THE 8TH KINGDOM:
Biomimicry as a systems lens for organic architecture in Methow Valley, Washington

James Ditto

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Abstract
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Thinking outside of the (literal) box, would our world look like if the design of the built environment was predicated upon the assumption that a building is a living thing? It consumes, it expels waste, it takes up space, might move or be stationary like a person or a tree. It reproduces through us, as does corn. It has systems which make it hospitable to life at various scales. As a living organism, how well it does all of the above, the effectiveness of its feedback mechanisms, and its resilience to stresses would determine its survival and how likely we are to breed/ build another like it.

In experience and outside of theory, buildings are more than just an assortment of inhabitable spaces, they become characters unto themselves. They are chimeric, pieced together like creatures of mythology to help us create our own stories. Some are monsters, ravaging the landscape, consuming endless amounts of energy, even killing people by their poor design. The built environment is acknowledged as a primary contributor to climate change and the lifespans of buildings do not speak of the damage done through their construction and destruction. Between us and the non-biological species we create, the biodiversity and the balance of the planet has been so deeply altered that the fate of our own species hangs in the balance.

This thesis explores these ideas through architecture, landscape architecture, biosystems engineering using the lens of biomimicry to turn an opportunity for land development in the Methow Valley into a sink for carbon, a well of biodiversity, and an effective collector of solar powered energy. Several alternative energy systems are explored and integrated into architecture and landscape along side gray and black water treatment, geothermal heating, food and alcohol production while promoting local and regional biodiversity. Modeled as a "holistic health and healing center," the structure and systems represent another species of building, a close cousin to the Bullitt Center, Earthships, and the future habitats of Mars. This is the 8th Kingdom, the kingdom of the built and grown, the Kingdom of the Archinae. The thesis concludes with a section reflecting on the design and larger systems potentials.

Keywords: biomimicry; biodiversity; renewable energy systems; wastewater treatment; mycoculture; Hugelkultur; glulam; Japanese joinery

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INTRODUCTION

Questions

What is the role of biomimicry in the built environment? What is it and how does it both define and redefine our understanding of human cultural and social development? Finally, in what ways can a biomimetic approach to design of architecture, landscape architecture, and engineering be applied to site specific applications?

This thesis is about shifting perspectives entirely on how we view the built environment and the ways in which we design it. It stands on firm ground, as it is compatible with much of what exists and is considered widely acceptable in terms of building and creative culture. Yet it addresses a shift in perspective that may yield a wide divergence from where one stands as the thesis begins. Like the way a giant ship is swayed to turn with the aid of a trim tab, as Buckminster Fuller would remind us. ("Dymaxion Forum", 2015) Imagine if you will, a world which is entirely alive and spectacularly diverse. The plants, the animals, the fungi, the chromista, the protozoans, the archaea, and the bacteria, of course, but also the buildings, the streets, and all of the brownfields and lifeless rivers as well. Take a minute. Fresh air, food, an environment that is not merely mechanical, but truly responsive - not to mention a delight to behold. Culture, style, art, and the way we live shifted to ensure contact with life because the world we've built was arguably alive.

Arguments

This thesis argues that this vision we may share of living in a biophilic, magnificently diverse environment, is not only necessary, but it is literally the most natural thing in the world for us to do. Seeing green is a good thing, as studies have shown. (Grinde, 2009) It's natural to want to see more of it. This thesis simultaneously submits that everything our species has done since it branched off has been entirely natural as well. It's just that over the last few hundred years, not all of it has been very pro-Nature. Certain peoples maintained a working knowledge of how to be pro-Nature and we owe them debts of recognition and collaboration.

The reason this is important is that biomimetic design is neither inherently nor necessarily sustainable. In fact it is not necessarily sustainable because when we apply it we are typically seeking answers to individual problems, rather than to systemic issues that will reverberate over generations, millenia, epochs and eons. It is design which abstracts from or corollates to nature, but natural processes and principles recreated out of context can conveniently leave sustainability behind. Turned on its head, however, what if we ask whether all sustainable design is necessarily biomimetic? Does that imply that in pursuing a sustainable society, must all design and management (of the built environment) dig deeply into Nature, biology, and ecology to tease apart the rules and shortcuts already in use by the other Kingdoms of Life, forever more? Whether a cataclysmic event is a hurricane, a glacier, a supervolcano or a meteor, life must move, adapt, and evolve in order to survive. In the face of every threat, our built environment must learn to do the same. It can be bionic, but it has to be biomimetic if it is going to succeed. Nature must be nurtured.

Fig. 1 - An ocean liner with a trim tab. A small push can shift the course of a ship or tilt a planet.

If we shift to looking at the built environment as something that is meant to grow - not just be built up - designers have the opportunity to approach their work with a vision that incorporates the other Kingdoms of Life as partners in a regenerative process rather than aiming to exclude them en masse. With that, the pollution in our air, our gray and black water, street runoff, etc, can be purified without the need to run machines day and night sucking carbon out of the air or sifting our sewage. With that, food can be a right that isn't questioned, as can homes. We can provide the scaffolding and the opportunities for life to happen on a scale our recent predecessors had not dreamed, let alone understood.

This thesis considers the access to clean water, food, shelter, and education as fundamental rights in accordance with - and beyond - the United Nations Universal Declaration of Human Rights. (United Nations, 2017) What's more, it considers the documented positive psychological and physical health effects of human interaction with plants, soils, and animals as fundamental rights. Non-human lives deserve protection and promotion, even as most deserve and require a great reduction of our direct influence. If we design our world for synergistic biodiversity, we may provide more opportunities for people to participate in a living environment and for Nature to bounce back.

The tools are becoming easier to use and we are seeing designers forego the ease and tidiness of static, minimalist interiors, exteriors, and modernist yards with their tightly manicured patches of grass. Adding three to five geometrically arranged ornamental species, a gridwork of fences and walls like tiny grass ranches for hungry lawnmowers to consume. Fossil fuels get burnt, petrochemicals get sprayed, leaves are yardwaste, and the soil, the SKIN of the planet, loses its diversity. The patchwork resembles an infection.

"C'est une boîte en l'air..."

~Le Corbusier, Précisions sur un état présent de l'architecture et de l'urbanisme, 1930

Fig. 2 - Le Corbusier's conception of "A house is a machine to live in" (Corbusier, 1930) is embodied in La Villa Savoye and is lauded for a purported integration with the environment and evidence for "form follows function." With a bad orientation, a leaky roof, cold and damp interiors, massive energy loss, lawn of dying grass, and immediate lack of habitability, these statements ring hollow. How much could these designs, and their future inhabitants, have benefitted from a biomimetic approach over one that was deeply mechanistic and abstract? What is the purpose of a box in the air?

Biomimicry In Practice

Meanwhile, a parcel at a fraction of an acre can produce enough to feed a family and produce an income. (The Urban Homestead) Permaculture practices and food forests provide evidence and examples of ways in which synergistic relationships between plants, their growth habits, nutrient cycling, and informed layout can not only produce an abundance of food annually, but also radically cut back on the amount of human intervention (labor) is required to maintain it as a healthy ecosystem. Biodynamic and regenerative agriculture represent other toolkits which happen to share particular tools with the above. Why? Why the commonality?

This thesis proposes that biomimicry is at the root of all of our sustainable practices and inventions. The things we design and create which can be considered sustainable draw either directly from biological examples or ultimately prove to have a biological equivalent. Biomimicry, a term coined by Janine Benyus as a name for a growing field of study which, as the book's subtitle suggests, promotes "Innovation inspired by nature", provides a framework for abstracting concepts and systems from the study of living organisms. (Benyus, 1997). Mimicry itself is a biological act and process which has its own subset of types. Batesian mimicry, Muellerian mimicry, self-mimicry, and aggressive mimicry. If we consider the history of architecture, it is possible to recognize the ways in which human habitation models mimicry as a means of facilitating very specific relationships with its environment and the biodiversity within it.

