uses materials, are the materials locally available and abundant?
This garment is made with natural fibers (cotton and alpaca) that are both grown and harvested domestically using regenerative practices.

INTEGRATE CYCLIC PROCESSES

Are processes cyclical?
The fibers used in this garment have desirable properties that adapt to changing conditions: moisture-wicking, naturally antimicrobial, etc. It however is not designed for disassembly or reuse. In this iteration, it does not utilize recycled materials, however it may be reintroduced back into nature and may biodegrade at end of life.

Does it integrate local feedback loops?
This design does respond to feedback, both through the thermal energy developed by the wearer, and in response to environmental changes.

RESILIENT

Can it withstand disturbance while maintaining function?
Yes, the weave of this garment if functional and moves with the wearer. The hexagonal shape can expand, and contract based on sensory inputs from solar and thermal energy and the ridges promote air flow that aid in temperature regulation

Are there opportunities for cross-pollination and mutation?
This design does not cross-pollinate or mutate.

OPTIMIZE VS. MAXIMIZE

Does it integrate multiple functions?
This design both absorbs solar energy and retains solar and thermal energy to maintain optimal temperature. The natural properties of the fibers also work together to maintain the comfort of the garment.

Does it recycle all materials/is it recyclable?
This design is not made of recycled materials, but the fiber may be reused.

Does it perform functions with minimal material and energy?
This design will need to be manufactured with a new method for knitting that includes a hexagonal form at varying depths, as well as a base layer of woven fibers. It would ideally be constructed by a single solar-powered machine.

USE BENIGN MANUFACTURING

Is it made from life-friendly materials?
Yes, the sweater is made from cotton and alpaca fiber and it can be reincorporated into nature's cycles at the garments end of life.

Is chemistry done in water?
Water is used both in growth and manufacturing, but the garment is not self-assembled. The knit is however built to shape through the wavy hexagonal pattern.

Are processes done at ambient pressure and temperatures?
Chosen fibers are naturally antimicrobial, thus self-cleaning and are processed with minimal energy derived from solar. Heat and pressure are not used.

LEVERAGING INTERDEPENDENCE

Does it foster symbiotic, cooperative, and community-based relationships?
This product creates opportunity rather than competition in the apparel space. It maximized the benefits of the fibers being used and creates more opportunity for regenerative farming practices and collaboration with the apparel sector.

Does it foster emergent relationships?
This design is not a self-organizing system, nor does it take the energy path of least resistance.

CHALLENGE TO BIOLOGY

LAP 3

IDENTIFY | TRANSLATE | DISCOVER

LAP 3

OVERVIEW

For my third lap around the Challenge to Biology design spiral, I wanted to consider the care of the sweater to ensure it has a long lifespan. Many sweaters pill if they aren't made of complementary fibers, others lose their shape after washing or require dry cleaning. Here, I wanted to find a solution that could be scalable and adoptable by the general public.

PURPOSE

Provides warmth
Provides modesty
Fits the wearer
Is reusable
Is washable
Makes a statement
Provides sense of style
Influences others

FUNCTION & TRANSLATION

Reusable
- How does eucalyptus regenerate?
- How do lysosomes recycle proteins?

Washable
- How do butterflies stay clean?
- How do pansies self-clean?
- How do fungi clean?
- How does licking cool skin of kangaroos?

Sends signals
- How do hummingbirds communicate?
- How do dolphins send signals under water?
- How do slime molds communicate without brains?

Respond to external conditions
- How do pinecones respond to changing temperatures?

Provides comfort
- How do cell walls of vascular plants provide strength in changing conditions?
- How does foam provide shelter and water to frogs?

Indicates organisms/functions chosen for further exploration

Image Source: Jennifer Burk via Unsplash

PINECONE

Pinecones adapt to their environment and open and close depending on the levels of humidity in the air. If it's dry and windy, the pinecone will open as the conditions are conducive to seed dispersion. On the other hand, if it is humid or rainy, the mechanism that controls the scales contracts to "close" the scales and saves the seeds for more optimal conditions.

