

**Bio-inspired Product Design:
The Study of Pinicola Shelves**

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A Creative Thesis


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THE STUDY OF PINICOLA SHELVES

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Pinicola Shelves is the product of extensive biomimetic research and a product design senior studio with its focus on home-goods. With the use of biomimicry the product of this project remained innovative while also reducing the raw material usage and carbon emissions. *Pinicola Shelves* was able to fill an innate human need to have a closeness to nature through biomimicry. Inspired by *Fomitopsis pinicola*, this shelving unit is ready to assemble by the user and can be flat-packed for shipping purposes. The product consists of one large dowel, and five stackable shelving trays secured by dowels. The unit follows the seven universal design principles which are a set of guidelines for designers to develop products that can be utilized by the majority of the population; exceeding the average user and bringing usability to those whom might be differently abled with limited mobility. The features that make this shelving unit more sustainable than those that precede it include: a large reduction of materials used, a physically lighter product, and a product that has flat-packing capabilities.

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“Humanity needs a vision of an expanding and unending future. This spiritual craving cannot be satisfied with the colonization of space...The true frontier for humanity is life on Earth, its exploration and the transport of knowledge about it into science, art, and practical affairs.”

E.O. Wilson, Author of Biophilia¹

Preface

Biomimicry is the application of naturally occurring mechanisms in man-made products. Bio, translating from Greek means life, while mimesis translates from Greek to imitate. Biomimicry is literally the imitation of biological systems into the application of a human made application. The book, *Biomimicry: Innovation, Inspired by Nature*, defines it as, “The conscious evaluation of life’s genius.”² The topic of biomimicry is a field of research still in its infancy, compared to most other scientific fields, having only recently emerged in the seventies. Biomimicry is a rapidly growing field that has found itself surfacing in many professions. Specifically, biomimicry has infiltrated many aspects of the design world, gaining popularity as a new way of design thinking, as well as a way to develop sustainable design. Biomimicry can be interpreted as an innovative design strategy or even a way to make industrial designs more environmentally friendly through light-weight products, or even flat-packing products. The practice of biomimicry can ultimately enhance many fields of study, but it can especially enhance the world of design.

¹ Wilson, Edward O. *Biophilia*. Cambridge, MA: Harvard UP, 1984. Print.

² Benyus, Janine M. *Biomimicry: Innovation Inspired by Nature*. New York: Perennial, 2002. Print. P.2

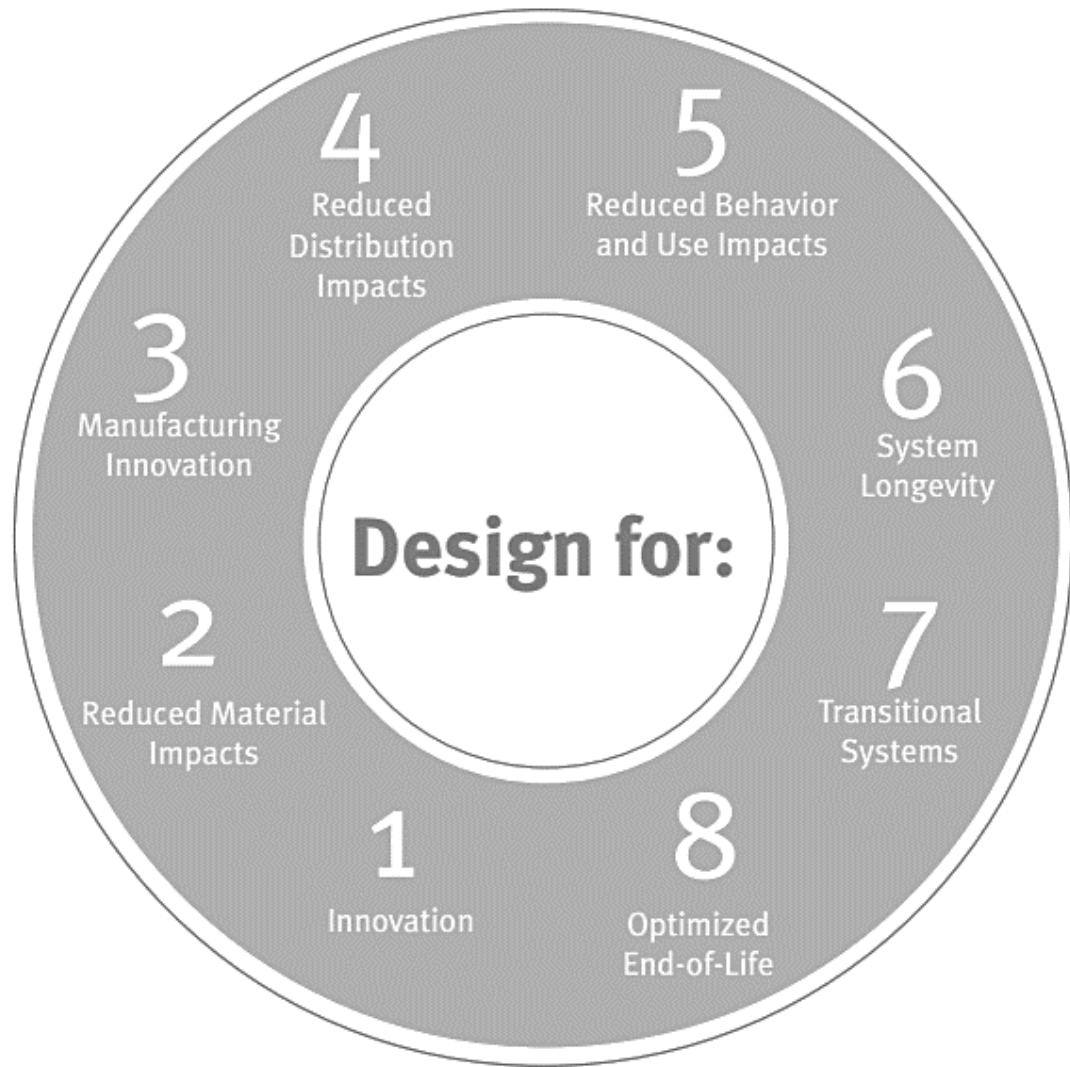


Figure 1 Biomimicry Design Lens: Biomimicry Thinking
Developed by Biomimicry 3.8, the biomimicry design lens acts as a tool kit for designers to plot a step by step process for bio-inspired design.³

³ "Biomimicry Thinking." *Biomimicry* 38. Design Lens, 2012. Web. 25 Feb. 2014.

Chapter 1

Bio-Inspiration Overview

By looking to biology as a form of product design inspiration, novel insights are gained. For example, “Biomimicry uses an ecological standard to judge the sustainability of our innovations. After 3.8 billion years of evolution, nature has learned what works and what lasts,” and, “After 3.8 billion years of research and development, failures are fossils, and what surrounds us is the secret to survival.”⁴ Biomimicry could be applied to design in many ways, and in this study is focused on the benefits connected to effective raw material usage and compactability for users as well as the benefits of compactability in transportation.

Three words that, until now, have been associated with industrial and product design are: heat, beat and treat. Developing biomimetic products can help remedy the current industrial processes. ‘Heat, beat and treat’ was a concept deriving from the work by Janine Benyus, and describes the arduous methods that are encountered during manufacturing, and depicts three ways in which materials can be processed to achieve a given design. In a recent TED Talk with Janine Benyus, this is what she had to say about ‘heat, beat and treat’: “...This is how we make things. It’s called heat, beat and treat -- that's what material scientists call it. And it's carving things down from the top, with 96 percent waste left over and only 4 percent product.”⁵ However, by processing materials to such an extent much of the quality diminishes along with the sustainability

⁴ "Biomimicry Institute - What Is Biomimicry?" *Biomimicry Institute - What Is Biomimicry?* Biomimicry Institute, n.d. Web. 12 June 2013. <<http://biomimicryinstitute.org/about-us/what-is-biomimicry.html>>.

⁵ Benyus, Janine. "Janine Benyus: Biomimicry's Surprising Lessons from Nature's Engineers." *TED: Ideas worth Spreading*. N.p., Feb. 2005. Web. 16 Nov. 2013. <http://www.ted.com/talks/janine_benyus_shares_nature_s_designs.html>.

of the design. Much of the current industrial design field features man-made design out of man-made materials.⁶ Not only is the ‘heat, beat, and treat method outdated and environmentally unsustainable, it can also be replaced by mimicking the materials found in nature because some natural processes have developed sustainable ways to produce materials just as good if not better than those produced by humans today.⁷ One case study of a natural mechanism compared to a manmade mechanism involves: abalone shells in comparison to the most high-tech ceramics in development; while maintaining a similar aesthetic abalone shells are actually twice as strong as the toughest modern ceramics. Spider’s silk is another example of a natural marvel, because it is ounce for ounce stronger than steel. The adhesive a mussel uses is not only waterproof, but can stick to all surfaces. These are only a few examples of the many possibilities in developing products from biomimetic inspiration.’ Discoveries found in nature, such as those listed above, have the opportunity to be implemented as solutions to many of the problems that are faced in everyday life. What if the things that surround our lives, the things that helped us thrive, could mimic these engineering marvels found in nature for a more efficient, more sustainable world?

Biomimicry offers a sustainable solution to problems facing many designers. By making efficient use of sustainable materials, the possibility of light-weighting a product is greatly enhanced. Light-weighting a product is a process to reduce the materials of a design to the very, essence leaving only what is vitally necessary for the

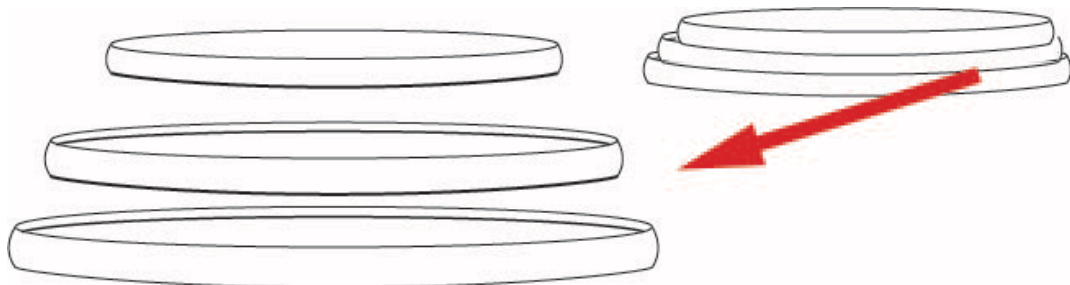
⁶ Islam, Rafiqul, A. B. Chhetri, and M. M. Khan. "Chapter 8, Diverging Fates of Sustainable and Unsustainable Products." *The Greening of Petroleum Operations*. Hoboken, NJ: Wiley, 2010. 335-66. Print.