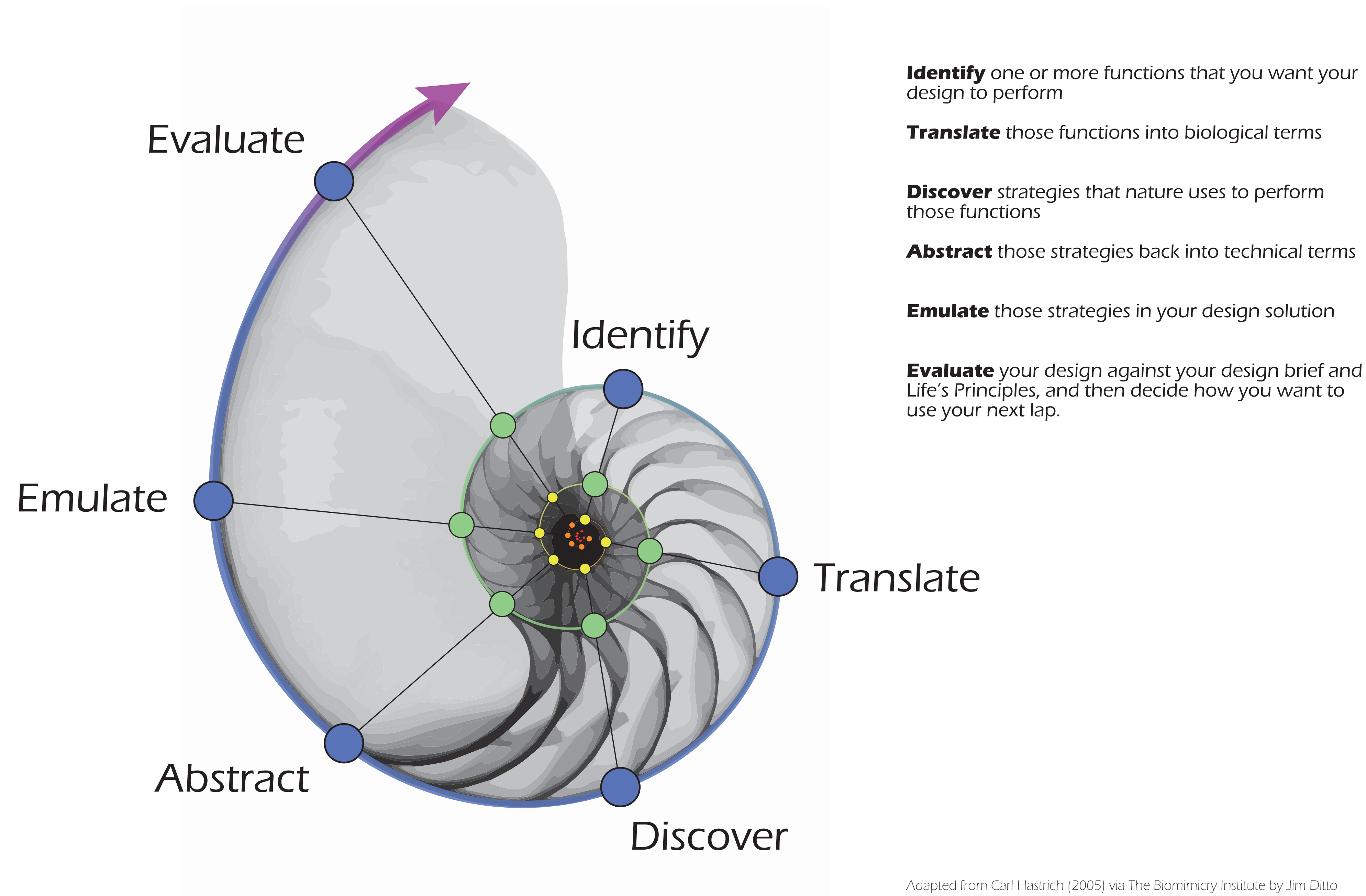

Fig. 3 - The Biomimetic Spiral is a set of steps for applying the concept of biomimicry to design problems. The spiral form allows for an iterative design process, with new solutions evolving out of earlier explorations.
Image adapted from The Biomimicry Institute, 2014.

Protection From Our Own Worst Enemy

Homo sapiens can, has, and does engage in nearly all of these kinds of relationships, so clever are we. Relationships have a way of defining us to others and to ourselves. And the types are not mutually exclusive. A person who preys from the inside a mutually beneficial community is a parasite, even as they view themselves as the lone wolf. Nations and corporations use cooperation to the betterment or detriment of communities, which is all eco-systems are. Some of these organisms are benign while drawing benefit from their partner species in a commensal relationship. We have these relationships with other animals and they define us. Think of the love of a dog and the generations who nurtured that interspecies relationship. At a genetic level our paths have become intertwined. We are masters of adapting to each type of relationship and we are passing on those traits to our creations..

So too, we have adapted to relationship types with part of the living environment (L.E.) which we call the built environment (B.E.). It is defined by its rigidity and is prone to breaking down in non-regenerative ways. Where I live, the B.E. lives on a life support system. Electricity generated many miles away, water is siphoned from the mountains, and our waste pours through a human sized catheter to be processed as the foul mess it has become. When the rain falls too hard here, millions of gallons of sewage may combine with polluted street runoff and pour into the bodies of water which, arguably, make this one of the most beautiful cities in the world. With few exceptions, most of our buildings and landscapes thrive through this parasitic relation-ship.

"We are called to assist the earth, to heal her wounds, and in the process, heal our own."

~ Wangari Maathai

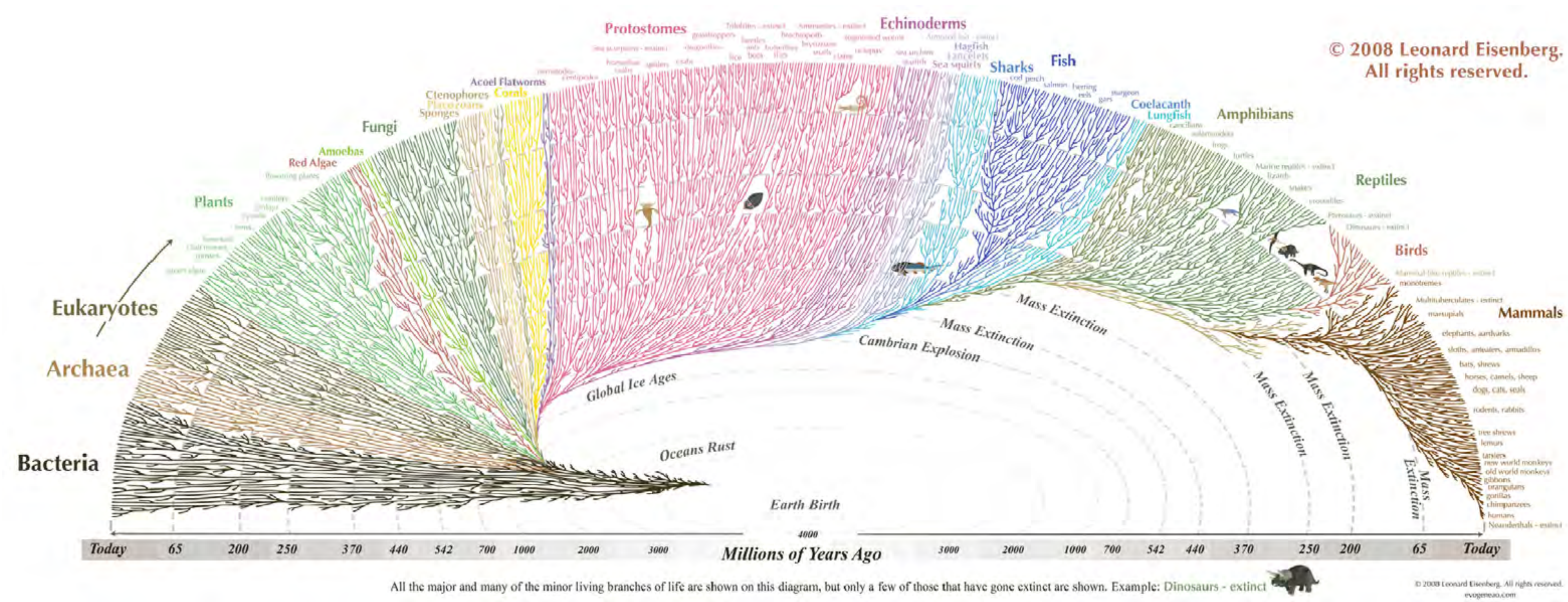

Fig. 4 - A phylogenetic tree of life showing the common genetic roots of all life on earth. Is there a possible branch missing for the built environment? Would it look more like a convergence of different branches? With the advent of genetic modification, the future patterns of these trees may require an extra dimension to capture these kinds of grafted relationships.
Diagram by Leonard Eisenberg ("The Tree of Life: We Are Related to Every Living Thing!")

It was not always so. Until very recently (within the last 170 years - literally a moment in the astronomical calendar) Seattle was a food forest. The shores were filled with shellfish, the waters filled with fish and other sea life, prairies flowered with food, and trees towered above the edible understory. By sticking to a worldview which recognized the value of biodiversity, the Duwamish drew from a generations long study of how their biome worked, what worked where, and how to keep the cycle going in perpetuity. The cycle was regenerative, filling in the land that had been formed with the creation and recession of the Vashon Glacier. The abundance of old growth forest, salmon the size of large dogs, and creative expression of the humans who lived here were all thanks to what were arguably biomimetic applications of biological processes to the habits and systems which would guide their lives. (Reimann, 2017)

So too, the modern interaction of the B.E.with the L.E. can be viewed as biomimetic. Given the nature of the parasitic relationship it is copying, it must be argued that the B.E. is in dire need of another biological concept: Metamorphosis. Through metamorphosis, an organism may shift its relationships and change biomes entirely. It may employ mimicry in any stage of its life as a means of improving survival and quality of life. We do not have to start from scratch if we begin a metamorphosis. Every generation of the B.E. will continue to grow and evolve as it has since we built the first wall. Seeing it for what it is, an overlapping system of biomes that are arguably alive, offers a shift in perspective from the modernist nod and subsequent avoidance of nature. It steps back into the vernacular architecture that spoke to the sun and reacted to the land within which it rooted. It asks how you will design a world that grows and evolves through this current mass extinction.

