Passive Wooden Furniture Recycling

This design addresses the waste generated by the furniture industry and supplies furniture manufacturers with an alternative material made from this waste. The furniture industry is the third most consumptive sector of wood in the US economy, preceded only by the construction and paper industries. According to an EPA study, furniture is the least recycled sector of waste exiting US homes. On average, 12 million tons of waste is generated by the furniture industry per year. Wood based material waste is not just limited to wood fabricated furniture pieces but is present in the construction and demolition industry as well. The annual estimated generation of wood waste in the construction and demolition industry is 36.4million tons with 29.7 million tons generated from demolition activities and 6.7million tons occurring during construction. This discrepancy leaves the massive amount of wood waste as a resource that is currently going untapped.

Design Overview

Our solution is to implement a passive decomposition process. In this process, wood is treated with a series of enzymes, fungi, and bacteria to first remove foreign chemicals, like sealants and adhesives, and is then processed into an inert state. The resulting pulp will then be envisioned as a new material. This material will be made as a material replacement for wood, to alleviate the strain placed on trees and ecosystems from the lumber industry. To encourage the furniture industry to adopt more sustainable practices, the material must be low cost. This is why this process is designed to be as passive as possible.

It remains our aim throughout this process to provide a life safe solution to this material waste problem and mitigate the generation of carbon and methane created when wood materials are deposited in landfills. In accordance with the United Nations Sustainable Development Goals, we aspire to meet the following goals:

Goal 3: Good Health and Well-being
Goal 6: Clean Water and Sanitation
Goal 9: Industry, Innovation, and Infrastructure
Goal 12: Responsible Consumption and Production
Goal 13: Climate Action
Goal 14: Life Below Water
Goal 15: Life On Land.

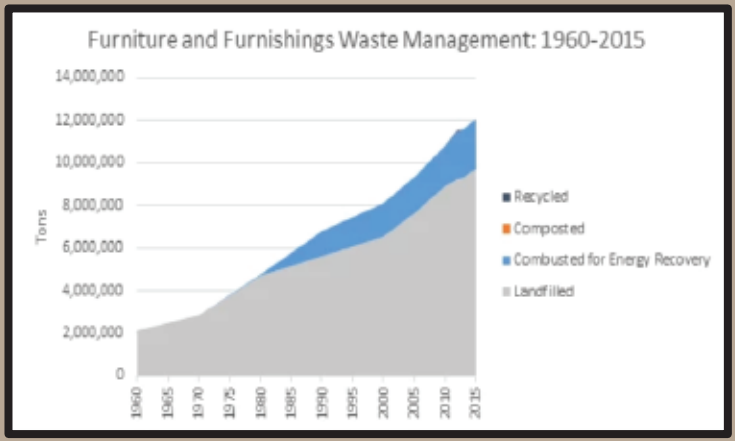
Understanding the Problem

Furniture may not seem like the most pressing issue when looking at the fact that it represents only 4.1 percent of the waste entering landfills. What that number doesn't show is that the furniture sector is the third most consumptive sector of wood cellulose (preceded only by the construction and paper industries). Furniture is a fruitful sector to be examining, because it is the least recycled form of waste leaving US homes. Creating new options for material reclamation in this sector, sends a message that recycling is always an option.

Of 35 individuals surveyed, only 28% said that their home, business, or organization recycles or donates wooden materials such as broken furniture or the byproducts of construction projects. 28% of individuals surveyed indicated that recycling or donating was not done due to lack of access to recycling services and 25% said that it was due to the inconvenience of relocating these bulky materials. 63% stated that they would be willing to participate in a materials exchange to donate, sell, or buy used furniture, or use refurbished and reclaimed C&D materials.

This system is meant to be implemented when re-use is no longer an option. The result of this system is a resource for the furniture industry to look to in place of virgin lumber. Lumber is considered a renewable resource simply because we can grow more. This fails to account for the loss of carbon sequestration and habitats every time a forest is clearcut.

The goal is to achieve this by overwhelmingly passive means. To ignite the kind of change this industry is in need of, there must be sufficient financial incentive. Passive processes help achieve this goal.