⁷ Benyus, Janine M. *Biomimicry: Innovation Inspired by Nature*. New York: Perennial, 2002. Print. P.97-99

design to function (See Figure 1, segment 2). The weight of the product is reduced, thus shrinking the amount of fossil fuels used in transportation as well as making the product easier to transport by the final user. Also, by light-weighting a product the raw materials usage can be greatly diminished. When light-weighting precision is incredibly important because of the lack of stability that can be produced through light-weighting.

A great example of a structurally sound light-weight form would be bracket or shelf fungus, which is more common in the pacific north-west. In particular, the fungi *Fomitopsis pinicola*⁸ is particularly interesting because it not only is structurally sound and light weight, but it also nests its layers within itself, see Figure 2.

Figure 2 Pinicola fungi stacking and layering properties.



An effective space saving biological system of the Fomitopsis pinicola fungi.

This design aspect gives designers a new way of looking at flat-pack design, since it brings assembly and disassembly to its essence. Flat-pack design describes the way that a product can be transported, disassembled and re-assembled on site, allowing it to lay flat during transportation and take up as little space as possible. That being said, when a design is flat-packed, it then must be designed simply enough that the person receiving

⁸ Emberger, Gary. "Fomitopsis Pinicola." *Fomitopsis Pinicola*. Messiah College, 2008. Web. 02 Nov. 2013. <http://www.messiah.edu/oakes/fungi_on_wood/poroid_fungi/species_pages/Fomitopsis_pinicola.htm>.

it can put it together and break it down with ease. Products that are flat-packed take up less space during transportation, meaning that more can be transported at any given time, ultimately reducing fossil fuel usage. By flat-packing you also give the user the option to stow away the product when it is not in use.

By applying biomimicry to furniture design this project will achieve thoughtful application to a product used daily, which effects consumers directly. A tool available for designers to more easily develop a biomimetic product is the Design Lens, a guide developed by the Biomimicry Institute to act as a step-by-step guide for biomimicry (See Figure 1 and Appendix A for graphic representations of the Design Lens). The Design Lens provides a qualitative source of discovering highly efficient solutions in nature and applying them opportunely to the products around us. The Design Lens interacts with the conceptual process of design, and works to spark connections between products and biomechanics. All things have the potential to be bio-inspired, especially furniture. The goal of this research is to develop a shelving unit that is minute, light, and durable; it will also be able to withstand daily use, wear-and-tear. This shelving unit will help educate the public to the vast possibilities of bio-inspired design and show that while on the large scale, yes, biomimicry can be applied to bullet trains, it can also be something you take home with you.

Chapter 2

Introduction to Senior Studio

Product design studio courses push students to innovate, invent and experiment. It is expected that those taking part in the senior studios have already gained a strong foundation of design principles in the three prior years. During these studios students are given a prompt and a general brief to follow during their design process; these constraints aid the designer in rapidly developing ideas.⁹ Design students are given freedom in studios to pursue aspects of design that they find most interesting, allowing the students to personalize their curriculum. This senior studio was adapted to further the research and application of biomimicry in products.

Pinicola Shelves was developed in a studio that had been established to design and produce home-goods. As an additional form of inspiration, this studio also focused on the ideal of “home-away from home” and how that may look to the user. Pinicola Shelves embodies the natural yearning for humans to become closer to nature. By adapting the biological forms found in the natural world and holistically incorporating them in the man-made world.¹⁰ The craving for humans to connect with nature could be satiated with the implementation of man-made products inspired by the natural world.

Product design courses at the University of Oregon are ten weeks long, following concept to completion. A studio mid-term is an opportunity to have design work criticized and to gain feedback on the design half way through the term, with the

⁹ Brown, Tim. "Design Thinking." *Harvard Business Review* June (2008): 84-96. Web. 25 Jan. 2014.; Dorst, Kees, and Nigel Cross. "Creativity in the Design Process: Co-evolution of Problem and Solution." *Science Direct*. Elsevier, Sept. 2001. Web. 2 Nov. 2013.

¹⁰ Wilson, Edward O. *Biophilia*. Cambridge, MA: Harvard UP, 1984. Print.

largest benefit being the ability to alter or enhance the design prior to the final review. At the final review all of the product design professors look over the design work and listen to the presentations. Feedback is then provided to students so that the strengths and weaknesses of their project become apparent for future improvement. The greatest part of studios is the freedom to experiment, innovate, and learn.

Chapter 3

Bio-Inspired Design Process

An overview of the process of bio-inspired design within the context of home-goods.

3.1: Bioimetic Design Developmental Research

The beginning of the Pinicola Shelves design came to fruition after having read the three major books on biomimicry and several articles supportive articles.

Biomimicry: Innovation Inspired by Nature, by: Janine Benyus was the most important book for research in biomimicry because this was the text that coined the term ‘biomimicry’. Benyus described and analyzed the process of using biomimicry in a variety of case studies, and gave the reader the tools to apply biomimetics within product design, as well as other fields. *Gecko’s Foot: Bio-inspiration*, by Peter Forbes gave an in-depth description on the engineering possibilities with the implementation of biomimicry, as well as the positive effects regarding biomimicry in material choice and development. E.O. Wilson a biologist, theorist, and author of the book *Biophilia* uncovers the innate desire for humans to connect with other living organisms, which

may have been a true catalyst in the fundamental development of biomimicry as a whole. These books influenced the design process as a foundation for physical biomimetic research.

3.2: Interpret

Biomimicry as a foundation for product design, was a known constraint to the design process prior to this project. Biomimetics worked as an additional limit within the context of a product design senior studio. Specific biological forms that exuded inspiration were spider webs of the *Caerostris darwini* species, leaves of *Carpinus betulus*, and fungi of *Fomitopsis pinicola*. Interpretation begins with research as the first step of the design process. The design process is a non-linear strategy in which a product could be produced. There is no one design process, it changes from individual to individual. The implementation of the design process was strategized for this product through a biomimetic lens, by means of biomimicry and product design research. These researching constraints direct the designer, while also giving the designer product specificities. Literature and scientific research was mentioned in the prior paragraph, while research through design inspiration (precedent boards) and design aesthetic boards (mood boards) can be seen below in Figures 3 and 4.

The precedent board displays inspiring biomimetic products that already exist. Figure 3 shows the precedent board that was used in this research. The column on the left depicts products that were inspired by human cell formations. At the top and bottom left a human cell inspired shelving unit had been created. In the middle of the far left

column a chair inspired by human bone cell form had been developed. The center column of products were inspired by flora, and specifically trees, pods and flowers. The products at the top of the center column were chairs inspired by pods and floral blooms. The product in the center of the center column was a fan inspired by the sycamore seed, which used the physical form of the seed to aid the fan's rotation without using as much electricity or materials as a commercial fan. The product at the bottom of the center column was a free standing shelf inspired by tree branches. The column on the right portrays products that were inspired by spider's webs. At the top of the right column a shelving unit had been developed, at the center of the right column bowls were developed, and at the bottom of the right column a chair had been developed; all inspired by the spider web. All of the products depicted in the precedent board are biomimetic, and make productive use of space, materials, and energy.

A mood board is a display of inspirational images and elements that a designer might look to in order to derive innovative information (See Figure 4). The biological organisms shown above were used as inspiration to develop a strong, light, and seamlessly functional product. Though, the spider's web, shells, feathers, nests, and leaves were not directly mimicked in Pinicola Shelves, they were all initially looked at as inspirational life forms because they exude ideal characteristics for a biomimetic home-good.

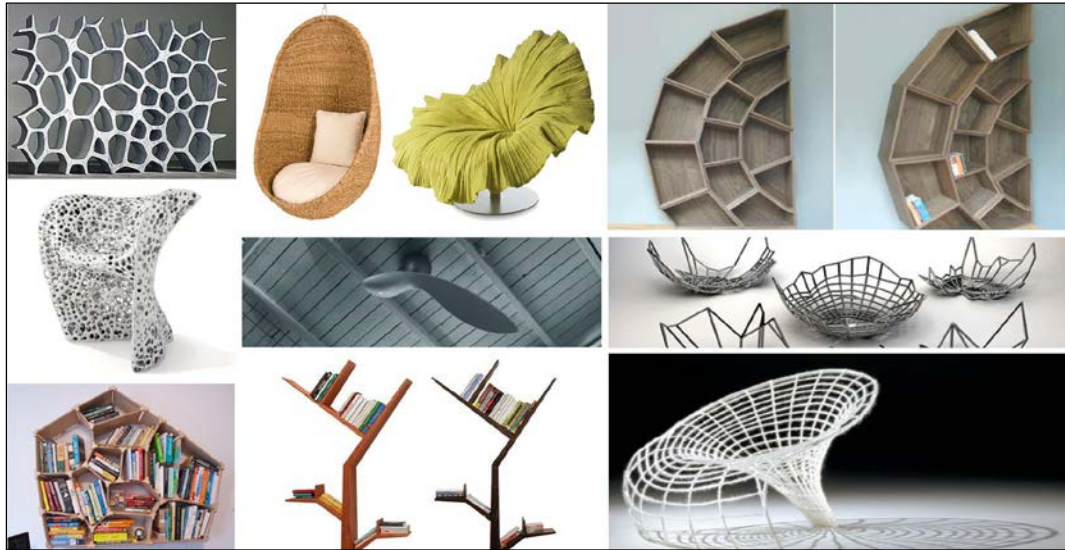


Figure 3 Precedent Board
Biomimetic product design: cell, flora, and web inspired.



Figure 4 Mood Board
Aesthetic representation of inspiring biological forms

3.3: Observe and Discover

Observing biological forms gives the designer an inspirational and functional foundation to a product. The discovery of *Fomitopsis pinicola* was what truly brought forth the unique assembly and function of Pinicola Shelves. However, prior to the *Fomitopsis* discovery; the hornbeam leaf, as well as spider's webs were also observed and investigated. The hornbeam had interesting folding characteristics that would increase the sustainability of the shipping process because a product could fold down and flat pack which optimizes space used in transit. Spider's webs were intriguing due to their structural tolerance under heavy weights, and the small amount of raw materials needed for production. However, neither of these two organisms seemed as appealing as *Fomitopsis pinicola*, a fungus found in the Pacific Northwest.