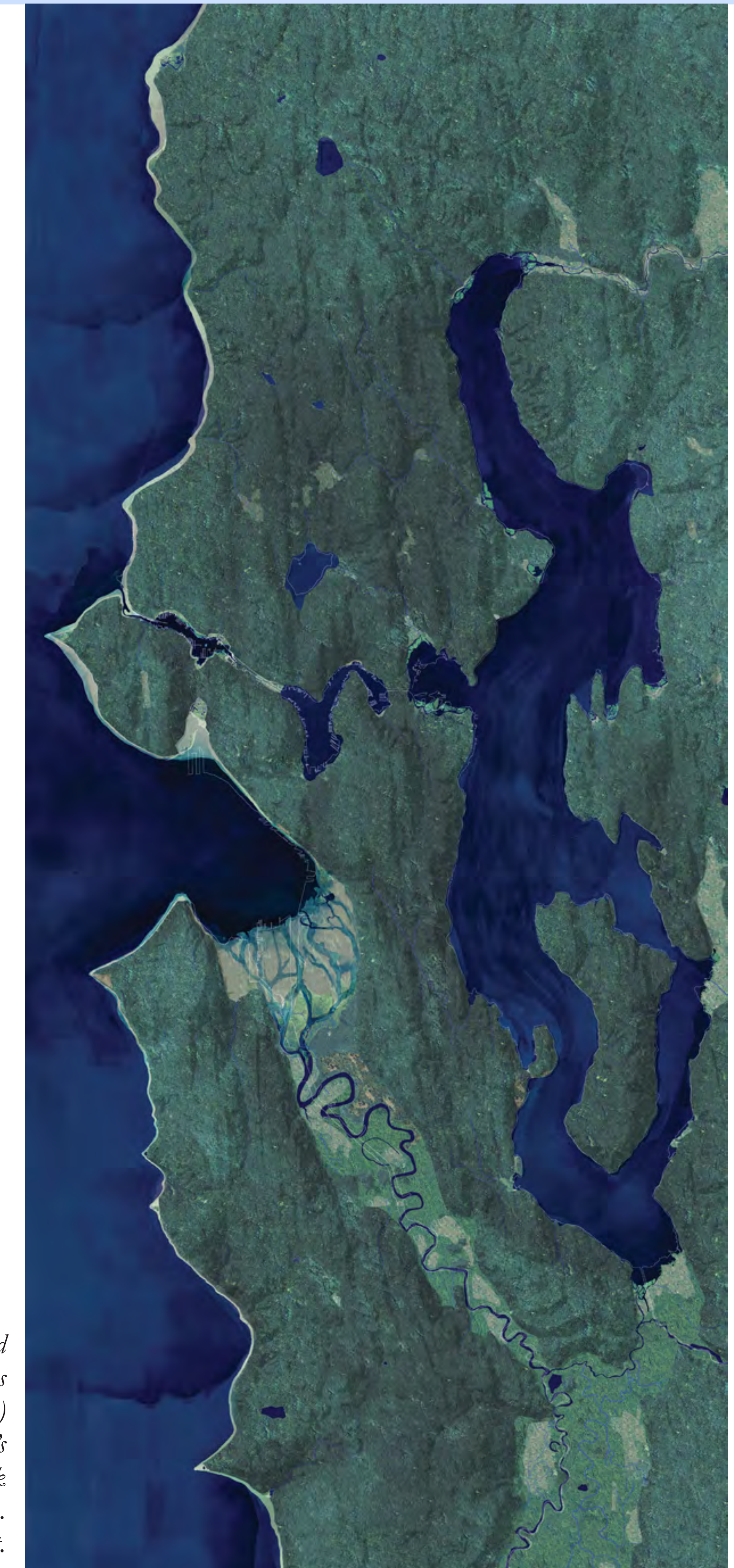

Fig. 5 - The Waterlines Project by the Burke Museum provides an overhead glimpse at what the land we now call Seattle looked like before the trees were felled and the ecosystem stripped and shipped off for profit. (Lewis) The symbiotic relationships with nature practiced by the ancestors of today's Duwamish and Coast Salish peoples made the shores of the Salish Sea look like this. This was a scientific practice grown from biomimetic design. Image: Burke Museum Waterlines Project.

We are currently experiencing, first hand, the 6th major mass extinction event on this planet. Not only are we sitting in the proverbial pot as it boils, we lit the match on this one and are pouring gasoline on the fire (literally). Out of each of these events, new survival tactics are employed by the species agile and adaptable enough to make it into the new epoch. From the microscopic to the multicellular, species band together across kingdoms, forming new relationships of coexistence, cooperation, and predation. Survival requires an evolution at every level of organization, from the genetic through the ecosystem and into the abstract.

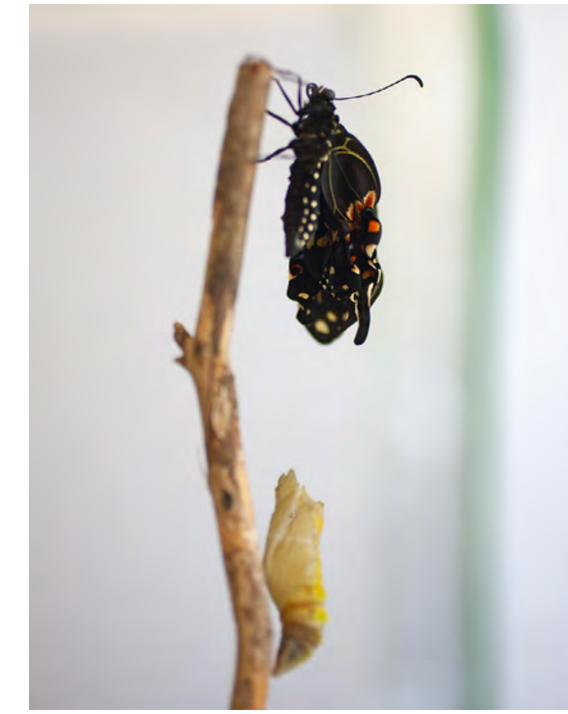

Fig. 6 & 7- Metamorphosis: An Eastern black swallowtail caterpillar (above) and an emergent butterfly (left), Papilio polyxenes*, provides a glimpse of one of the most powerful transitional tools of the L.E.. The first part of its life is a gathering of materials before building a temporary home of entirely self-produced materials. It goes on to mimic that which deters predation at each stage of life.*
Photos by Kate Moore.

Fig. 8 & 9 - In an act of mimicry, the chrysalis shifts from the green of a living leaf (left) to the mottled brown of one that is withered and dead (right).
Photos by Kate Moore.

Fig. 10 & 11 - Having rebuilt itself entirely from the inside out, the emergent butterfly (left) is a Batesian mimic, taking on the appearance of the poisonous Pipevine swallowtail, Battus philenor (L.) (above).

Case studies like The Plant in Chicago (fig. 113) reveal an opportunistic metamorphosis of the built environment.
Photos by Dean Morley (left) and by Ryan Kaldari (right).

The 8th Kingdom

This is the story of the 8th Kingdom. The first four Kingdoms of Life are invisible to the naked eye, though evidence of their existence surrounds us. Archaebacteria, Eubacteria, Chromista, and Protozoa inhabit the planet in all kinds of contexts and extremes. Before we invented the microscope, their presence was evident in many of the illnesses which plague the more complex forms of life. It took some time until we gave the name Yersinia pestis to the Black Plague or were able to identify the culprit behind cholera, Vibrio cholerae. Today these microbes are the descendents of the organisms which formed the basis for all complex life. The flagellum-motored microbes from which Fungi arose and conquered the land, prepared the cycle of growth and decay which made every species in the Plantae and Animalia possible. Plants have roots, it is believed, because they learned to do the trick that mycelium, the "roots" of the fungus, performed as an exchange for photosynthesized nutrients. (Field, 2019) The largest organism on the planet is a honey mushroom in Oregon which feeds and feeds upon the forest in which it thrives. (Ferguson, 2003) Without the forest, no fungus. Without the Kingdom Fungi, no forests.

This form of symbiotic mutualism is seen where animals feed upon and distribute mushrooms and spores. As termites and ants farm fungi, so too do we, for food and medicine. And like these comparably tiny animals, the structures we build to house ourselves are designed to promote beneficial fungal and microbial partners or risk illness and death. Now, if we consider an ants nest or a termite mound, the latter of which has been called a "lung" by researchers (Alter, 2018), the question can be asked, "At what point is the termite an individual organism and at one point is it the mound?"