Image Source: Jeremy Bezanger via Unsplash

BLUE MORPHO BUTTERFLY

The blue morpho butterflies are not only incredibly beautiful, they are extremely clean. Structures on their wings alternate between ridges and squama repel water as air is trapped in the interstitial spaces of the wing surface. Dust and dirt adhere to the droplets through adhesion, while gravity pulls the droplets toward the ground, cleansing the surface of the wing.

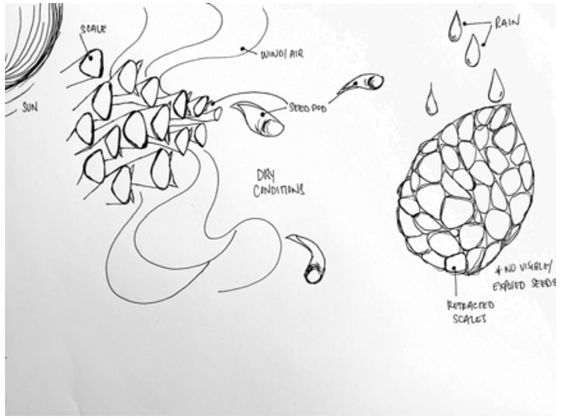
Image Source: Hans Veth via Unsplash

FUNGI

Fungi have the ability to break down chemicals through their own enzymes to absorb energy needed to live. This could be adapted to creating regenerative clothing. The fungi process of breaking down chemicals is a slow one, but they could be constantly rebuilding from exposure to pollutants.

ABSTRACT | EMULATE

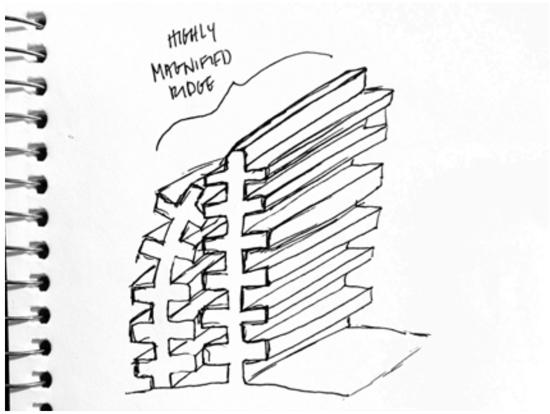
LAP 3



ORGANISM Pinecone

DESCRIPTION

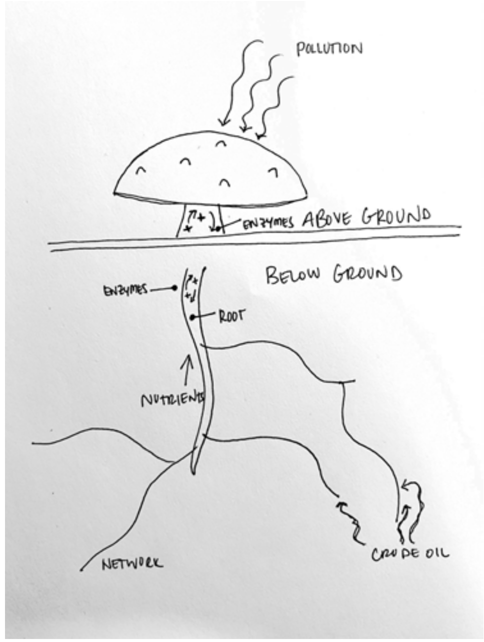
The rigid plate of this organism responds to environmental conditions such as temperature, humidity, and wind. In dry, windy conditions the rigid plates open exposing the fertilized embryo allowing it to move through the atmosphere via arial locomotion until it settles on a surface and may grow. In wet conditions, the rigid plates close, protecting the embryo until more favorable conditions come to pass.



ORGANISM Blue Morpho Butterfly

DESCRIPTION

The pillar-like structure that makes up the rigid panels of the appendage can form together to make ridges. These ridges allow air to flow through them, whilst carrying away dirt and debris with the force of gravity.