The most remarkable aspects of *Fomitopsis pinicola* were the layering properties and the directional growth properties of this fungus. Each year that *Fomitopsis* lives it grows a layer of fungus nested on top the prior year's fungus layer (refer to Figure 2, on page 5). In addition, if a host tree to *Fomitopsis* were ever to fall or become cocked the fungus *Fomitopsis pinicola* would adjust its growth direction to maintain a parallel relationship to the ground beneath it. This is due to the hard woody surface incasing the top of the shelving fungus which is used to protect the growth and spores from the sun, while the fleshy underbelly of each fungus shelf absorbs moisture that evaporates from the ground beneath it (see Figure 5, below). These were the innovative properties of *Fomitopsis*, and the basis for a light weight, flat-pack, shelving unit that gains stability through its 10° lean: Pinicola Shelves.



Figure 5 Fomitopsis pinicola Sample

A sample of the fungus showing how the layers form a whole. As well as depicting the woody top and porous underside of this fungus.¹¹

¹¹ "Fomitopsis Pinicola (MushroomExpert.Com)." *Fomitopsis Pinicola (MushroomExpert.Com)*. N.p., n.d. Web. 23 Feb. 2014. <http://www.mushroomexpert.com/fomitopsis_pinicola.html>.

3.4: Ideation:

The exploration of multiple product concepts inspired by *Fomitopsis pinicola* were honed in during the ideation process. Ideation is the process that designers take to quickly iterate design concepts through sketching and modeling; it is an affordable way of exploring all concepts before finding the correct solution to a given problem. Miniature models are a cost effective and fast way for designers to physically formulate biomimetic design concepts. Through the process of ideation the biological form *Fomitopsis pinicola* took form. The product of the ideation process was Pinicola Shelves. The cantilevered shelving design was conceptualized in its miniature form, pushing the design process forward and bringing *Fomitopsis* one step closer to a product of someone's home.

This method of ideation allows designers to explore the physical 3D form and functionality of their design concepts on a small scale. Each design of this project had desirable attributes (See Figure 6), and ultimately the product Pinicola Shelves came from the combination of the two lower left models, as well as the third model from the left on the top row. These designs are indicated with circles. The dowel concept was adapted from the lower left, while the cantilevering and leaning shelves in the other two models were adapted to form Pinicola Shelves.

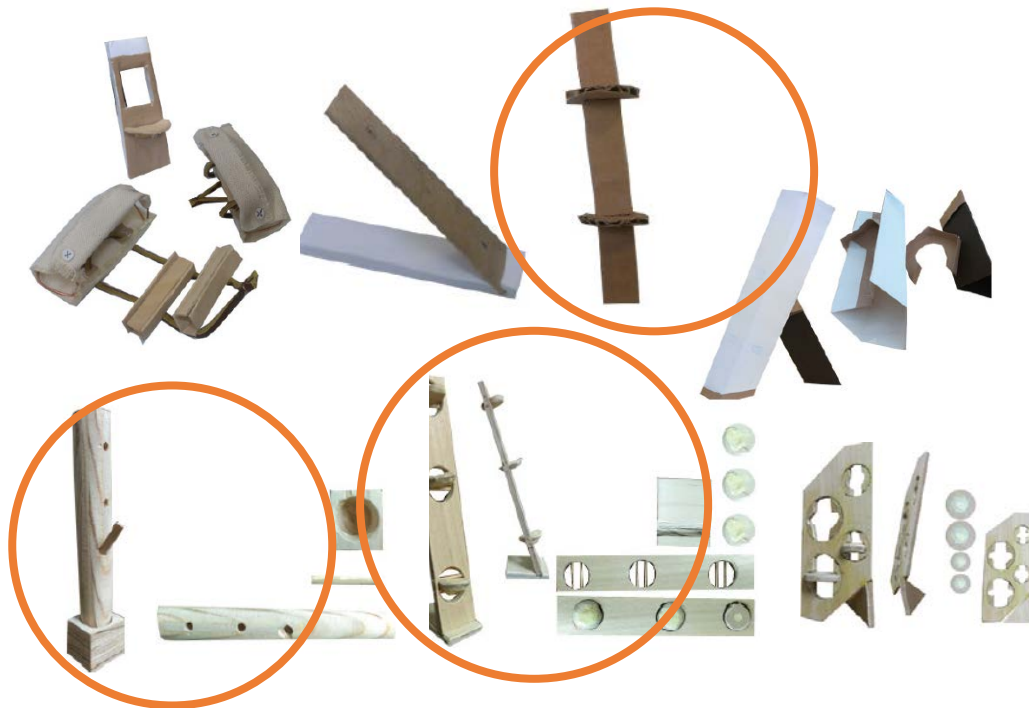


Figure 6 Miniature Ideation Models
An iterative design strategy to explore possible design concepts.

3.5: Abstraction

The product inspiration from *Fomitopsis pinicola* came in a couple of parts. Firstly, *Fomitopsis pinicola* has a unique quality that allows each shelving fungi to always grow parallel to the ground beneath it (in that if a tree is cocked or fallen the *Fomitopsis* will compensate in growth to then become parallel with the ground beneath it). This feature inspired the 10 degree lean that Pinicola Shelves takes, where even though the unit is leaning each individual shelf remains level to the ground beneath it. Also, by giving each shelf a lip the varying sizes can be nested within one another

which is how the growth of *Fomitopsis pinicola* progresses yearly. Finally, the choice to use hardwood (a porous material) was inspired by the porous structure of *Fomitopsis pinicola*. By using hardwood, Pinicola Shelves maintains the organic material structure also common to fungi, while holding durable qualities that will extend the lifespan of the product which in turn make this a more sustainable.

3.8: Emulate

Pinicola Shelves would not only be a biologically inspired consumer product, but the shelves would also emulate the biological world as a call to action for designers. Pinicola Shelves will give other designers inspiration through sustainable and biomimetic products. By inspiring designers with biology, a mindset shift occurs where it is then hard to ignore environmental repercussions to products that are developed without taking into account their sustainability. Dayna Baumeister, Co-Founder of The Biomimicry Guild Stated, “One of the big realizations that designers have when they play with biomimicry is that it’s not a tool, it’s a mindset shift.”¹² The purpose of this product would ultimately be defined by the user, and would be adaptable to its users’ needs. Pinicola Shelves appears to be a furniture piece that can aid in the organization of the user’s environment- their home. However, Pinicola Shelves is more than a shelf, it is a mentality and a design statement. Pinicola Shelves questions the typical shelving

¹² Walker, Alissa. "What Would You Ask Nature?" Fast Company. Mansueto Ventures, LLC, 15 Mar. 2010. Web. 17 Apr. 2014.

formation and raises the bar for designers to think more deeply in the design process. Whether the shelves be used to support snowboards, books, purses, or keys, the message of these shelves will always stay the same. The goal of Pinicola Shelves is to inspire the user to be aware of their power as consumers in all parts of their life, and their ability to make a choice when purchasing products; to choose a product that makes a difference.

A product, a mentality, Pinicola Shelves embodies the true message of the natural world. Giving the users a piece of nature to bring home with them, a bio-inspired product to connect with on a day-to-day basis. While, giving designers a challenge to apply to all design processes.



Figure 7 Pinicola Shelves

Final product in two variations, as well as with and without other products

Chapter 4

Why Fungi?

Fomitopsis pinicola was not a biological form that appeared quickly in this process. Designers are often faced with having to begin product developmental processes prior to knowing what it is they are going to make, which is why ideation is vital to any designer. The ideation, observation and interpretation segments of the design process are often interchangeable in any designer's process. A designer may work on a given concept for weeks, prior to discovering exactly what design they will move forward with. When deciding upon a biological form, the options presented by the worlds flora and fauna were overwhelming. The choice of *Fomitopsis pinicola* as inspiration for Pinicola Shelves only came about after having investigated a multitude of other biological forms. Moreover, the object of design which ultimately took the form of a shelf, had not been decided on until the solitary form of inspiration had been discovered. Prior to the discovery of *Fomitopsis pinicola* products such as: bags, chairs, lights, planters, shelves, tables, and ottomans had also been ideated and iterated based on the inspiration of other biological forms. The inspirational biological forms outside of *Fomitopsis pinicola* included: spider's webs, hornbeam leaves, and fungi. The spider's web seemed desirable due to the minimal amount of materials hosting a great amount of strength. These aspects to spider's webs appealed to the design of bags, chairs and planters, as a form of evenly supporting suspended weight while also reducing the use of raw materials. The hornbeam leaf seemed very interesting due to its compact folds that allow for generating a design that can be compacted and then deployed easily when needed. The features of the hornbeam were applied to the design

of a collapsible ottoman, to be stored and shipped laying entirely flat. Also, designs such as, accordion folded hanging shelves, and pop up lighting were derived in the initial ideation phase with inspiration from the hornbeam. Finally fungi seemed quite inspirational due to its lightness and structural stability, through fungus the exploration of tables, chairs, and shelves took place. *Fomitopsis pinicola* was chosen due to the fact that it shares the same design language as a standard shelving unit, in that a shelf consists of a back section with perpendicular surface jetting from the back toward the user. It is this sharing of design aesthetic paired with the one-of-a-kind biological features hosted by *Fomitopsis pinicola* that made this the source of biological inspiration for Pinicola Shelves.

Chapter 5

How is this a sustainable design?

The importance of bio-inspired design reaches past the final product, and encompasses the entire life cycle of a product and changing the way in which designers think. There are three tools that are vitally important to understanding not only the sustainability of a product, but of the entire product's life cycle. First, to describe what the life cycle of a product is would best be explained as looking at the products life in a 'cradle to grave' or even better 'cradle to cradle' view point; to observe every step taken to produce a product from the first step of manufacturing to the last step of disposal- and everything in between.¹³ In 2002 the ground breaking book, *Cradle to Cradle*, that described the need to be designing with the product life cycle in mind. It was stated in *Cradle to Cradle*, "We see a world of abundance, not limits. In the midst of a great deal of talk about reducing the human ecological footprint, we offer a different vision. What if humans designed products and systems that celebrate an abundance of human creativity, culture, and productivity? That are so intelligent and safe, our species leaves an ecological footprint to delight in, not lament?"¹⁴ This quote describes the need for products with meaning that are intelligently crafted and develop joy through ecological effectiveness; this is the goal of Pinicola Shelves.