1960–2017 Data on Furniture and Furnishings in MSW by Weight (in thousands of U.S. tons)

Management Pathway	1960	1970	1980	1990	2000	2005	2010	2015	2016	2017
Generated	2,150	2,830	4,760	6,790	8,120	9,340	10,820	12,050	12,210	12,210
Recycled	-	-	-	-	-	-	10	10	30	40
Composted	-	-	-	-	-	-	-	-	-	-
Combustion with Energy Recovery	-	-	90	1,150	1,570	1,700	1,910	2,350	2,380	2,380
Landfilled	2,150	2,830	4,670	5,640	6,550	7,640	8,900	9,690	9,800	9,790

Scoping

This design will...

- -Break down wood
- -Metabolize wood
- -Build from metabolized wood
- -Strip adhesives and paints
- -Bring materials to a more pure and inert state

Translate design into these functions...

- -Physically break down
- -Chemically break down
- -Physically assemble into new material
- -Modifying material characteristics
- -Sorting or filtering materials
- -Coordinate within the same system
- -Sense and respond to data
- -Utilize biotic factors in cyclic processes

Discover

Strategies from nature that breakdown wood cellulose

Wood-decay Fungus

These fungi feed off of and breaks down lignin in wood in a process that naturally bleaches/weaken the wood

Saprotrophic fungi – horsehair parachute fungus grows and feeds on leaves and pine needles, while Sulphur tuft fungus grows and feeds on logs at advanced stages of decomposition.
FUNCTION: Physically breaks down abiotic materials
STRATEGY: Attacks dead wood and thrives in environments of excessive moisture. This fungi not only grows on wood but it permeates woods fibrous structure and causes physical break down and decay.

Wet rot fungus (coniophora puteana) and Jelly rot fungus (phlebia tremellosa) aid in the decomposition of tough wood and woody structures. Fungal hyphae aids in decomposition and provides access to detritivorous creatures. Fungus feeds on cellulose and lignin.
FUNCTION: Captures, absorbs, or distributes resources
STRATEGY: secretes the enzyme cellulase from their hyphae, which causes decomposition in wood that is resistant to biological attack.

Detritivores

Beetles and larvae are first to jump into action. Next, invertebrates such as woodlice & millipedes feed on the decaying wood before flies and wasps swoop in to feed on the beetles and other invertebrates. Earthworms and springtails help to return the remaining matter to the soil.
FUNCTION: Affect physical integrity of materials
STRATEGY: 1)Termites have a symbiotic relationship with bacteria in their mid-gut that allows them to fully digest wood cellulose.
2)Wood-boring beetles used their mandibles to consume dead wood in various habitats where higher moisture content is present. Adult beetles exploit and create weaknesses in wood structures and materials by laying their eggs in cracks, grooves, and holes in the wood. The resulting larvae will bore out of wooden structure over time.

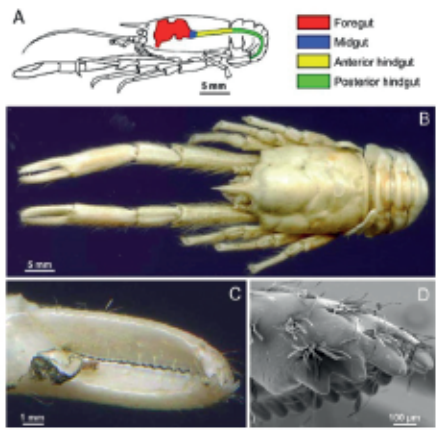
Panaque Catfish

Armored, wood eating catfish have been discovered in the amazon that feed on wood. Researchers speculate that xylivory (wood-eating) was a necessary evolution for this species of catfish in order for them to survive due to the strong competition for food in the amazon rivers.
FUNCTION: Move or stay put by attaching temporary
STRATEGY: Stay attached to submerged wood through the use of suction and grip from the barbels (short pointed structures) on either side of their sucker-mouth.

Discover

Strategies from nature that break down wood cellulose

Galatheid Crabs



Enzymes in the guts of these crabs ensure that their main diet subsists on a mostly wood-based diet. Wood and the biofilm covering sub-surface woods is the main food source for these crabs and is necessary for their survival.

FUNCTION: Physically breaks down abiotic materials. Captures and absorbs bulky solids and energy.