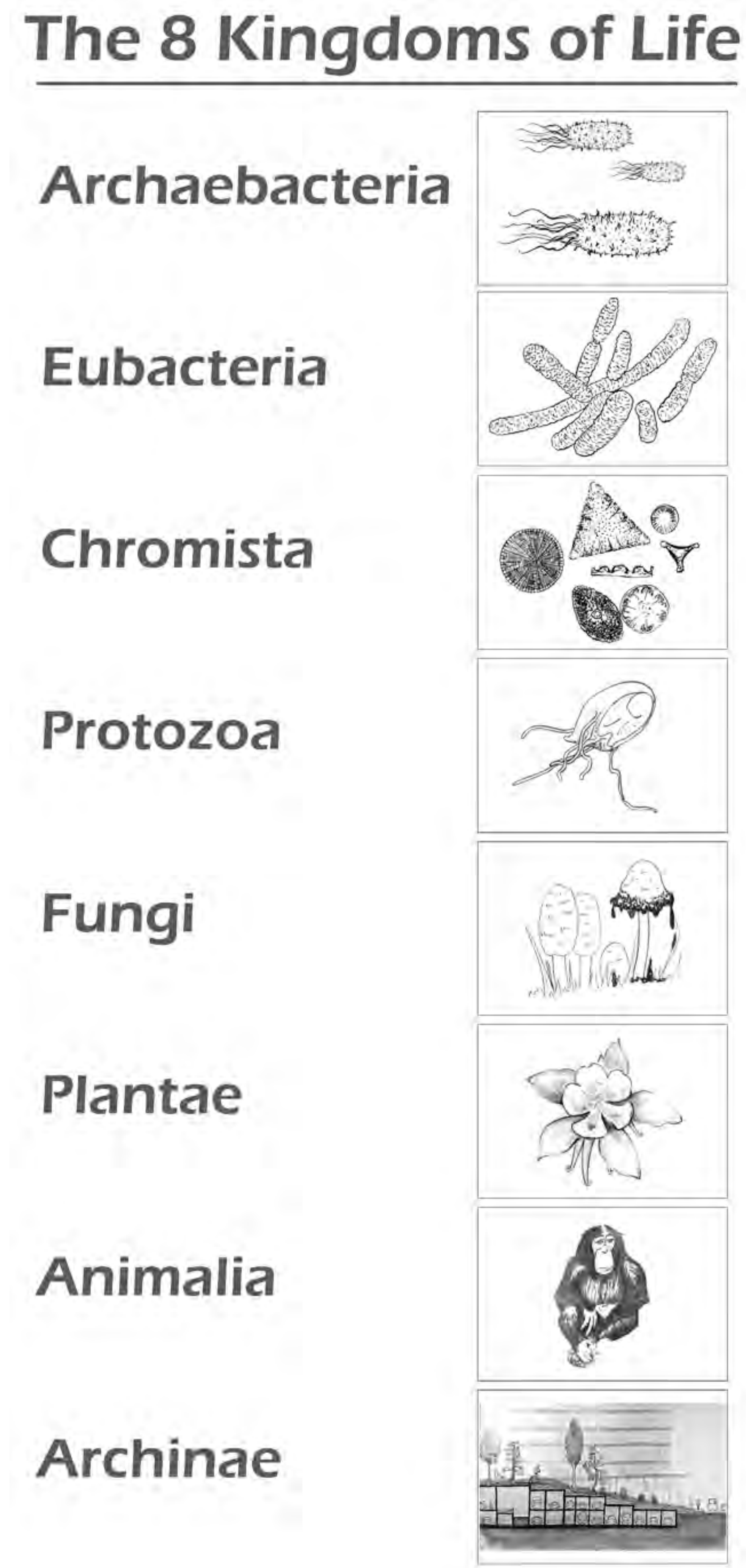

Fig. 12 - Differing versions of the Kingdoms of Life vary in number. This reimagining is based on Cavalier-Smith's 7 kingdoms model ("Cavalier-Smith's System of Classification," 2020) and the Catalogue of Life. ("Browse Taxonomic Tree," 2020)
Arranged from oldest to newest members, the Archinae is conceived as a multicellular organism which incorporates the other seven kingdoms into novel structures based upon biomimetic and abstract design principles.

Viewed as a more complex organism than an individual termite, an analogous relationship is revealed between the structure and its animal and microbial inhabitants and those within our own bodies. Of the over 60 trillion living cells in your own body, maybe 50% are genetically Homo sapiens. (Sender, 2016) We are symbiotic superstructures which operate in a cultural and psychological hall of mirrors which convince us that we are individuals, apart from the larger organism to which we belong. (Deleniv, 2018) Stepping back, a biome and an ecosystem are, in this thinking, living things themselves, fostering and benefitting from symbiotic exchange with and between other biomes and ecosystems. A shift in perspective and it is possible to see that without our shelters and the other organisms which call them home, we are like the termite or the amputated toe - a collection of dying cells without a body to live in or a way to carry on our genetic lines.

Thus, I recommend we consider the built environment - the sum collection of habitable environments from the tent, the teepee, the shanty, the ship, the house, a hotel, a chateau, to the village, the town, the city, and metropolis - as a living network of organisms. The 8th Kingdom, the Archinae. This thesis argues that this Kingdom of Life is not new, but merely unrecognized. The limitations of our own perceptions blind us to the reality which surrounds us. As designers, we might look to this as an opportunity to acknowledge the parasitic qualities the B.E. has been "bred" to exhibit and to forge ahead with bolder plans for a world populated with beautiful, biodiverse, regenerative, and resilient creatures of the Archinae.

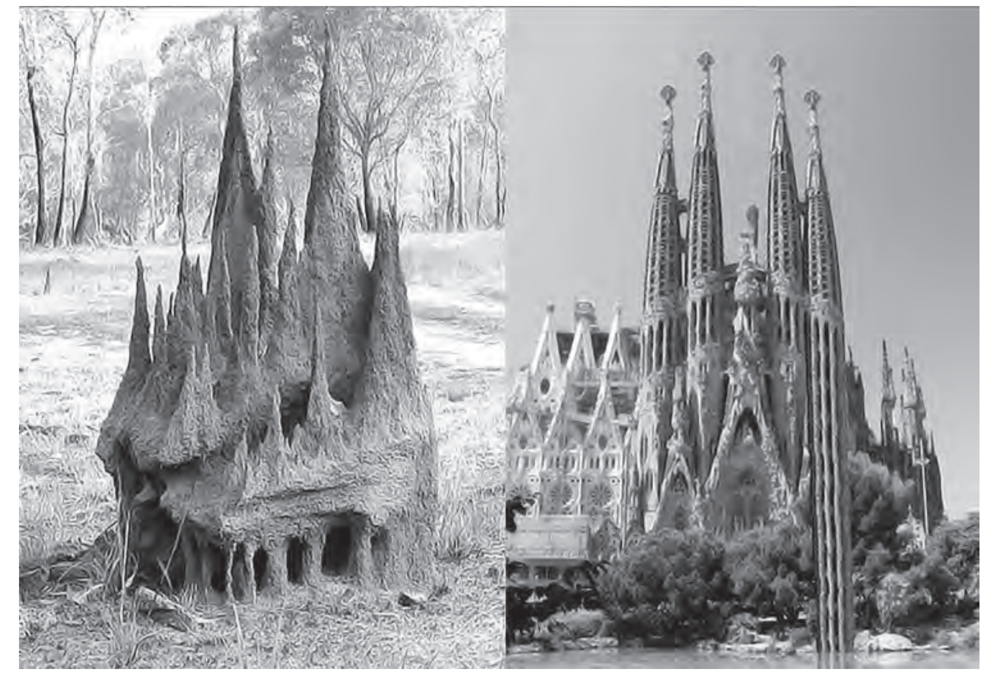

Fig. 13 & 14 - Gaudi's cathedral (below) is a miniscule variation of the termite mound on the left, if brought to scale. The structure is made of feces, mud, and wood and their mounds can reach 26' in height, which, scaled, is approximately four Burj Khalifa's tall. While the particular structure of the termite mound is believed to be the result of some hasty work to regain the height that is essential to the movement of air within the mound (Collins, 2017), the evidence suggests that Gaudi's own inspiration was drawn from nature and is, essentially, biomimetic.
The laborers on the left are actually two species of termite, 'magnetic termites' amitermes meridionalis and 'cathedral termites', nasutitermes triodiae. Given that the building falls short of the termite mound in food and a world-class maternity ward, La Sagrada Familia is evidence of an Archinum with opportunities to evolve.
Images: adapted from Collins, 2017.

Design Thesis

This thesis does not provide answers to how to apply this vision to every aspect of the world. It looks at the power of Story over the co-evolutionary development of our species and the larger organisms to which we belong. Exchange of information is at the heart of mimicry, and Story is element that drives it through culture and genome alike. Semiotics, biology, bioengineering, structural engineering, architecture, landscape architecture, and philospy are explored before turning the question to design in real, even concrete, terms.