¹³ McDonough, William, and Michael Braungart. *Cradle to Cradle: Remaking the Way We Make Things*. New York: North Point, 2002. Print.

¹⁴ *Cradle to Cradle*, P.16

The ways in which the EPA (Environmental Protection Agency) has encouraged sustainable design, such as biomimetic design, was by adhering to documents such as the LCA (Life Cycle Assessment) and the Okala Impact Factors.¹⁵ The LCA provides a scope to analyze and strategize practices used in production and manufacturing. “LCA is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service, by: compiling an inventory of relevant energy and material inputs and environmental releases, valuating the potential environmental impacts associated with identified inputs and releases, interpreting the results to help you make a more informed decision.”¹⁶ By coupling this quantitative source for interpreting environmental impacts with the quantitative information found in the Okala document, a truly concrete foundation can be built to derive tangible product solutions with the use of biomimicry. The Okala report is a quantitative way of making an ecological evaluation of materials. Okala Impact Factors/the Okala Practitioner serve as a step by step guide to aiding Designers in becoming aware of all/any repercussions that might arise negatively in the environment, and the Okala document can be used while the Designer is still in the innovation process. A Senior Designer at IDEO, Greg Burkett states, “As a designer working in the early, conceptual stages of design and innovation, I find that the Okala Practitioner serves as a useful and accessible framework for integrating Ecodesign into the process from day one.”¹⁷

¹⁵ "Okala Practitioner." *Okala Practitioner*. N.p., n.d. Web. 23 Mar. 2013. ; “Life Cycle Assessment (LCA)." *EPA*. Environmental Protection Agency, n.d. Web. 3 July 2013.

¹⁶ “Life Cycle Assessment (LCA)." *EPA*. Environmental Protection Agency, n.d. Web. 3 July 2013.

¹⁷ Okala, Figure 2

The Okala report states in impact factor millipoints a quantitative way to compare the environmental impact of materials. Pinicola Shelves was initially constructed out of one inch thick birch plywood which holds 280 impact factor millipoints and was a producer of acid rain due to the manufacturing processes of plywood.¹⁸ Alternatively, ash solid wood has a similar aesthetic quality as birch plywood. The impact factor millipoints for ash was only 4.7 per pound and does not contribute to adverse environmental reactions such as acid rain. Also, by reducing the amount of materials of the back of the shelving unit, from a full sheet to encompass the entire back section of the shelving unit; which would have been a total volume of 1224² inches. By using a 1.25 inch in diameter dowel that is six feet tall the materials were a total volume of 88² inches; reducing the total materials used in the back of the shelving unit by 1136² inches. The weight of 1² inch of birch plywood is .338 pounds, while 1² inch of solid ash is .258 pounds.¹⁹ The impact factor millipoint reduction by using ash instead of birch plywood was 93.4272 impact factor millipoints, which equals a 98.7% reduction of impact factor millipoints due to using ash instead of birch plywood, and a 97.67% of reduction emitted carbon dioxide per pound of material.²⁰ By lightweighting these materials the impact factor millipoints related to production materials are reduced as well as the transportation impact factor millipoints being greatly reduced.

The millipoint reduction in relation to transportation factors is dependent on the form of transportation taken to distribute this product. Each form of transportation will follow with the percentage of materials that were reduced by using solid ash wood

¹⁸ Okala ecological design, course guide, 2007 (p.52)

¹⁹ "Hardwood Lumber and Plywood Distributor - Product Weights." *Hood Distribution*. Hood Distribution, 2011. Web. 30 Dec. 2013.

²⁰ Okala ecological design, course guide, 2007 (p.52-53)

instead of birch plywood. In driving by truck or floating on a container ship the impact factor for one ton of solid ash wood was roughly 11.28 impact factors per mile, while birch ply encompassed 499.2 impact factor millipoints per mile, for a total reduction of 487.92 millipoints. Transportation of a ton of solid ash by freight train was 21.15 impact factor millipoints per mile, while transporting a ton of birch plywood by freight train would be 1260 millipoints per mile, for a total reduction of 1238.85 millipoints per mile. On a regional air freight the impact factor millipoints per mile of solid ash would be 202.1, while the same for birch plywood would be 12040; an 11837.9 reduction in impact factor millipoints per inner continental mile. The general impact factor reduction no matter the way of transport, was 98% by using ash instead of birch ply. Reducing the amount of carbon emissions exposed to the atmosphere supports the sustainability created by developing this product, Pinicola Shelves.

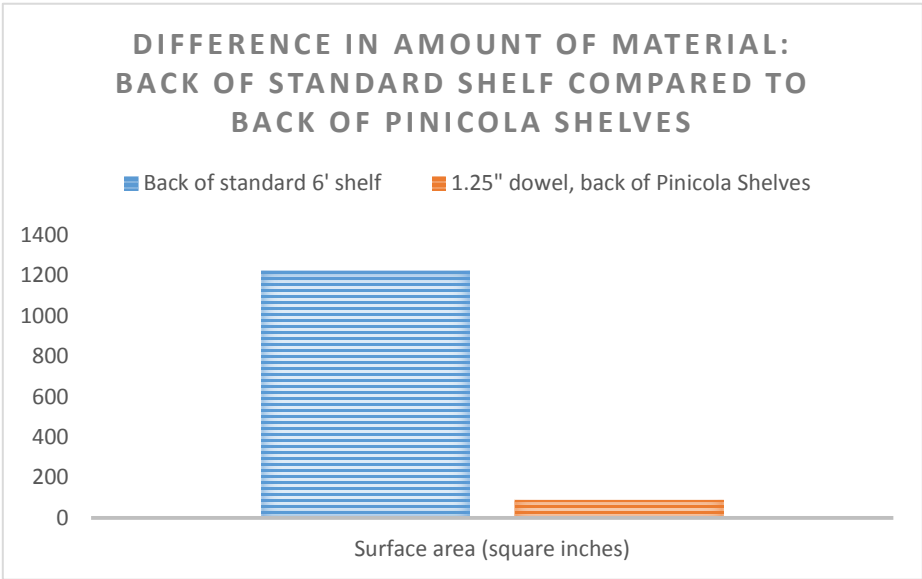


Figure 8 Raw material usage reduction

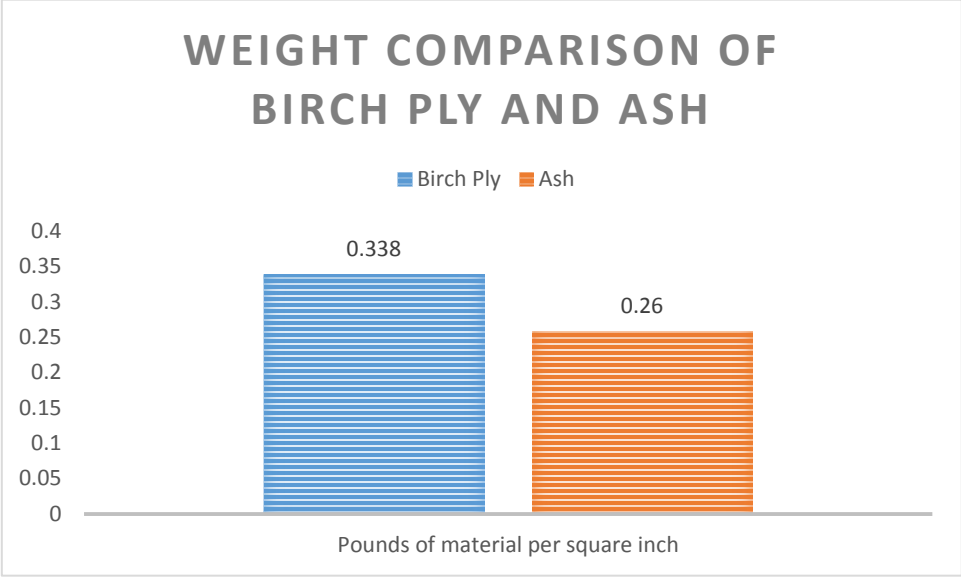


Figure 9 Weight reduction of Pinicola Shelves through materials selection

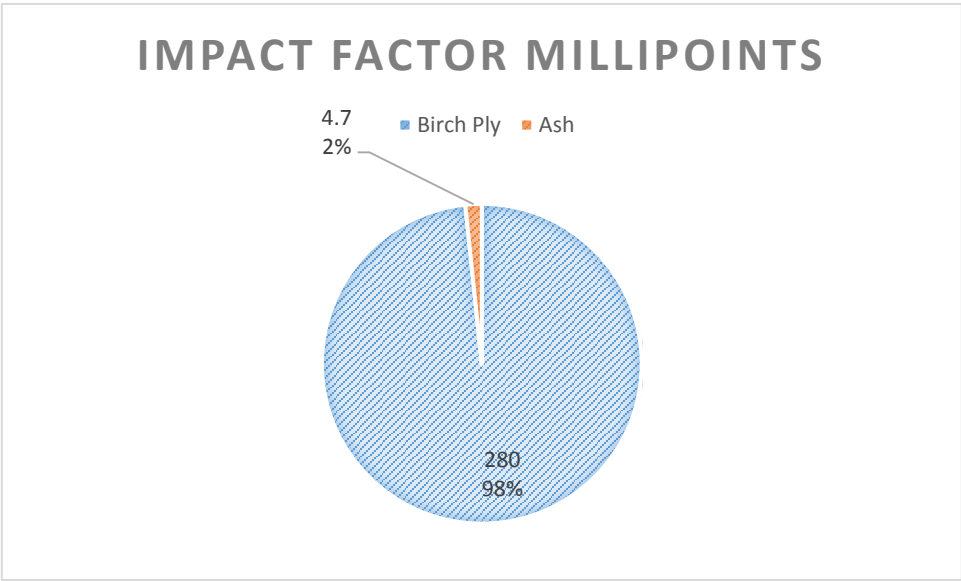


Figure 10 Impact Factor Millipoint comparison

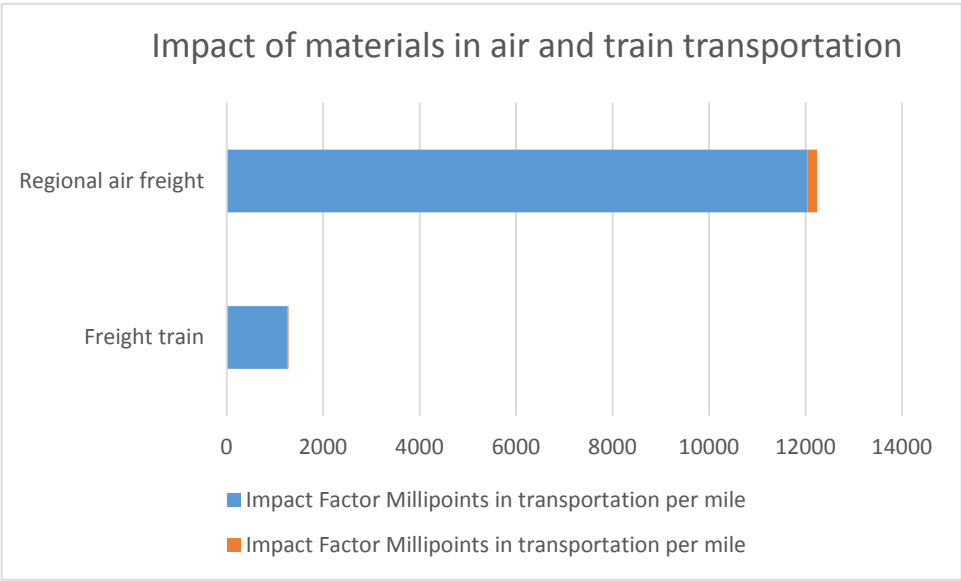


Figure 11 Birch in blue, Ash in Orange
Impact factor millipoints acquired airing air and freight trasportation