STRATEGY: Digest and gain energy from wood on the ocean floor by first passing it through a gastric-mill of strong teeth. The wood pulp then broken down by bacteria and fungi which inhabit the stomach.

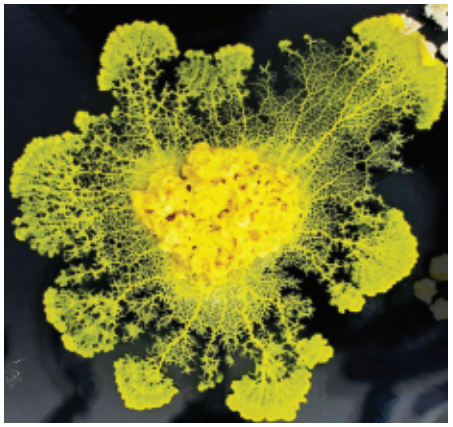
Paper Wasps / Vespa Hornets / Termites / Song Thrush (Bird)

These creatures all create protective nests/hives through chewing wood into a pulp and combining it with saliva to form/shape the material into a paper substance that is durable for protection and habitation

FUNCTION: Modify physical characteristics & Protects from abiotic factors

STRATEGY: Gather wood fibers from found wooden materials and chew the fibrous material to create an amalgamation with their saliva. The resulting mucoprotein-rich substance is made of cellulose and chitin-like saliva with a high-proline content that dries quickly and has inherent hydrophobic properties.

Slime Mold

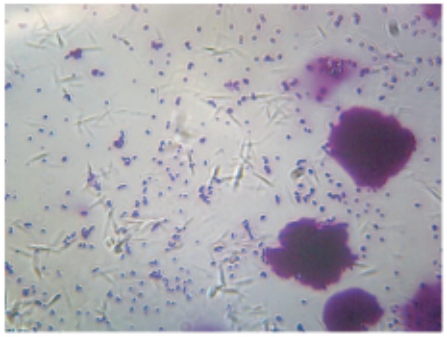


This unique eukaryotic organism feeds on microorganisms that live in any type of dead plant material. They contribute to the decomposition of dead vegetation, by feeding on bacteria, yeasts, and fungi.

FUNCTION: Modifies physical state

STRATEGY:When slime mold encounters bacteria and spores within a log, it grows to envelope and digest these opponents. Slime mold transforms its' byzantine pattern of tendrils into a more-efficient network of tubes. When nutrients become scarce, slime mode will contract and eventually disappear.

Bacteria



This is a broad category, and it is present at all stages of decomposition. Microbes aid in the breakdown of plant and animal materials. The process of them feeding preforms the chemistry of decomposition.

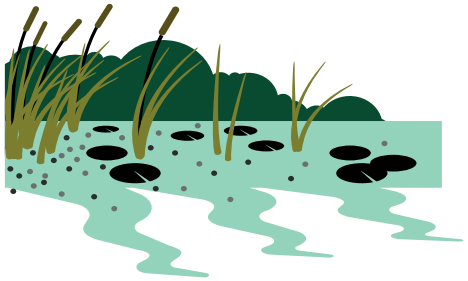
FUNCTION: breaks down abiotic and biotic material

STRATEGY: Mixed communities of bacteria play a supporting role in material decay of abiotic and biotic material and contributes to the breakdown of cellulose and pectin. A fluid filled environment is more conducive to bacteria's material breakdown process as wet and waterlogged wood provides a low oxygen concentration where bacteria thrives.

Discover

Inspirational Strategies from Nature

Wetlands

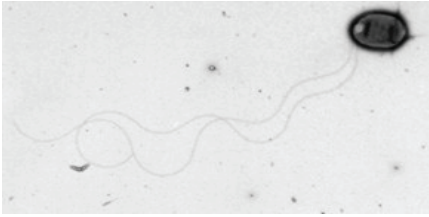


Wetlands exist at the boundry between water ways and land. The sponge-like structure of wetlands slows the flow of the contaminated water, this allows particulites to settle out. Wetlands are also among the most diverse ecosystems on the planet.

FUNCTION: Utlizes biotic factors in cyclic process

STRATEGY: Slow the flow of water and attract many plants, animals, and microbes to clense and process the contaminents.