The design side of this work drops the scale from global change over deep geological time to the present, switching locations and climates entirely from Seattle, where it was written. To the northeast of where I live, a valley was carved out by another glacial lobe a very long time ago. Within the Methow Valley sits the tiny town of Twisp, Washington. To the east of the town, not far from Highway 20, the land rises along Balky Hill Road. Nestled between taller cousins, a hilltop looks out and around on a dramatic scrubby steppe landscape. To the East, a much larger hilltop hides the early morning sun half the year, with a wetland area between the site and the giant next door. The site itself is made up of two parcels, totalling 10 acres. No large trees are present on the site. No known humans have inhabited this site, though there are homes on nearby parcels.

That is about to change. The King family has owned the property for over 20 years and now Clayton King is planning to retire there. This thesis analyzes, assesses and proposes an integrated development of the site which is based upon client needs and is rooted in theory, living examples in the form of case studies, and science. From this, a set of design principles are developed that may be applied elsewhere.

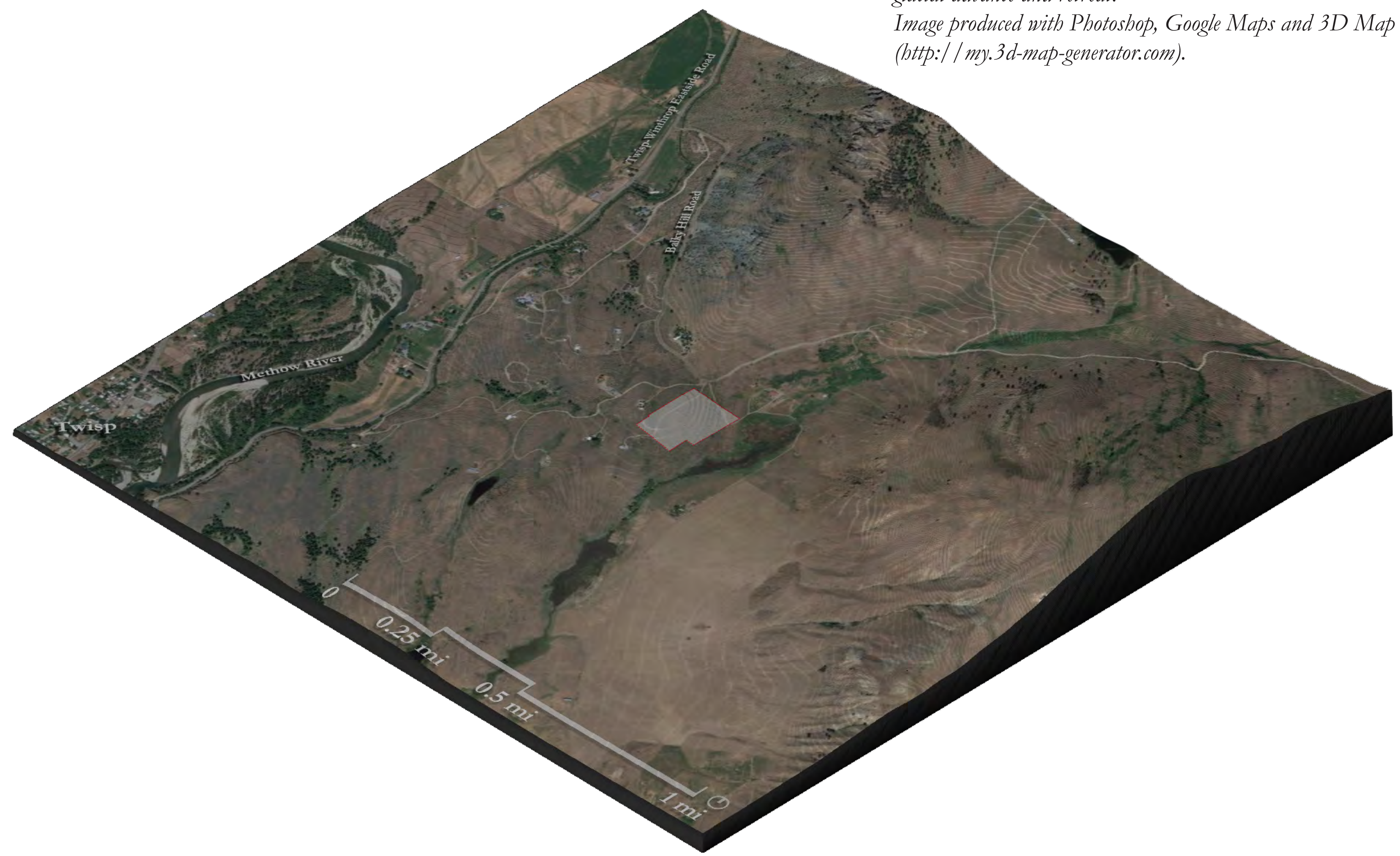

Fig. 15 - A topographic model of the design proposal site (in white with a red border) in the Methow Valley, Washington. Located just over half a mile from the Methow River, it is bordered to the east by wetlands habitat and a steep sloped hillside. The land, like Seattle, was formed by glacial advance and retreat.
Image produced with Photoshop, Google Maps and 3D Map Generator (http://my.3d-map-generator.com).

This template is not considered to be all-inclusive, nor does it propose limits on variation of design or style. The measures of success for all future design of the built environment (to include this project) fall under the metrics of sustainability, regeneration, biodiversity, community, experience, cost, products, waste, accessibility, and ability to inspire stewardship. Impacts to the residents ofthe overlapping biomes and wider ecosystem from the construction, maintenance, and life cycle may require further calculation.

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1 CRITICAL STANCE

Background, Biases & Influence

When I first applied to the concurrent degree program for the Masters of Landscape Architecture and Architecture, I came with a specific project in mind. The site mentioned belongs to my wife's family and has remained undeveloped, though plans for an "earth-bermed house" were drawn up several years ago by Howard Cherrington. Howard is an architect in the Methow Valley who apprenticed with Jim Gerlach, an architect who had himself studied under Bruce Goff who was an advocate of "organic architecture." I met with Howard to show him the design concepts I was developing in teaching myself Sketchup, concepts which were already drawing on biological inspiration and biomimetic design. While my ideas were intriguing to Howard, he admitted they were beyond his own knowledge of passive solar designs and encouraged me to keep pursuing my ideas as they seemed important.

In applying to the University of Washington, my intention was to gain intimate knowledge of both architecture and landscape architecture, assess how and where they overlap, and to approach this with sustainability and social and environmental justice in mind. I have a background as a landscaper in installation, maintenance, irrigation and light construction. I have also been a lifelong artist, most recently specializing in oil painting.

Fig. 16 & 17 - Explorations in symbolism & studies in refracted light: Focus & Determination *(left) and* Migration *(right) from the Kickstarter funded series KOISchool. Traditional oil paints and interference pigments on round canvas. 48" diameter and 46" diameter, respectively.*

Interference pigments are mixed using additive blending, rather than the traditional subtractive where colors get darker and muddier. These effects are only visible in when viewed in person.

With my application to UW and within my portfolio I submitted a diagram titled "Dynamic Water and Organic Waste Conversion and Purification System Concept" and a project concept titled "ReSeedence: Earthbound Architecture Concept & Proposed Capstone Project." This was, to some degree, what I had shown to Howard Cherrington the year prior. Granted, I knew next to nothing about how to design any of these things, yet my self study was surprisingly in line with the design process I've encountered at UW.

Through my explorations at UW I am developing a personal design ethic and seeking out frameworks which push back against many of the norms of conventional architecture schooling, in particular the beliefs around the relationships between the built and the grown. Like many others, I am seeking guides away from exploitation and back towards regeneration. The encouragement I have received over the past 3+ years has consistently reaffirmed the value of my willingness to take on new approaches and push bold ideas. Building biomimetic and biologically integrated habitats for humans which foster health, wellness, creativity, and community is a dream I hope this project can get me closer to making real through the development of a set of biomimetic design principles.