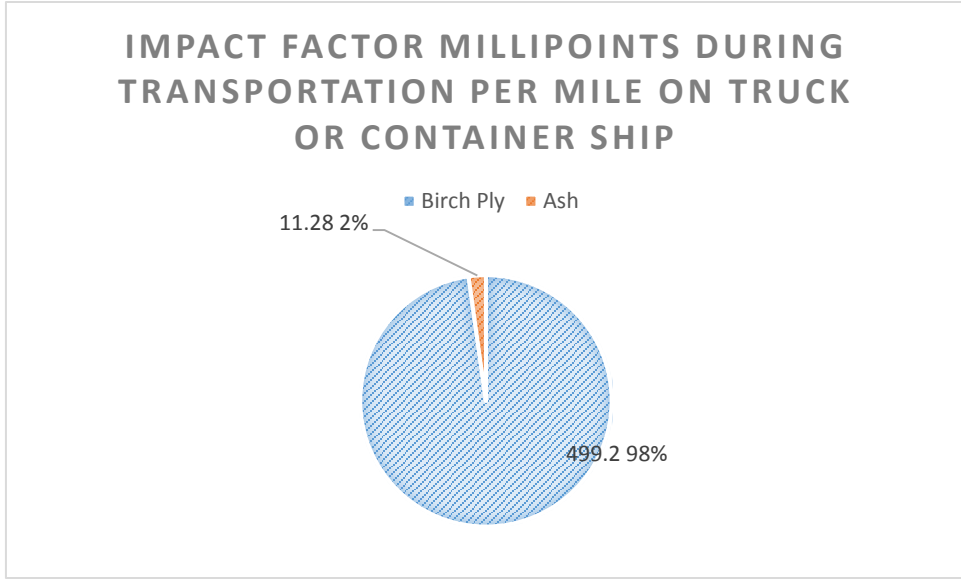


Figure 12 Impact factor millipoints acquired during truck and container shipping

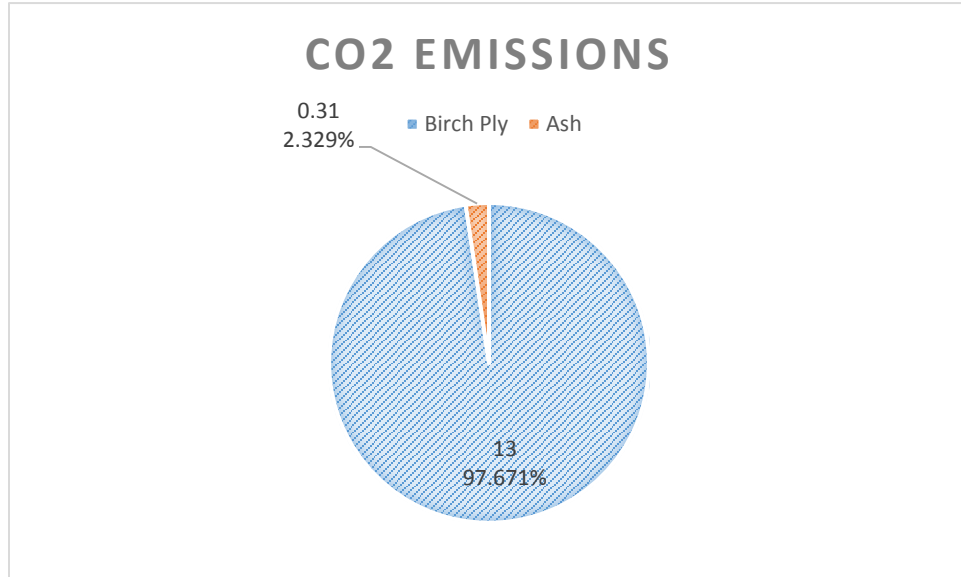


Figure 13 Total CO2 reduction by using Ash instead of Birch Ply ~98%

Chapter 6

ADA and Universal Design

"The true brilliance of the human-centered design process is that it keeps us humble. I am in awe of this humbleness." - Susie Wise, Stanford Design School²¹

Pinicola Shelves were designed for all users and to meet all needs of any consumer whom may want to purchase this product. There are seven principles of universal design: equitable use, flexibility in use, simple and intuitive, perceptible information, tolerance for error, low physical effort, and size and space for approach and use.²² These seven principles make up a clear guideline to develop a product that is applicable for all users. By following these principles a design could be developed to follow its proper function and easily be used by users across the spectrum, not just the 'average' user.

6.1: Equitable Use

A design that can be used by all abilities

Equitable use means that the design is useful and marketable to users with a variety of abilities.²³ Pinicola Shelves is a light weight unit, having reduced 13% of the

²¹ "17 Career Lessons from Ideo's David Kelley | Fast Company | Business + Innovation." *Fast Company*. N.p., n.d. Web. 01 Feb. 2014. <<http://www.fastcompany.com/1150457/17-career-lessons-ideos-david-kelley>>.

²² "Center for Universal Design at North Carolina State University". Design.ncsu.edu. Retrieved 2013-07-26

²³ Connell, B., M. Jones, R. Mace, J. Mueller, A. Mullick, E. Ostroff, J. Sanford, E. Steinfield, M. Story, and G. Vanderheiden. "What Is Universal Design- Principles of UD." *What Is Universal Design- Principles of UD*. NCSU, 1997. Web. 08 Feb. 2014. <<http://www.ncsu.edu/project/design-projects/sites/cud/content/principles/principles.html>>.

product weight by using Ash hardwood rather than commercially used Birch Ply. Pinicola Shelves weighs in at only 9 pounds, that's the same amount as an average vacuum cleaner or a little more than a gallon of milk. This makes Pinicola Shelves easily moved and transported. No parts are smaller than a half of an inch, and no part requires strong force to be put in place, making it a product that can be used by those with limited dexterity in their hands, such as people who suffer with arthritis. All ways of using the product interface and assembling the product is the same, as a way not to highlight those who might not have full mobility.

The unit is assembled by the user. By having this feature, each user can place the shelves wherever he/she seems fit. This means that someone who may need a shelf lower, or higher can do so on their own accord without having to alter any structure of the design to fit their needs. By giving a range of 120 variations in which the shelves could be positioned, users who maybe in a wheelchair or those who have other bodily limitations can use Pinicola Shelves at their leisure.

6.2: Flexibility in Use

An accommodating design for both user preference and ability

Flexibility in use is a primary feature of Pinicola Shelves. This feature allows the user to apply the product to their exact needs and in whatever method they seem to find appropriate. The variety of shelving sizes allow the user to either use all of the shelves, or only use a select number, while using the un-used shelves as organizational trays. In addition, along the entire 6 foot dowel back, the shelves can be set at 3 inch

increments allowing the user to set them as low or high or near or far from one another as they desire. No matter how short or long a user's reach distance is, they can set Pinicola Shelves to the exact height that they find necessary.

At the base of each shelf on the Pinicola Shelves unit, there is a feature that adds stability to each cantilevered shelf. The shelves sit on a half inch dowel that acts as a peg which sticks out of the main unit 6 foot dowel. The half inch dowel rests within a half inch groove in the bottom of each shelving tray, this groove holds the shelf against the unit and is large enough to aid in any issues of accuracy that might arise when putting the unit together. While the unit is also able to be used by both left and right handed users. By providing users with a product that is flexible, the user is empowered as the owner of a product that accommodates their needs, and does not make the user feel overwhelmed by their product or without control of their product.²⁴

6.3: Simple and Intuitive Use

A design that is easily understood to the novice or advanced users

Simple and intuitive use is a way of designing a product that explains itself, and presents an obvious use and easily understood form. The design of Pinicola Shelves has eliminated all of the unnecessary complexity that can be involved with a flat-pack shelving unit. There are no external tools needed to assemble this unit, and the only material that makes up this unit is wood. The only pegs that fit into the holes that

²⁴ "Universal Design.. What It Is and What It Isn't." *Universal Design.. What It Is and What It Isn't*. University of Wisconsin, n.d. Web. 8 Oct. 2013. <http://trace.wisc.edu/docs/whats_ud/whats_ud.htm>.

support the individual shelves stability are the half inch dowels, while the only dowel that fits into the hole that the shelves slide along is the 1.25 inch in diameter dowel. The shelves easily stack on one another to make storing the shelves more simple. In addition, the hole in the top of the unit (where the main dowel fits into) is at a 10 degree angle, which matches perfectly with the 10 degree angle in the base, which holds this unit at the designed angle for use and the angle in which each shelf cantilevers.

The unit can be easily understood without specific language directions, but with images. By supplying the user with a variety of images that depict the product assembly, any barrier that may have existed due to language inefficiencies no longer exist. This makes the design language universal, and allows universal users to use this product. See Figures 14 and 15 below.