Rhodobacter sphaeroide



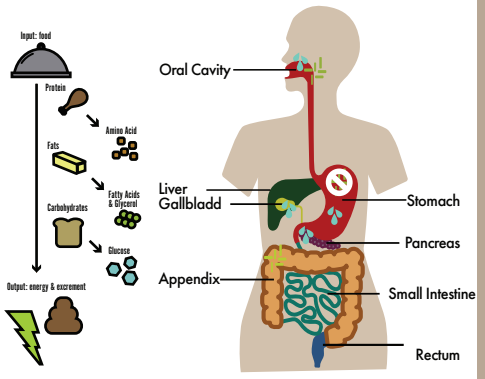
This particular bacteria is of note Because it has the ability to break down Formaldehyde and Urea-formaldehyde, two common wood adhesives. Formaldehyde is a compound found in nature, even sunlight will degrade it. What is special about these bacteria, is that they break this chemical down in aquatic and arid conditions.

FUNCTION: Chemically breaks down.
STRATEGY: Harness photosynthetic power to feed on formaldehyde.

Antenna

Sensing begins with a chemical engaging with the sensilla. Chemical energy is converted to electrical energy. That impulse travels along neural pathway, informing the organism of environmental conditions. The interface can also trigger a chemical reaction where the sensilla produce binding proteins.
FUNCTION: sensing and responding to data.
STRATEGY: Maximized surface area for sensors. sensors are specially attuned for factors most in need of detection.

Digestive System

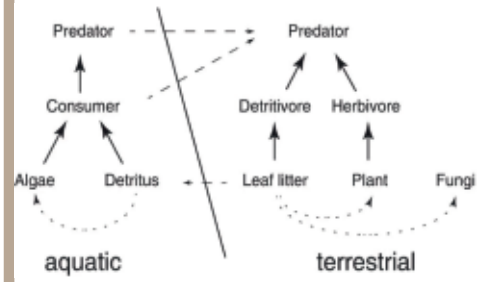


Digestion is a process of specialized organs that sense and secrete substances that break down food. Food is comprised of a mixture of caloric sources in the form of carbohydrates, fats and proteins, as well as other compounds like vitamins and minerals.
FUNCTION: Chemically and phyisically breakdown
STRATEGY: sequentially breaks down complex compondnds with a series of specialized chambers and chemical responses.

Abstract

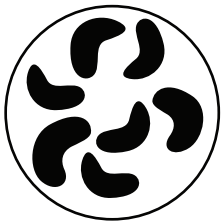
Translating the nature's pertinent strategies to design

Wood Decay Fungus



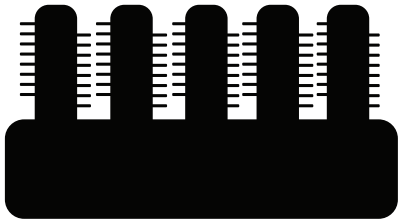
Nature creates an opportunity for decay as its' own form of clean up that occurs without facilitating potential creation of contaminants as a result of the process. Applying what we know of forest decay and the ecosystems that encompasses where decay occurs we can observe that participants in the process are both consumers of the plant matter itself and consumers of other participants within the system who have served their purpose and now become nutrients to the rest of the system's key players. Spent participants are filtered out and become food for the next level of decomposers and consumers within the system.

Bacteria -Agents of Break Down



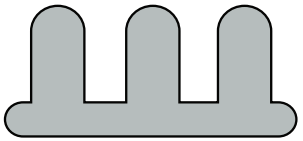
A large variety of organisms partner with bacteria to break down a variety of compounds. It may be a lower energy investment to facilitate an environment which nurtures bacteria, than to do the task by conventional means.

Antenna-Sensing



Sensing what is in an environment, creates the opportunity to calibrate the response. This ensures that the energy being used is going towards what needs doing. Getting an accurate chemical reading can be done by structures similar to insect antenna. These mechanisms protrude into the environment, and are covered in a series of increasingly smaller filaments. This ensures that a great deal of surface area is exposed to the sample environment without using excessive space or material. When chemicals are engaged with a sensory structure they can release energy, which can be harnessed to deliver the message to the central computing program.

Digestive System-Sequential Break Down



- Utilizes structures which expand surface area for both sensing and absorption.

-Sensing earlier in the system prepares next phases to accept and address materials.