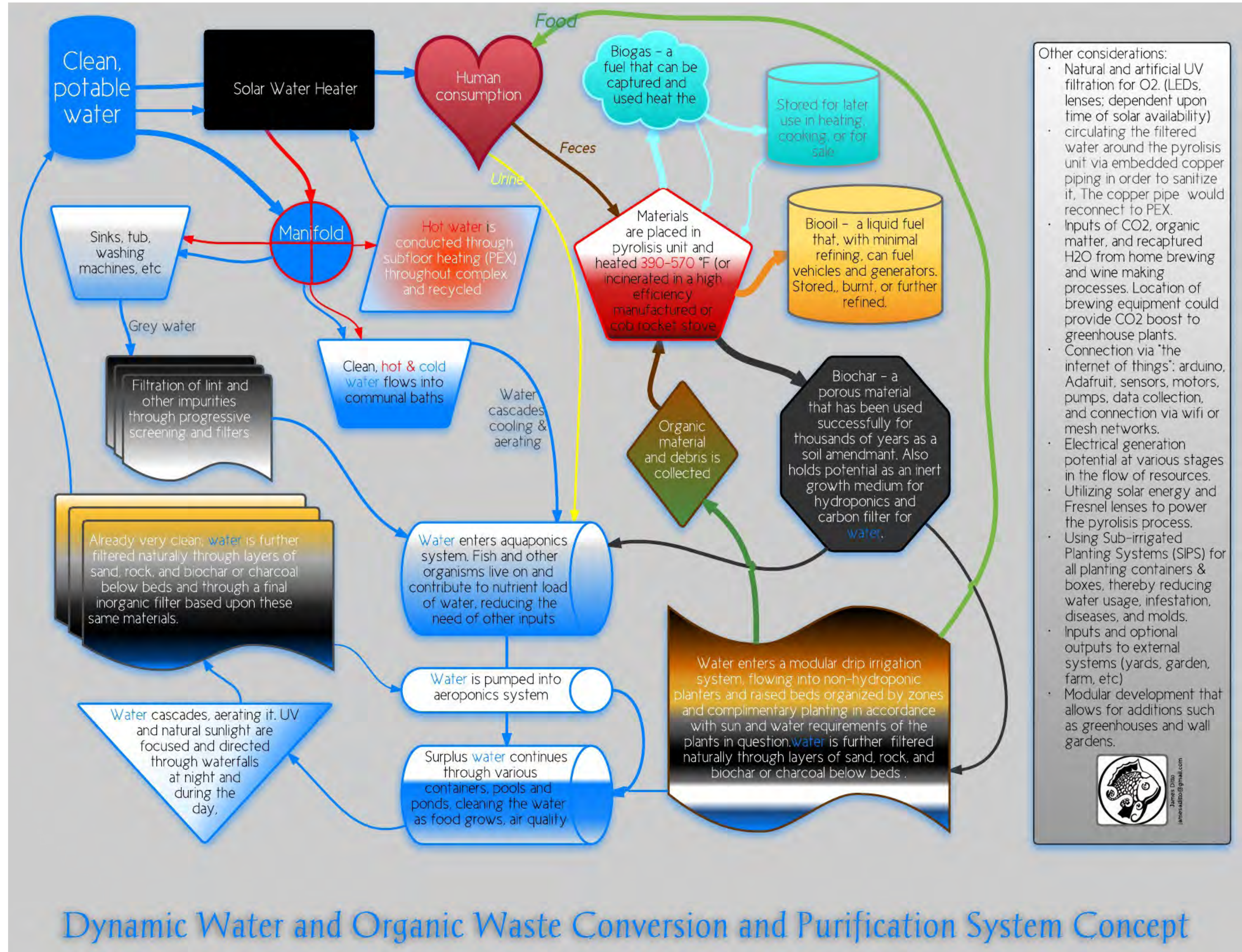


Fig. 18 - Self-study of sustainable design led to early diagramming of a system which aimed to purify water and turn wastes into energy and soil. In this thesis, these ideas resurface as Organs, specifically GUTS and HEART.

Now that I have four years of graduate study in the design of the built environment under my belt, it is clear that I my early approaches were leaning towards biomimetic and climate adaptive design. A growing interest in aquaponics, bioremediation, permaculture, pyrolysis is pushing a design perspective that continues to be influenced by past work and experience. Volunteerism, waste stream diversion, and warehousing in the materials reuse industry in NYC; introduction to Life Cycle Assessment (LCA), carbon footprints, net zero design, glulam and CLT, through internship an with The Carbon Leadership Forum here at UW; landscape construction and maintenance with Ecoyards, LLC; each experience has helped to inspire a vision of an integrated environment. The anthropocentric lens which I am applying herein has been heavily influenced through studying the humanities, working with nonprofit organizations, training with a theater group whose mission is "To promote, through active and challenging dramatic work, open and honest dialogue about racism and oppression in America in order to repair its damaging legacy." ("Conciling the Past: The Conciliation Project"), and working on film and art projects exploring the impacts of colonization, oppression, racism, and religion on identity, history, and our current reality.

Today's reality includes a raging pandemic, deep social divides, tremendous inequity, a global food system on the edge of collaps, and rapidly gaining climate and weather extremes. In presenting this thesis, it is worth noting that this has been an unprecedented time with unique challenges. These challenges are already on top of the other social, physical, and mental health issues experienced during graduate school for these professions. It is with profound gratitude that I thank everyone who has provided scholastic, editorial, emotional, psychological, material, monetary, moral, and spiritual support. I am better for having gone through it with you all.

Fig. 19 - "ReSeedence" considered using shipping containers as a delivery mechanism for tools, materials, and photovoltaics, which could convert to structure for a building growing out from within. The site was the same as that covered by this thesis, though the concept has shifted since. If anything, I do wish my pre-grad school explorations had been immediately encouraged within the context of the program.

The site being considered for this project was the same as that covered by this thesis, though the concept and program has since shifted. If anything, I do wish my pre-grad school explorations had been immediately encouraged within the context of the program.

Endnotes

"Conciling the Past: The Conciliation Project." TCP. Accessed June 8, 2020. https://www.theconciliationproject.org/.

2 FRAMEWORK & LITERATURE REVIEW

2.1 Building History

It begins with a story. The Story of Story, as it were. It being the origin of our species and how we have come to define ourselves, and, by doing so, affected the evolutionary path of every living organism that lives today. When we look at the threats we face as a species, author Yuval Noah Harari points to the power of story as both the potential way for making our way beyond our current catastrophic state of affairs and the essential answer to how we got to this point in the first place. His book, Sapiens, tells the story of our species in a way which weaves together everything from evolution, religion, to the development of Limited Liability Corporations. He acknowledges that stories are born of language as a means of communicating information. But Homo sapiens is not the only species to develop linguistic skills or communicate with sound. Our sounds, themselves, are often born of mimicry of other species and natural phenomena. Some languages, dialects, and accents appear to be inspired by the calls, crashes, and cacophonous interactions particular to the environments in which they developed. As Timo Maran argues, mimicry is a part of a larger sign process between species, where information is shared, interpreted, and affects the wider environment. (Maran, 2017, pp 1-10)

Fig. 20 - Nearly 400 human footprints estimated at 5,800 to 19,100 years old preserved in the mudflats near Ol Doinyo Lengai volcano in Tanzania. (Liutkus-Pierce, 2016, pp 68-82) What united them as a people? According to Harari, it was (and remains) the power of Story.
Image: Liutkus-Pierce, 2016.

Within the framework of biosemiotics, our language and stories fit into this larger pattern (and pattern sharing) of phenomena in a way that makes it less unique and more clearly biomimetic in nature. What differs, however, is the ability to share information that is entirely invented and not reflective of any objective or subjective reality. Harari shows how abstraction and myth alike are tools we possess that, in some ways, do set us apart from our closest evolutionary relations.

As designers, we learn the power of story is essential in conveying our ideas and swaying others to pursue our concepts and solutions as the best choice of action. Again, Harari's point holds. In his lifetime work as a designer and influencer, R. Buckminster Fuller was most effective in his writing and self promotion. Like Harari, and as I saw at the Bjarke Ingels Group (BIG) exhibition at the Danish Architecture Center in Copenhagen recently, these authors and designers framed their work and arguments within the context of the full scale of known reality, from the Big Bang, the formation of the stars, to the condensation of our solar system into the masses of the planets spinning around the Sun, and on through the evolution of life upon the face of our Earth. Fuller references our planet as a spaceship, a fitting metaphor for a person trained by the Navy. It is through the retelling of the story of human social development in his Operating Manual for Spaceship Earth that Fuller pushes for a reassessment of how we consider our own place here "aboard" the planet. (Fuller, 1969, pp 58) Resources have been seen as finite, but Fuller reframes the standard economic model of scarcity entirely.