- All Parts:
 A.(1) 6' dowel with .5" holes
 B.(5) circular shelves with troughs in the bottom
 C.(1) 17" diameter base
 D.(1) 4" diameter top
 E.(5) 3" pegs for each shelf to rest on

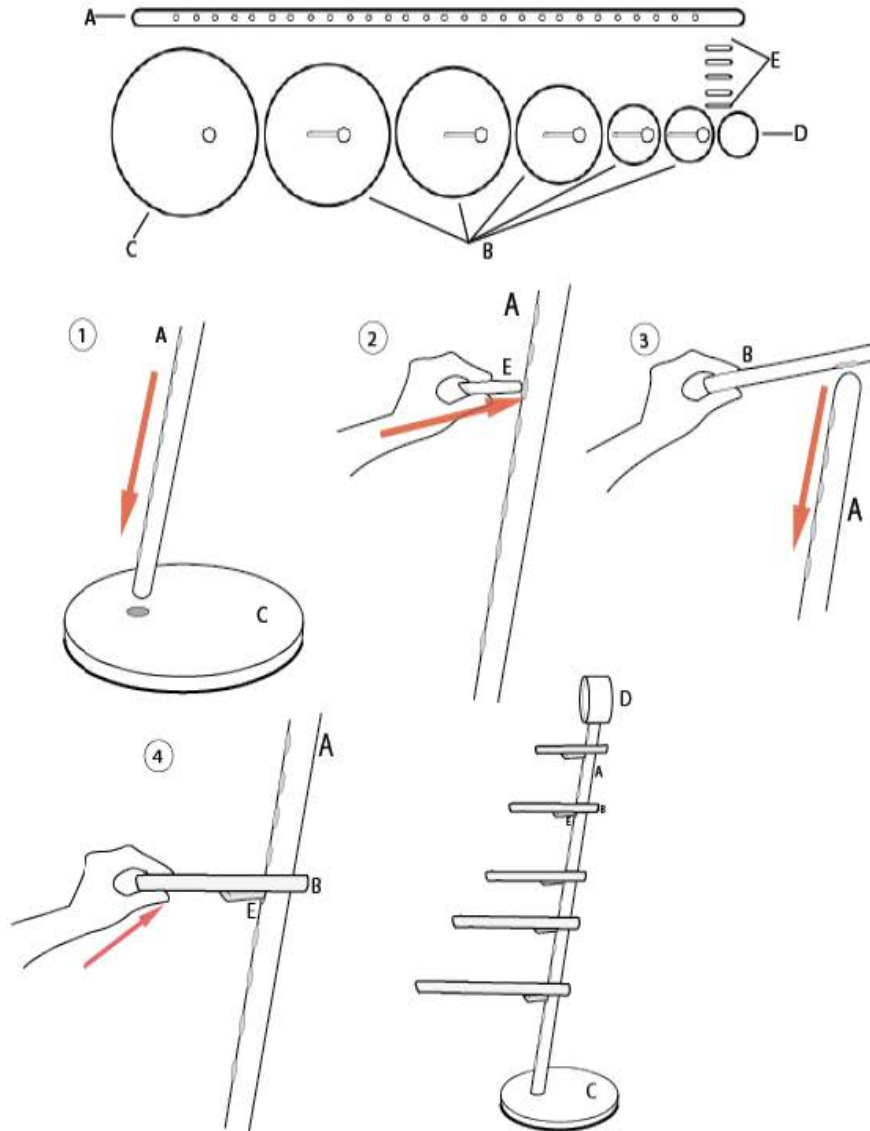


Figure 14 Infographic: Bill of Materials and how to assemble shelves

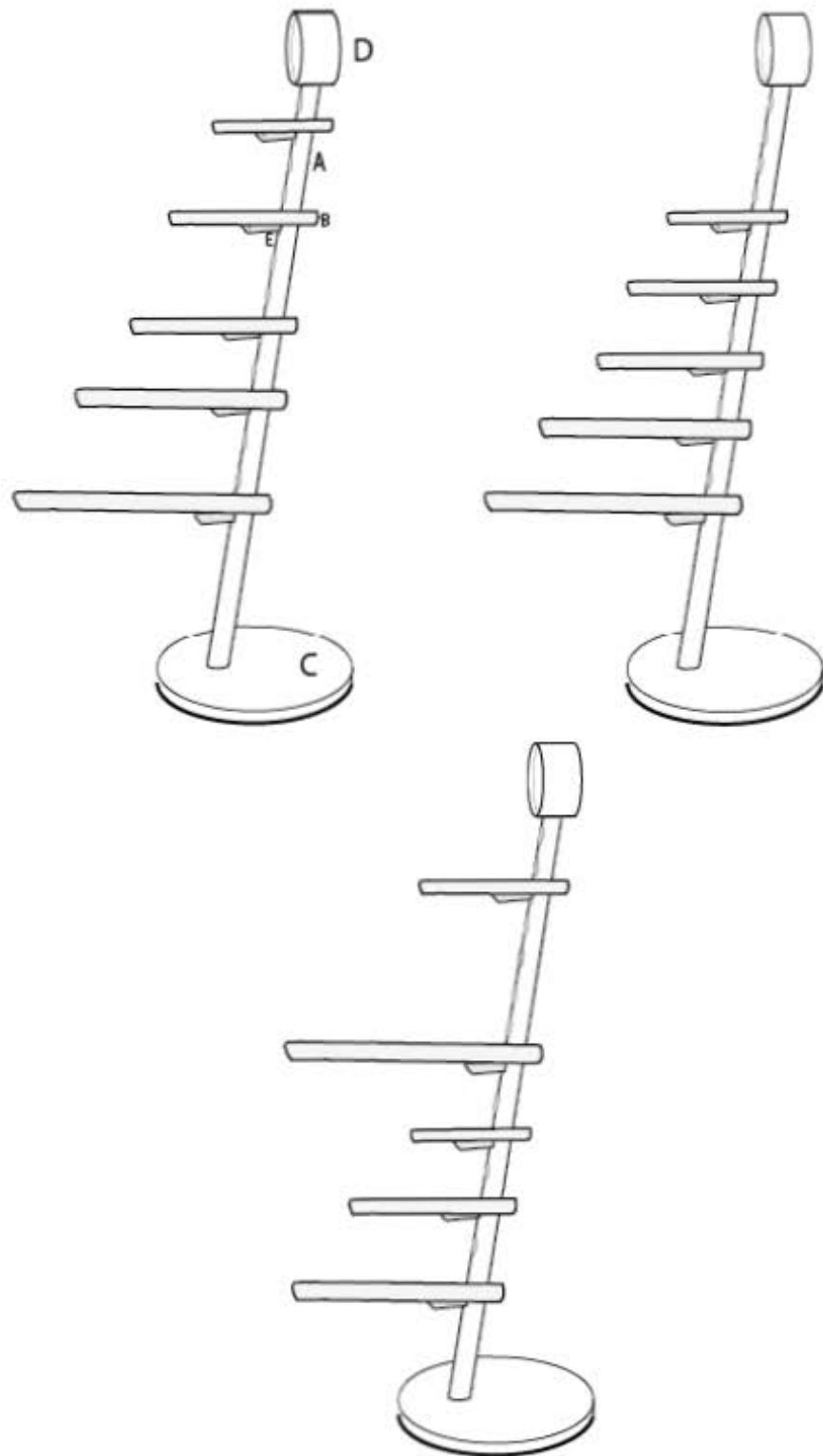


Figure 15 Pinicola Shelves variations: 3 of 120 possibilities

6.4: Perceptible Information

A design that can be understood regardless of sensory abilities and environmental conditions

Pinicola Shelves, as mentioned in the last section can clearly be understood by using a universal image language. Moreover, perceptible information as a principle states directly that a product or design be easily used by a user that might have imperfect sensory abilities or who might be in an unfavorable ambient spatial condition. In addition to that infographic language, there are also tactile features, that can indicate to those with impaired vision as to how the unit is assembled; especially related to the varied hole and dowel size as well as the ‘bumper’ located on the base, and the groove that sets each shelf in the correct location. The shelf top is slightly inset which gives tactile security to placing objects on each shelf in knowing that there is a slight ‘stopper’ before an object might roll off the shelf if it was now placed on the shelf correctly. Also, the redundancy that this unit provides, in that each shelf is set up exactly the same way as the one prior, provides familiarity to the user and gives the user a fast learning curve to assembly.

6.5: Tolerance for Error

A design that minimizes any adverse consequences that could be connected to accidental use

Tolerance for error is a way of defending the user when it comes to the design of a product, in that if there is an error produced by the product it by no means is the fault of the user, but it is a fault in the design. By using dowels and a minimal number of parts, the probability for error is greatly reduced. Also, by using similar objects for similar jobs (placing dowels in holes) but with different sizes allows for a consistent design language to be perceived by the user.

The front of the shelving unit can be easily discovered by the user in that it is the location where the holes for the smaller dowels are located. The smaller dowels don't have a specific way in which they need to sit in the hole in order for the unit to work, they just need to be in the hole of the back and in the groove of the bottom of each shelf. Also, by providing the users with a sequence of images as well as options for the final assembly of the product it gives the user a reference as to what the shelving unit should look like if they begin to feel lost.