ORGANISM Fungi

DESCRIPTION

The primary root expands into secondary roots that are used to communicate with other life and absorb nutrients from the soil. Sometimes these roots also extract chemicals and convert them with enzymes into energy. A similar process can happen above ground where chemicals enter through the surface or gills, enzymes are used to counteract chemicals, and are thus converted into energy conducive to life.

Indicates organisms/functions chosen for further exploration

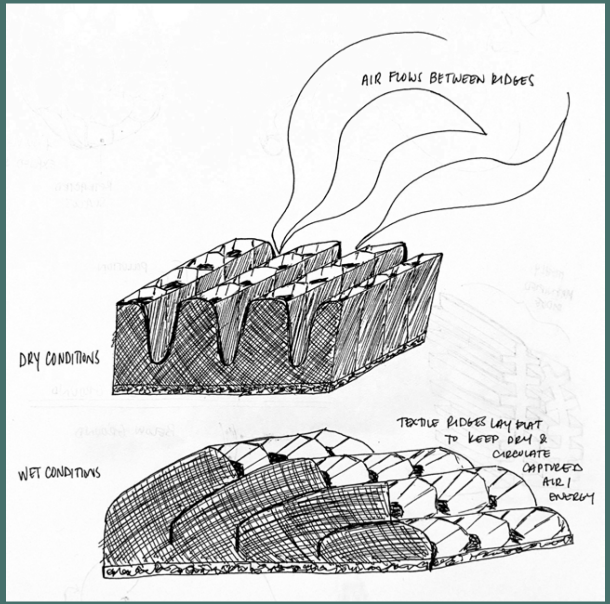
EMULATE

DESIGN CHALLENGE

Design a cold-weather sweater that uses life-friendly materials in order to retain warmth.

FUNCTION

Regulate temperature during environmental changes



DESCRIPTION

The most recent feature from this third lap of the design spiral would adapt to environmental conditions by opening to allow more air flow in warm conditions and close and provide protection from cold and rain in cold or rainy conditions.

Instead of using plant and animal fibers in their raw form, what if they were converted into a new type of material via 3D printing or a new method of knitting/weaving fibers together to create a more structural textile composed of several layers?

EVALUATE

LAP 3

A design may be strengthened by assessing it against Life's Principles. Below, I explore which changes could make my design more sustainable, innovative, and/or higher performing. How could this new sweater design better regulate temperature for the wearer during changes in the environment?

LOCALLY ATTUNED & RESPONSIVE

Is the design resourceful?
This design utilizes shape, color, and solar and thermal energy in order to maintain homeostasis. The shape of the individual textile features is what allows the garment to function at a higher level than other knitwear.

Does it leverage feedback loops?
The design responds to solar energy to trap and circulate heat with the addition of thermal energy, maintaining homeostasis for longer. With this third spiral it also responds to moisture.

When it uses materials, are the materials locally available and abundant?
This garment is made with natural fibers (cotton and alpaca) that are both grown and harvested domestically using regenerative practices.

INTEGRATE CYCLIC PROCESSES

Are processes cyclical?
The fibers used in this garment have desirable properties that adapt to changing conditions: moisture-wicking, naturally antimicrobial, etc. It however is not designed for disassembly or reuse.

A cool opportunity could be to use recycled, natural fibers to create a sort of "super fiber" that could be formed (3D printing for natural fibers?) into the structural form in this design. Ideally it would biodegrade at end of life.

Does it integrate local feedback loops?
This design does respond to feedback, both through the thermal energy developed by the wearer, and in response to environmental changes.

RESILIENT

Can it withstand disturbance while maintaining function?
Yes, the weave of this garment if functional and moves with the wearer. The hexagonal shape can expand, and contract based on sensory inputs from solar and thermal energy and the ridges promote air flow that aid in temperature regulation. With the third lap it can also respond to moisture changes by regulating airflow and continuously circulating existing air or allowing new air to pass through.