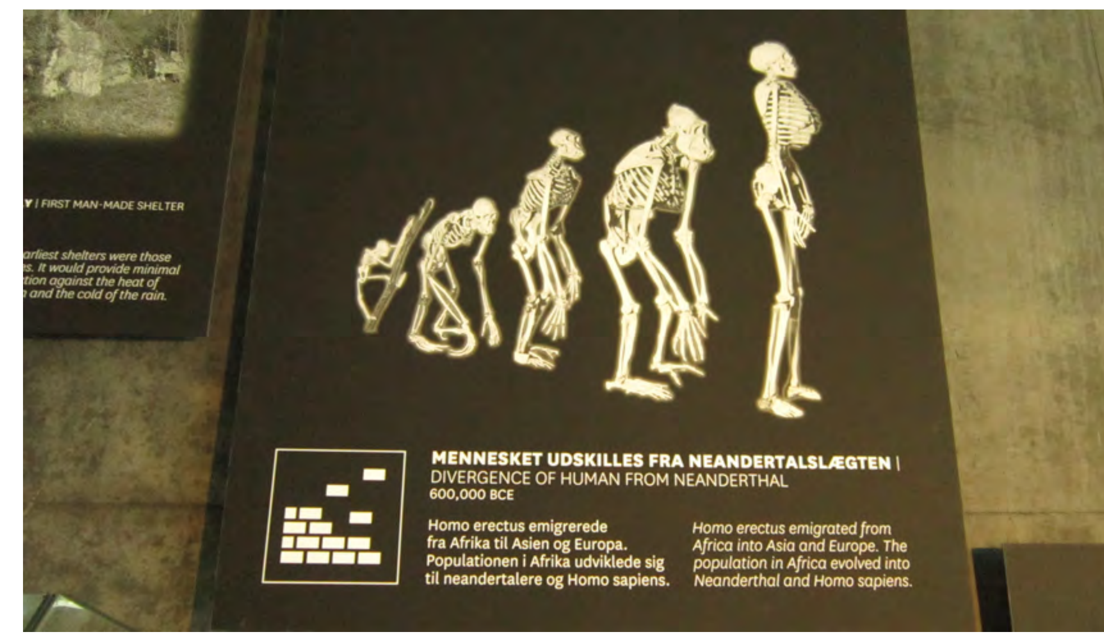


Fig. 21, 22 & 23 - Bjarke Ingels Group (BIG) recent exhibition at the Danish Architecture Center tells the story of the development of the built environment within the context of deep time, evolution, human inventions, and the near-distant future.

2.2 Animal Architecture

This framing, however, is limited in the way it reframes the planet in mechanistic human terms. The planet becomes machine, one that we must operate as only our species is able. It may be too close a corollary to the words of Le Corbusier, for this planet, our home is so much more than a machine - as the leaking roof of our ozone layer and climate change-driven flooding is proving. Our world is alive. An alternative perspective to the mechanistic arises from the study of evolution, animal architecture and biomimicry. The iterative process of design is revealed to be an evolutionary process which capitalizes on the flexibility of our brains and social networks, the increasing connectivity of which provide ever more elaborate reinvention and reenvisioning of what we had made before.

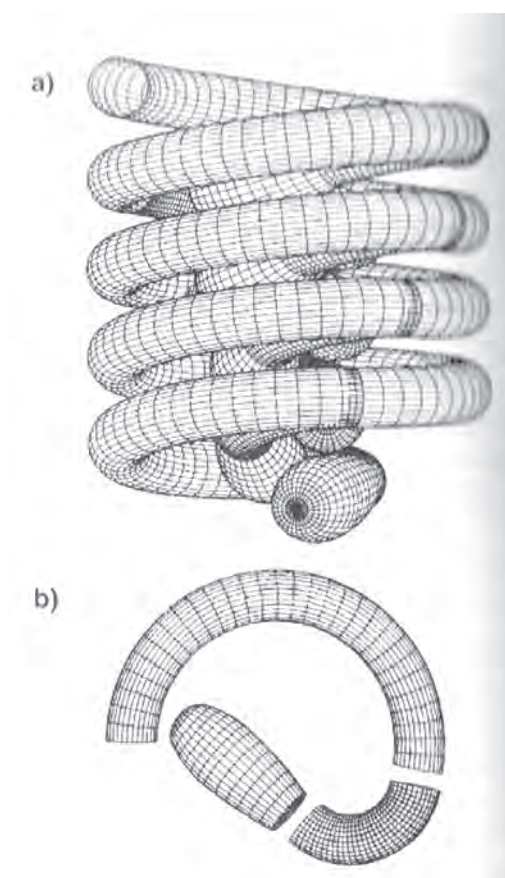
The germ of a great many of our species' inventions in the built environment are revealed in the works of Karl Von Frisch (Frisch, 1974) and later by Mike Hansell (Hansell, 2005). Animal Architecture is the title of the books by these authors and was adopted for the exhibition and accompanying book by Juhani Pallasmaa and the Museum of Finnish Architecture (Pallasmaa, 1995). What is revealed within the pages of each of these books are materials and construction techniques which predate our own often by millions of years and which demonstrate an elegance in structure and sustainable design which our own works have come to utterly disregard. Why the wide disparity? Here I argue that it comes down to the context provided through the stories and myths we have come to tell about ourselves and our relationships to nature.

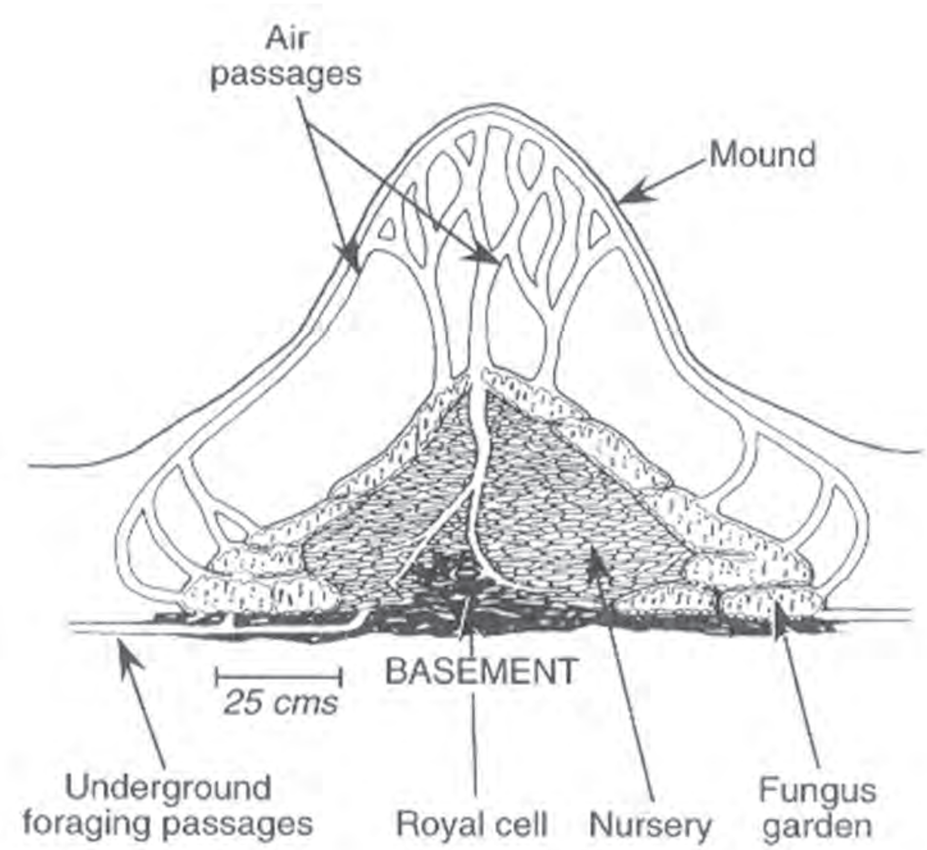
So this thesis, while being about the applications and inspirations available through biomimetic design, approaches this conflict through the method of story, framing the built environment as inherently biological. By reframing buildings and infrastructure through the concepts of living systems and as biological organisms, as members of the kingdom Archinae, design is then emphasized as a means for mitigating the harm done by the plagues our species has unleashed in the form of unsustainable, energy intensive, and invasive "species" of our own making. Like the selective breeding of corn and other domesticated species, it is through design, for now, that the Archinae must evolve.

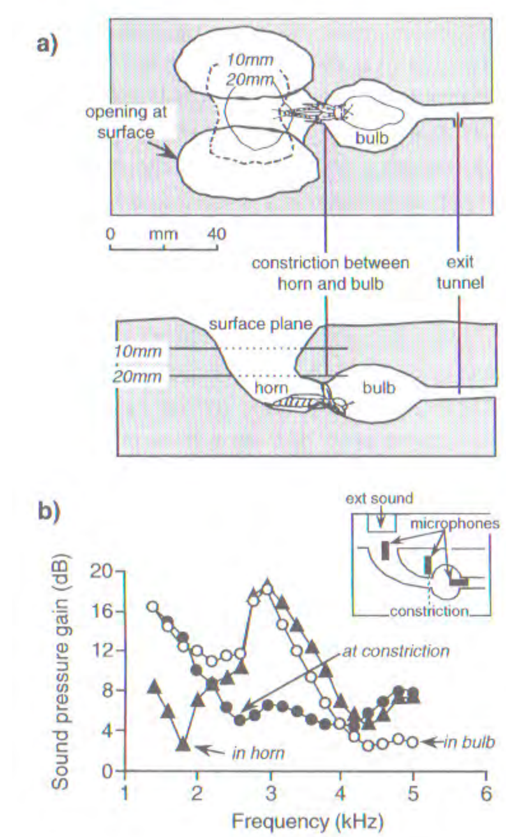
Fig. 24 (left) - Burrowing behaviors of bees give an insight into the ways in which the body influences the structure, while modular forms allow for easy repetition. One might even think this design was built to be ADA accessible. Image: Frisch, 1974, pp 138.