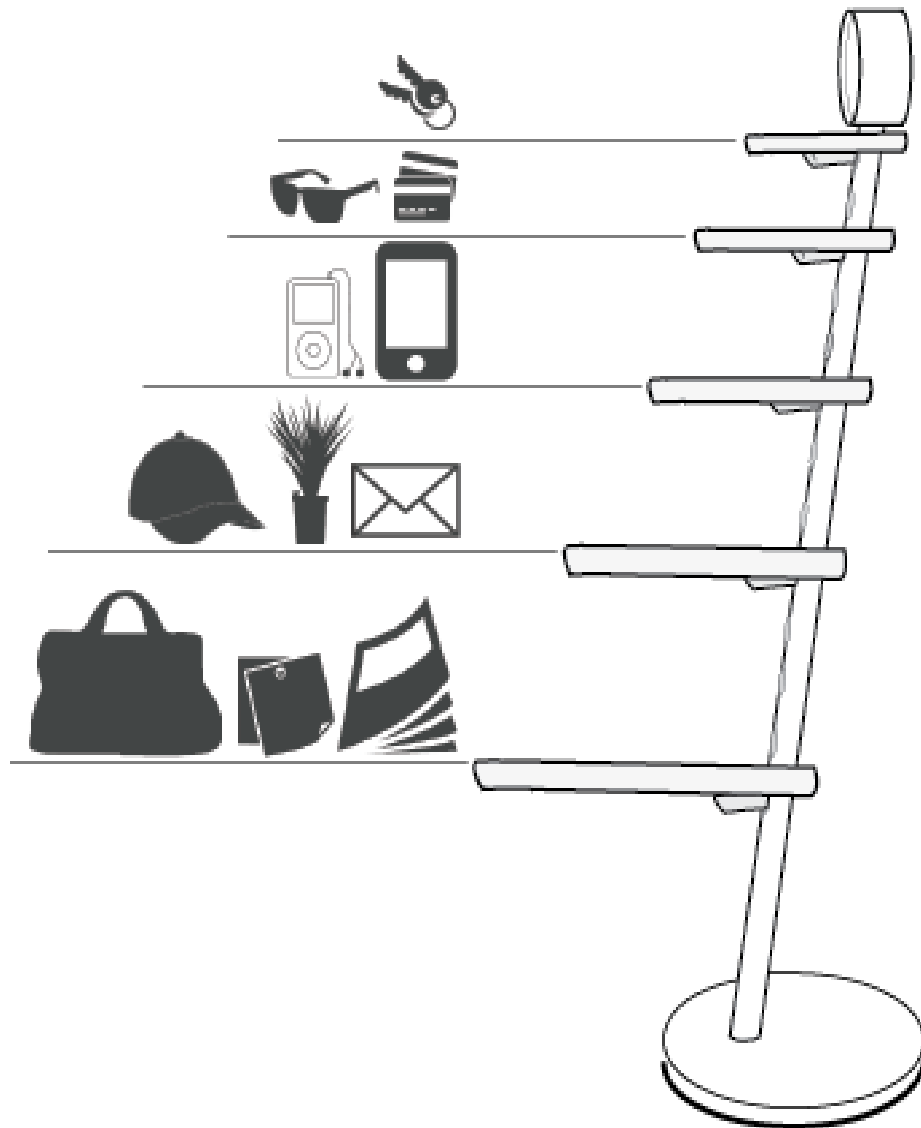


Figure 16 Example of materials that might be stored on Pinicola Shelves

6.6: Design for Low Physical Effort

A design that is comfortable and easy to use with as small of an amount of physical exertion as possible

A design that can be used with low physical effort allows all users to be comfortable with owning and using a product and in particularly those who may not have full mobility. This shelving unit can be set up on the floor and then placed against a wall or it can be set up while standing against a wall. Each shelf easily slides until it hits the peg set up to hold the shelf in place. This gives the user support in setting up each shelf, in that some of the weight is being supported by the structure while the user sets it up; this minimized the sustained physical effort by the user. Depending on the severity of mobility, the half inch pegs might prove to be difficult for some of the most extreme cases for hand/tactile mobility, however these pegs were designed at a much larger scale than the hardware that often comes with flat-pack furniture.

6.7: Size and Space for Approach and Use

The design is approachable and able to be manipulated regardless of user restrictions

The size and shape of a design is incredibly important to the user because if a product is too large or small or awkward the user will have no desire to use it.²⁵ For those with limited mobility this is an incredibly important part of design. Since these shelves can be manipulated to suit the user's needs, approachability can be altered to fit into the user's limitations. Space, height, and sight levels can all be adjusted by altering the shelves so that they fit into the user's needs.

²⁵ "Universal Design.. What It Is and What It Isn't." *Universal Design.. What It Is and What It Isn't*. University of Wisconsin, n.d. Web. 8 Oct. 2013. <http://trace.wisc.edu/docs/whats_ud/whats_ud.htm>.

Chapter 7

Milan Furniture Fair

It is an honor to have this product, Pinicola Shelves, included in an international furniture fair; the Milan Furniture Fair: Salone Satellite 2014. This product will display the importance of bio-inspired design in the development of sustainable products. Pinicola Shelves will also be a good representation of the inspiration derived from the Pacific Northwest and Oregon in particular. If this product serves as inspiration for other designers to develop sustainable bio-inspired designs than that would add to its utility and impact.



Figure 17 The student products being featured at the Salone Satellite

Conclusion

Developing a bio-inspired, sustainable, home-good for a senior studio course might be one of the most liberating processes a designer can experience. Delving into a design with so many constraints proves to be a complex problem, but those same constraints aid the designer in discovering a proper solution.

Illustrator, designer, conservationist, and self-proclaimed nature lover, Robert L. Peters, once said, “*Design creates culture. Culture shapes values. Values determine the future.*” This quote describes the exact impact that Pinicola Shelves is going to make. Home-goods do not just need to be designed for aesthetics or designed for fashion, but also for sustainability and universal use. Pinicola Shelves will be the game changer in home-goods helping to educate designers and consumers in using the environment as inspiration and as a factor in purchasing consumer products.

Biomimicry is a universal design language. It takes what naturally occurs with or without man, all over the globe, and places it intricately into the daily life of humans. Biomimicry helps humans get closer and more connected to the natural world, even if their physical location is in the center of a metropolis. Biomimicry helps designers focus more deeply at the task at hand, in doing so, more deeply solving universal design issues as well as environmentally sustainability. Biomimetics is a tool for designers that is mutually beneficial to the users as well as the environment.

Appendix A

Biomimicry design tools graphics

"For the Eameses, the design process would be successful only by identifying the overlapping needs of client, society, and designer and developing products that would serve all three."²⁶

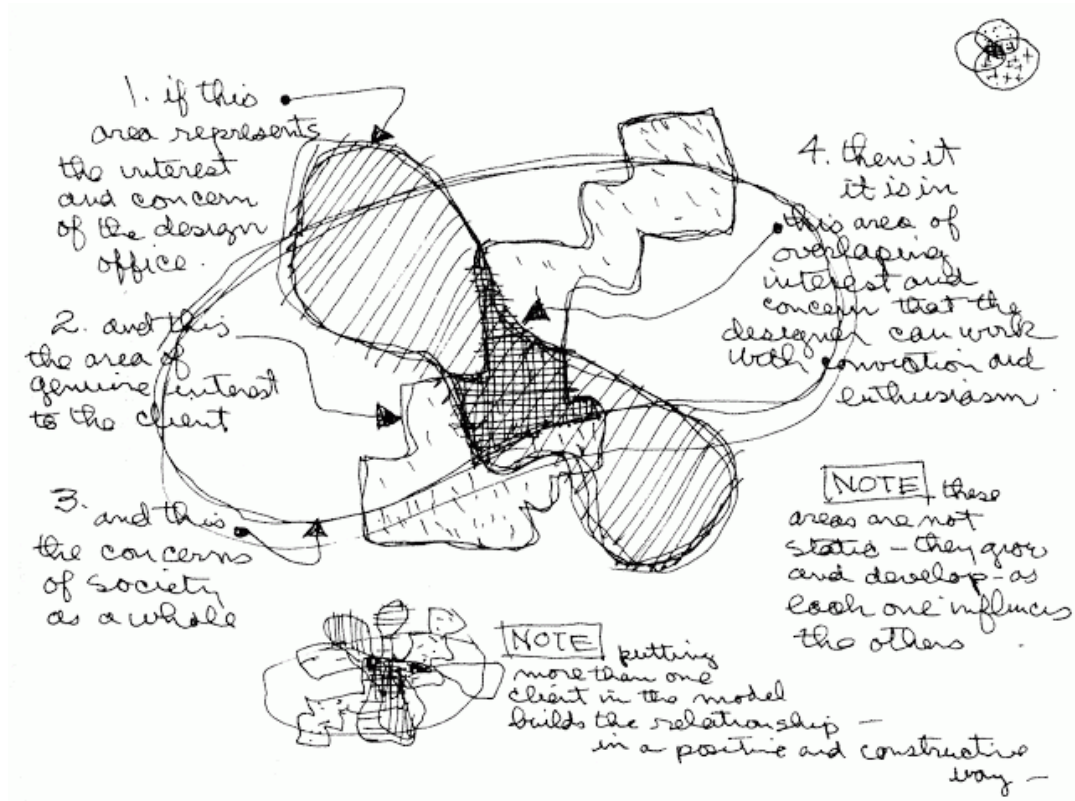


Figure 18 Charles and Ray Eames' Design Process Diagram.
From the initiation of a design, the designer is using constraints to focus themselves. Constraints include outside factors such as: consumers, culture, buyers, materials, etc. Designs truly develop where all of these aspects overlap.

²⁶ "The Work of Charles and Ray Eames: A Legacy of Invention Biography." *The Work of Charles and Ray Eames: A Legacy of Invention*. The Library of Congress, n.d. Web. 15 Nov. 2013. <<http://www.loc.gov/exhibits/eames/bio.html>>.



Figure 19 Biomimicry Design Lens- Design Strategy.

*Biomimicry Design Lens*²⁷

²⁷ "Biomimicry Thinking." *Biomimicry* 38. Design Lens, 2012. Web. 25 Feb. 2014.

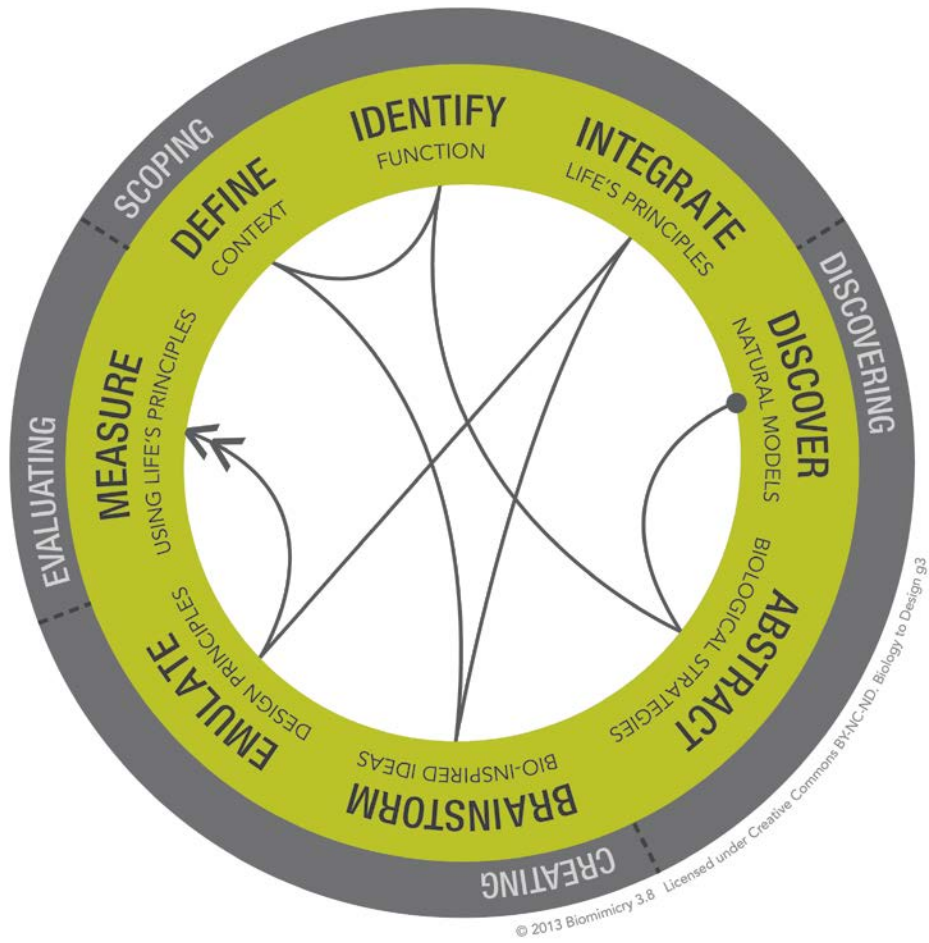


Figure 20 Biomimicry Design Lens- Design Thinking.