Are there opportunities for cross-pollination and mutation?
This design does not cross-pollinate or mutate.

OPTIMIZE VS. MAXIMIZE

Does it integrate multiple functions?
This design now regulates and responds to moisture, absorbs solar energy and retains solar and thermal energy to maintain optimal temperature. The natural properties of the fibers also work together to maintain the comfort of the garment.

Does it recycle all materials/is it recyclable?
This design is not made of recycled materials, but the fiber may be reused.

Does it perform functions with minimal material and energy?
This design will need to be manufactured with a new method for knitting that includes a hexagonal form at varying depths, as well as a base layer of woven fibers. It would ideally be constructed by a single solar-powered machine, possibly a new version of 3D printing

USE BENIGN MANUFACTURING

Is it made from life-friendly materials?
Yes, the sweater is made from cotton and alpaca fiber and it can be reincorporated into nature's cycles at the garments end of life.

Is chemistry done in water?
Water is used both in growth and manufacturing, but the garment is not self-assembled. The knit is however built to shape through the wavy hexagonal pattern.

Are processes done at ambient pressure and temperatures?
Chosen fibers are naturally antimicrobial, thus self-cleaning and are processed with minimal energy derived from solar. Heat and pressure are not used.

LEVERAGING INTERDEPENDENCE

Does it foster symbiotic, cooperative, and community-based relationships?
This product creates opportunity rather than competition in the apparel space. It maximized the benefits of the fibers being used and creates more opportunity for regenerative farming practices and collaboration with the apparel sector.

Does it foster emergent relationships?
This design is not a self-organizing system, nor does it take the energy path of least resistance.

DISCUSSION

Reflection

This project challenged me to slow down and follow the spiral instead of bouncing around to new idea after new idea. I'm a designer by trade, but I don't necessarily have a specific design process that I follow, the "process" is often rushed and ends up being a lot of "throwing spaghetti at a wall." I liked to be challenged in this way, but in total the whole project likely ended up taking me closer to 20 hours to complete. While there was a process in use, I certainly struggled with my efficiency.

My idea evolved, but not in an unreasonable way. It did spark my curiosity and made me wonder if there is a way we can reinvent the way we combine fibers in the first place. I've heard of "smart" textiles, but is that possible with natural fibers? Can we develop something entirely new without exhausting our planets resources further? My final design ended up being "smart" in a way, but not entirely the way that someone might expect (no electrical impulses or digital devices, simply through changing environments).

My favorite part of the project ended up being the time I spent sketching in the abstract. I don't spend enough time putting pen to paper, so that was refreshing, yet time consuming.

Potential

There is potential to redefine the apparel industry on several levels. I think manufacturing textiles could be changed significantly with technology, the use of solar or wind energy, and even taking a step back into agriculture and more regenerative farming practices.

More innovation in the way we create textiles is also possible. As I mentioned before, it would be really interesting to incorporate some sort of 3D process with natural materials that can still provide comfort, loads of function, and style.

Limitations

This design is currently limited by the current processes for manufacturing fiber yarns and textiles. Honestly, the entire system could use re-work from agriculture to retail. Definitely engineering and manufacturing advances are necessary, as well as chemistry and a consideration of the full lifecycle of the product.

One idea I hadn't explored further here, but would love to at some point is being able to fully plant a garment in the ground to grow a garden – maybe even the final iteration with inspiration from a pinecone could include actual seed that can be replanted into the earth after the garment is no longer wearable.

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CHANGE LOG

- Expanded the "Abstract" to include a more thorough description of the goal of this design exploration.
- Pp. 7 – added a note about the shift in the design from a system-level design, to a product-level design, thus updated functions were chosen for exploration.
- Pp. 9 – deleted duplicate information
- Added a "pink dot" to indicate organisms/functions I selected to explore further.
- Updated Life's Principle "Are processes done at ambient pressure and temperature?" for all three laps to better represent the design.
- Additional formatting updates: font color, size, moved some text that had been cut off, edited typos, etc.

THANK YOU