-As materials move through the system, they are broken down sequentially from large to small.

-Enzymes and bacteria are used to unlock molecules.

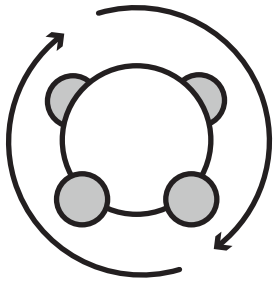
-Sponge-like filters are used to separate desirable material from undesirable particles.

-Undesirable particles are condensed before elimination.

Abstract

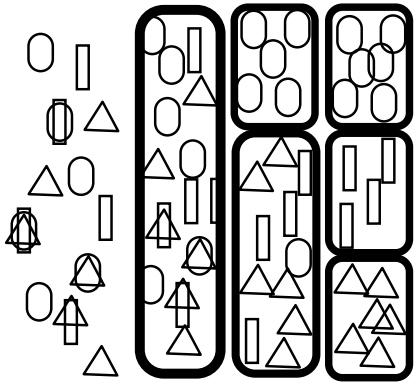
Translating nature's strategies to design

Galatheid Crabs - Enzymes at Work



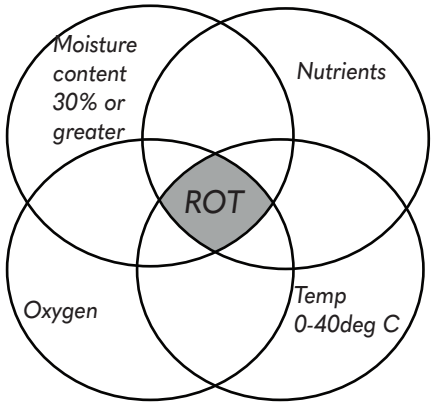
This organism functions to break down materials and harness/absorb energy while expending limited energy as a result of the process. The metabolism is the process by which matter is converted to energy. This process relates to thermogenesis partnered with minimal physical movement and energy waste. Special anatomical features include an intestinal tract ripe with beneficial bacteria and microbes that specialize in breaking down wood.

Wetlands



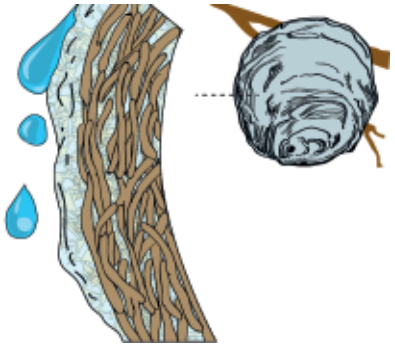
Wetlands process containments. They do this when containments are suspended in water. The structure of these systems slows the flow to a rate where the containments and be temperately processed. As the water flows through the system particulates are broken down and gleaned by a variety of actors. The sponge-like structure of soil, plant roots, and detritus

Wet Rot Fungus – Tough Decomposers



These spores are non-toxic and occur where high levels of moisture are present. 30-90% moisture saturation is ideal for this organism who gets it's food by breaking down the walls of wood cells over time, which results in the loss of strength of the wood. Moisture is required for this organism to thrive, and tot only takes place when these conditions are perfect.

Paper Wasps – Creating from Waste



200 tiny cells come together to form the shape of these pulped material structures. These water resistant structures are created using an oral secretion of protein and high-proline based matter mixed with plant based cellulose. The muco-proteins of the secretion provide adhesion and hydrophobic properties of this durable and recycled material.

Design

Patterns which Emerged

In wetlands, forest wood decay, and in the digestive system we observed a sequential process of filtration and utilization. These systems do not deconstruct everything all at once, rather there are many specialized actors or organs which address one element of the material being processed at a time.