*Biomimicry Design Lens*²⁸

²⁸ "Biomimicry Thinking." *Biomimicry* 38. Design Lens, 2012. Web. 25 Feb. 2014.

Steps of Biomimetic Design

Interpret: Taking the understanding of biomimicry and the understanding of product design, then combining the two inferences to deduce a product within a biomimetic lens. Research used to interpret was completed through literature, documentaries, and precedent and inspiration boards seen below in figures 4 and 3.

Design Lens: A way in which a problem can be observed and taken apart. Also thought of as a strategy to get to a design solution for a current problem. A *biomimetic design lens*, focuses on the problem and the strategy to get to a design solution that is biologically inspired.

Observe: Both passive and active observation was used in the process of designing to be sure that the product was addressing true user need. Passive observation is observation that has been observed by the designer without seeking it out, active observation is defined by the designer seeking out products in use to observe and take note of user behavior.

Discover: to come to a realization of the potential a biological form has, as well as seeing the potential of a product through either problems with product areas or discovering unfulfilled product niches.

Ideation: an iterative process taken by designers to manifest conceptual ideas in the form of drawing, sculpting, rendering, or any way to bring forth a physical representation of a conceptual design.

Abstraction: taking a form from its original biological concept and replicating it in the form of a consumer good to produce sustainable and biomimetic outcomes.

Emulate: to take inspiration from a biological form, mimic that biological form in a man-made way, and then go above and beyond display that biological form's true meaning. To make the man-made creation as convincingly biomimetic as it can be.



Figure 22 Fomitopsis pinicola
Woody fungi sample found in Oregon with inspiring lightweight properties and stackable nesting features

Bibliography

- Arora, David. *Mushrooms Demystified: A Comprehensive Guide to the Fleshy Fungi*. Berkeley: Ten Speed, 1986. Print
- "Ask Nature - the Biomimicry Design Portal." *Ask Nature - the Biomimicry Design Portal*, Biomimicry 3.8, n.d. Web. 6 July 2013. <<http://www.asknature.org/>>.
- Benyus, Janine M. *Biomimicry: Innovation Inspired by Nature*. New York: Perennial, 2002.
- "Biomimicry Institute - What Is Biomimicry?" *Biomimicry Institute - What Is Biomimicry?* Biomimicry Institute, n.d. Web. 12 June 2013. <<http://biomimicryinstitute.org/about-us/what-is-biomimicry.html>>.
- "Biomimicry 3.8." *Biomimicry 38*. B-corporation, n.d. Web. 16 July 2013. <<http://biomimicry.net/>>.
- "Biomimicry DesignLens." *Biomimicry 3.8*. N.p., n.d. Web. 10 July 2013. <<http://biomimicry.net/about/biomimicry/biomimicry-designlens/>>.
- "Bouncing Ideas." *Bouncing Ideas*. N.p., n.d. Web. 10 Jan. 2014. <<http://bouncingideas.wordpress.com/tag/biomimicry-design-process/>>.
- Brown, Tim. "Design Thinking." *Harvard Business Review* June (2008): 84-96. Web. 25 Jan. 2014. <http://www.ideo.com/images/uploads/thoughts/IDEO_HBR_Design_Thinking.pdf>.
- Casselman, Anne. "Strange but True: The Largest Organism on Earth Is a Fungus." *Scientific American Global RSS*. Scientific American, 4 Oct. 2007. Web. 25 Dec. 2013. <<http://www.scientificamerican.com/article/strange-but-true-largest-organism-is-fungus/>>.
- "Cosmit - SaloneSatellite." *Cosmit - SaloneSatellite*. N.p., n.d. Web. 17 Oct. 2013. <<http://www.cosmit.it/tool/home.php?s=0,2,67,71,82>>.
- Davis, Marcia. "Blogs." *Herman Miller*. N.p., 20 July 2009. Web. 16 July 2013. <<http://www.hermanmiller.com/discover/making-sense-of-bio-inspired-design/>>.
- De, Botton Alain. *The Art of Travel*. New York: Vintage International, 2004. Print.

- DeFocatiist, DSA, and SD Guest. "Deployable Membranes Designed from Folding Tree Leaves." *The Royal Society, Cambridge* 0928th ser. 10.1098.2001 (2001): n. pag. *Department of Engineering, University of Cambridge, Trumpington Street, Cambridge CB2 1PZ, UK*. Web. 23 Aug. 2013. <<http://www-civ.eng.cam.ac.uk/dsl/publications/leaves.pdf>>.
- Dorst, Kees, and Nigel Cross. "Creativity in the Design Process: Co-evolution of Problem and Solution." *Science Direct*. Elsevier, Sept. 2001. Web. 2 Nov. 2013. <<http://www.sciencedirect.com/science/article/pii/S0142694X01000096>>.
- Ellis, M.B. & Ellis, J.P. *Fungi without Gills*, 1990. Chapman and Hall: London, England. P.329
- Emberger, Gary. "Fomitopsis Pinicola." *Fomitopsis Pinicola*. Messiah College, 2008. Web. 02 Nov. 2013. <http://www.messiah.edu/oakes/fungi_on_wood/poroid_fungi/species_pages/Fomitopsis_pinicola.htm>.
- Course: ENVS 427, Fall 2013, University of Oregon, Boulay
- Forbes, Peter. *The Gecko's Foot: Bio-inspiration : Engineered from Nature*. New York: W.W. Norton &, 2006. Print.
- Gilbertson, R.L. *Fungi That Decay Ponderosa Pine*, 1974. University of Arizona, Tuscon. P. 197
- "Hardwood Lumber and Plywood Distributor - Product Weights." *Hood Distribution*. Hood Distribution, 2011. Web. 30 Dec. 2013. <http://www.hooddistribution.com/resources/product_weights.html>.
- Kuo, Michael, PHD. "Fomitopsis Pinicola." *Mushroom Expert*. Andrew Methven, Ph.D., George Barron, Ph.D, Rex Bartlett, Paul F. Hamlyn, Ph.D, John David Moore, Ph.D., Carol Schmutde, Ph.D, Douglas Smith, Ph.D., Feb. 2010. Web. 25 Aug. 2013. <http://www.mushroomexpert.com/fomitopsis_pinicola.html>.
- Lee, Dora. "Biomimicry: Inventions Inspired by Nature [Hardcover]." *Biomimicry: Inventions Inspired by Nature: Dora Lee, Margot Thompson: 9781554534678: Amazon.com: Books*. N.p., 2011. Web. 03 June 2013.
- "Life Cycle Assessment (LCA)." *EPA*. Environmental Protection Agency, n.d. Web. 3 July 2013. <<http://www.epa.gov/nrmrl/std/lca/lca.html>>.
- Lowe, J.L. *Polyporaceae of North America*, 1957. State University College of Forestry: Syracuse, NY. P.97
- McDonough, William, and Michael Braungart. *Cradle to Cradle: Remaking the Way We Make Things*. New York: North Point, 2002. Print.

- "The Nature of Things: Biomimicry, Part1 and 2 | Watch Documentary Film Free." *The Nature of Things: Biomimicry, Part 2 | Watch Documentary Film Free*. N.p., n.d. Web. 16 Oct. 2013.
<www.snagfilms.com/films/title/the_nature_of_things_biomimicry_part_2>.
- "Okala: The Ecodesign Strategy Wheel." *Okala* (2012): n. pag. Web. 3 Oct. 2013.
<<http://www.okala.net/Okala%20Ecodesign%20Strategy%20Guide%202012.pdf>>.
- "Okala Practitioner." *Okala Practitioner*. N.p., n.d. Web. 23 Mar. 2013.
<<http://www.okala.net/>>.
- Overholts, L.O. *The Polyporaceae of the United States, Alaska, and Canada, 1967*. University of Michigan Press: Ann Arbor, MN. P.466
- Vierra, Stephanie. "Biomimicry: Designing to Model Nature." *WBDG*. National Institute of Building Sciences, 09 Aug. 2011. Web. 1 Jan. 2014.
<<http://www.wbdg.org/resources/biomimicry.php>>.
- Walker, Alissa. "Biomimicry Challenge: IDEO Taps Octopi and Flamingos to Reorganize the USGBC." *Fast Company*. Business + Innovation, 11 May 2010. Web. 10 Nov. 2014. <<http://www.fastcompany.com/1643489/biomimicry-challenge-ideo-taps-octopi-and-flamingos-reorganize-usgbc>>.
- Walker, Alissa. "What Would You Ask Nature?" *Fast Company*. Mansueto Ventures, LLC, 15 Mar. 2010. Web. 17 Apr. 2014.
- Walter, Jennifer. "Blogs." *GreenBiz.com*. N.p., 2 Oct. 2013. Web. 10 Dec. 2013.
<<http://www.greenbiz.com/blog/2013/10/02/why-sprint-turned-biomimicry-packaging-design>>.
- Williams, Holly, "Leaders of the Flatpack: Self-assembly Furniture Is Reinventing Itself as Clever, Sustainable and Stylish." *The Independent*. Independent Digital News and Media, 27 Aug. 2010. Web. 19 Oct. 2013.
<<http://www.independent.co.uk/property/house-and-home/leaders-of-the-flatpack-selfassembly-furniture-is-reinventing-itself-as-clever-sustainable-and-stylish-2063284.html>>.
- Wilson, Edward O. *Biophilia*. Cambridge, MA: Harvard UP, 1984. Print.