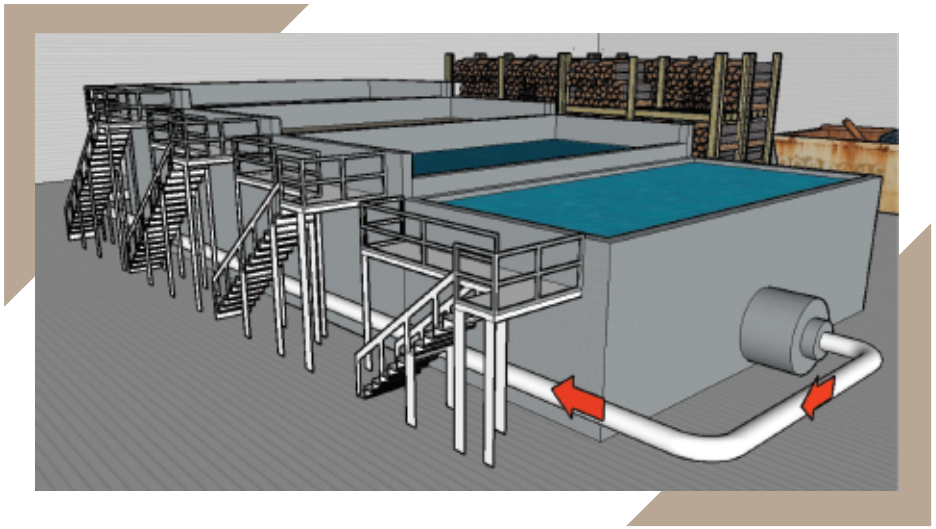
Another pattern which emerged among xylotrophic (wood-eating) organisms was a partnership with bacteria within the digestive tract.

The repeated appearance of these patterns is strong evidence that they are effective and efficient.

How wood waste gets from user to process

The wood waste we plan to address is that which is no longer useful for resale and repair. We plan to partner with resale organizations as well as furniture retailers to collect materials. We envision a system where in users can deliver this waste, as well as have it picked up. The return trips from delivery vehicles could be exploited to collect garbage bound furniture waste. Expanding opportunities for users to conveniently recycle used furniture will ease the transition of behaviors.

1. *System Overview*



This system is comprised of a series of chambers. Each chamber is specially tuned to a phase of breaking down furniture. The space between chambers is equipt with filters and sensors. Precise particle can be extracted in the filters. Compounds can be sensed, using an antenna like structures in the filters. That data is collected to further improve the system and to signal the inbound charmer to respond to the materials coming in.

Some chambers are filled with water and fed by gravity. In water, particles separate due to their density in relation to the medium. The aquatic environment also supports specific bacterial communities to thrive. The system is fed by gray-water which is filtered as it moves through the system. Unfiltered water is cycled back to the beginning to go through the process again.

2. *Removing Coatings*

The initial chambers address the variety of sealants and paints that coat wood.

Lipids- Waxes and hard drying oils are used to seal wood. These compounds may be addressed in a saline environment, specific sodium molecules like those found in liver secretions breakdown and lift lipids.

Synthetic sealants- Ideonella sakaiensis is a bacterium that has been shown to secrete an enzyme which breaks down polyurethane, a common base for sealants.

There are some compounds for which there are not sustainable solutions for at this time. The system deals with these by condensing them and flushing them from the system, similar to the excretions from the digestive system.

3. *Breaking-down Adhesives*

Bonded composite woods are prevalent part of modern furniture construction. Most of the plywoods and shipboards are bonded with either formaldehyde or urea formaldehyde. This compound is carcinogenic, if it becomes airborne. All if the additives to wood in furniture, make the wood unable to be recycled in conventional ways, such as mulch.

The Rhodobacter sphaeroide bacteria has the ability to breakdown these formaldehyde compounds. One of the byproducts of this process is fixed nitrogen, which could be harvested and used as fertilizer.

4. *Cellulose Break down*

The wood is treated with a series of fungi, bacteria, and enzymes to passively breakdown the wood into pulp.

5. *Extracting & Reforming*

In the final phase of this system the wood pulp is extracted and prepared to be reformed into new products.

Current Limitations

- This concept relies entirely on the ability of biologists to harvest and sustain microbes and fungi in a safe and non-harmful environment. In alignment with the United Nations Sustainable Development Goals 14 and 15, we must sustainably manage and protect marine and land-dwelling organisms and animals who contribute to the breakdown of wood-cellulose without causing harm to these species or causing harm to their ecosystem.
- Salvaging and the gathering of waste stream materials has not been addressed at this phase of the project and in order for this design to be successful, infrastructure will need to be created and harnessed that provides an avenue for wood waste materials to be redirected to this materials breakdown system.
- Exploring the feasibility of this design would require some financial backing.

Business Case

The cost of lumber is hitting historic highs. It would behoove all industries to begin looking for new, more sustainable, materials to replace lumber. This trend towards higher prices in conjunction with the fact that consumers are increasingly demanding more sustainable products, strongly suggests that it is time to begin exploring more regenerative material sources. Incorporating materials passively harvested from furniture waste is one way for producers to increase their profit margins while at the same time responding to their customer's demands.

Many companies are becoming aware that in the future materials will follow a circular pattern, however, they are struggling to changing tactics. This system offers a path of gradual change and evolution. If we can convince corporations to begin using this material, it would encourage them to make products which are easier to harvest from. Right now companies are deferring the cost of harmful sealants and adhesives on to the health of the planet and the organisms who live here. If the manufacturers are also harvesting form their products, it is in their financial best internist to manufacture in a way which is low cost to harvest from.

Reflection

Accessing Life's Principals

LIFE ADAPTS AND EVOLVES

Locally attuned and responsive: Responds to material inputs

Resourceful & opportunistic: Utilizes free movement from gravity

Shape rather than material: There are still places to evolve this principal, I suspect it will have something to do with fluid dynamics.

Cellular & nested: The resulting pulped material is cellular in nature and is a layered and nested compound.

Simple, common building blocks: This system does not rely on complex chemicals to break apart materials.

Free energy: The use of gravity and the partnership with bacteria are ways the system utilizes free energy

Feedback loops: The antenna in the filtration system allow operators to collect feedback

Antenna, signal, and response

Learns and imitates: The sensing system allows the system to learn and react to materials and patterns.

Integrates cyclic processes: Pulped material participates in further decomposition at end of life cycle by being reintroduced to filtration system

Cross-pollination & mutation: molecular decomposition occurs and ensures material breakdown

Resilient: Pulped material waterproofing as a result of composition of protein rich solution and decomposed plant based cellulose

Diverse: The system has a variety of chambers to diversify the ways in which the materials are broken down.

Decentralized & distributed: This system could be implemented anywhere. It has relatively few material or energy needs to operate.

LIFE CREATES CONDITIONS CONDUCIVE TO LIFE

Optimizing rather than maximizing: To change our approach to pulping wood, the system employs passive forces.

Using multi-functional design: the aquatic environment serves many purposes, like supporting bacteria and moving particles

Fitting form to function: The form is dictated by the functions of water and supporting how it flows through the system.

Leveraging interdependence: The bacteria help us break down and in return we help them thrive.

Recycling all materials: Water and wood waste is recycled.

Fostering cooperative relationships: This design fosters a healthier relationship between materials sourcing and manufacturing.

Self-organizing: The slurry of materials flow freely from pool to pool. The particles self-organize within the design.

Using benign manufacturing: This process helps ameliorate the effects of other more harmful forms of manufacturing.

Life-friendly materials: This design replaces many harmful practices with passive and life friendly alternatives.

Using Water-based chemistry: This process largely takes place in an aquatic environment to support water based chemistry.

Using self-assembly: Even though the point is to disassemble, this system does so by passive means.

Ability to Succeed

As sustainable designers, we have observed the need for the furniture design industry to adapt in order to address growing material strain. By mimicking natural systems throughout the life-cycle of products and furnishings, we plan to provide the opportunities to avoid material incineration or relocation into a landfills. Our proposal to generate a series of hospitable and controlled environments for material decomposition, provides consumers and manufacturers with a circular material system which will mitigate the effects of furniture waste generation. The furniture industry has introduced materials which are hazardous to the health and safety of individuals and ecosystems by using chemical adhesives and sealants. As sustainability specialists, each with specialties in the manufacturing and product systems, we are well poised to address these challenges.

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Angelina Malizia and Stephanie Wyler are students in Minneapolis College of Art and Design's MA Sustainable Design program. Angelina earned a BS in Product Design from the University of Oregon and Stephanie earned a BFA in Integrated Design from Finlandia University and both currently working in different sectors of the product design industry. Collaboration across multiple disciplines regardless of geographic distances is what makes MCAD's MA program truly unique and provides an opportunity for unique perspectives to come together in an effort to solve tomorrow's design challenges.

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