Fig. 25 (middle) - Termites move and mix earth, saliva, and dung to construct skyscrapers which behave as living lungs while simultaneously providing residences for inhabitants of all ages. They even practice mycoculture - mushroom farming. Image: Hansell, 2005, pp 7.

Fig. 26 (right) - Some crickets even excavate stereo amplifiers from the sand in such a way that they protect their own hearing while assuring themselves an escape route. No grand designer needed orchestrate this - it is the slow process of learning offered by ages of iterative, biological design. Design that science is only just beginning to uncover and unravel. Image: Hansell, 2005, pp 29.







2.3 Permaculture/Mycoculture/Urban Agriculture

We find echoes of this in the work of Bill Mollison, one of the originators of the concept of Permaculture (permanent agriculture). Emphasizing regenerative practices which are meant to mimic and integrate the natural processes of weathering and biological effects on resource flows, permaculture is as much a design ethic as it is a toolkit for design. Prior to publishing his books and even prior to developing the concept with David Holmgren in the 1970s, the practices of permaculture were passed within and between indigenous cultures as practice and through story. The description of permaculture as "the harmonious integration of landscape and people providing their food, energy, shelter, and other material and non-material needs in a sustainable way" (Mollison, 1988, pp ix) echoes the growing understanding of sustainable processes found in environments on nearly every continent prior to colonization and the spread of Western culture.

Today, the design of the built environment is finally beginning to come full circle. An emphasis on sustainability, locally resourced materials, integrative and iterative design practices, the incorporation of "nature" for biological processing of wastes and for biophilic effect, are coming to the fore thanks to scientific research and a rewriting of the racially charged, colonial narrative of oppression. Cooperation is what allows nature to create abundance, and it is from this example that authors like Paul Stamets propose a way to mitigate and even undo the harms done by the last few hundred years of human development.

"It is obvious that the real wealth of life aboard our planet is a forwardly-operative, metabolic, and intellectual regenerating system.

Quite clearly we have vast amounts of income wealth as Sun radiation and Moon gravity to implement our forward success.

Wherefore living only on our energy savings by burning up the fossil fuels which took billions of years to impound from the Sun or living on our capital by burning up Earth's atoms is lethally ignorant and also utterly irresponsible to our coming generations and their forward days.

Our children and their children are our future days.

If we do not comprehend and realize our potential ability to support all life forever we are cosmically bankrupt."

~R. Buckminster Fuller
from Operating Manual For Planet Earth, 1969, pp 87

In Mycelium Running: How Mushrooms Can Help Save the World, Stamets tells the evolutionary story of fungi and how their forms echo those of the universe beyond and are mimicked in the structures of our own brains and the internet we now rely upon. (Stamets, 2005, pp 9) Mushrooms - the fruiting bodies of fungi - providepowerful medicines which actively heal, kill off disease, and amplify the effects of other treatments. Mitigating the damage of industry and pollution, mycofiltration and mycoremediation not only allow fungi to do what they do best - break down materials and chemicals into inert and even beneficial byproducts - but to also provide food for ourselves and other species. Mycopesticides offer a potential for eliminating the use of widespread poisons which are devastating to our own health and the self-regulating effects of beneficial biodiversity.

Fungi, their mycelium and mushrooms, work with species, actively passing nutrients and messages between the roots of plants, breaking down plant and animal matter into readily absorbable nutrients, and adding value to ecosystems to the benefit of kingdoms and species well beyond their own. Stamets aims to integrate the utility of fungi into the built environment through mycoforestry and his “Stametsian Model for a Synergistic Mycosphere” - a twist on the Mollison’s permaculture model - laid out in his Growing Gourmet and Medicinal Mushrooms. (Stamets, 2000, pp 145) Here is an opportunity at maintaining and restoring an alliance with a fellow Kingdom of Life, one of the most intelligent and transformative we’ve come to know.

Fig. 27 - Paul Stamets’s spin on permaculture infuses fungal relationships into numerous aspects of the homestead for the treatment of wastes and production of food. This includes habitats and roles for: 1 - Oyster mushrooms; 2 - King Stropharia; 3 - Shiitake/Nameko/Lion’s Manes; 4 - Polypores & Clustered Woodlovers; 5 - Shaggy Manes; 6 - Morels; 7 - Mycorrhizal species; 8 - Sacred Psilocybes.
Image: Stamets, 2000, pp 38.

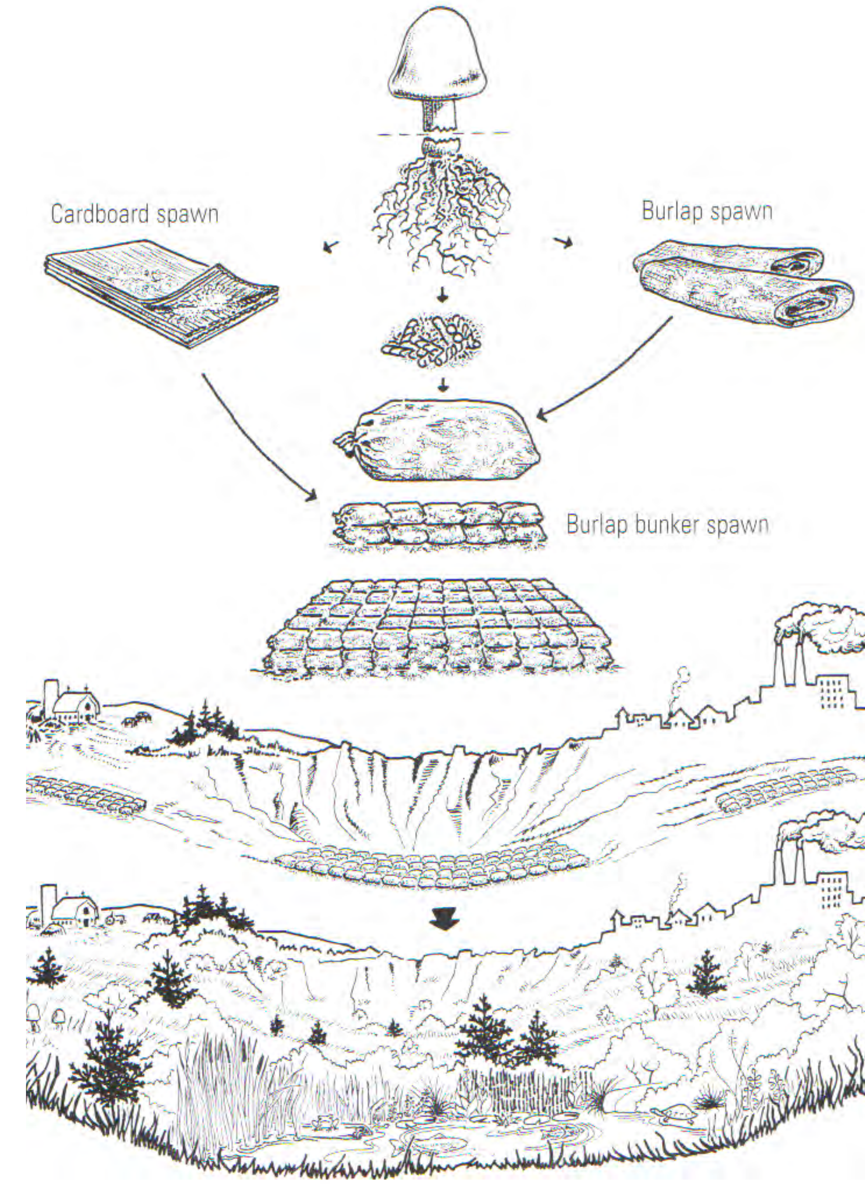


Fig. 28 - A mycological approach to environmental restoration from industrial and agricultural contamination and eutrification. In this case, the waste mushroom “butts” are used to innoculate wood dowls, cardboard, and burlap simultaneously. These are wrapped up and tied off to be used as erosion control and runoff capture, acting as a mycological filter for the pond below.
Image: Stamets, 2005, pp 145.

Such systems are readily applicable to those explored in the urban context through texts like Gundula Proksch's Creating Urban Agricultural Systems, 2017. Proksch provides a near exhaustive accounting of the systems being designed, built, and integrated into urban environments with the goal of creating a "Zero Waste Future." The case studies presented show how technology, infrastructure, and structures can and are being used to produce food in environments where biodiversity has dropped surreptitiously due to human development and humans rely extensively upon fossil fuels to not only bring their food from great distances, but also to provide artificial nutrients to replace those that have been stripped from our over-farmed soils through the industrial model of agricultural production. Aquaculture, hydroponics, greenhousing, and rooftop farms represent approaches which reduce agriculture's footprint, capitalizing on underutilized space while providing microclimates which increases the range and seasonality of the foods being grown. The limitations of these systems are explored, with costs and benefits sometimes painting unflattering pictures of projects that seemed great in concept but are less effective in reality than had been hoped. Seen as an iterative process, there is room for these concepts to evolve beyond their limitations if reconsidered within the biological systems perspective proposed within this thesis.

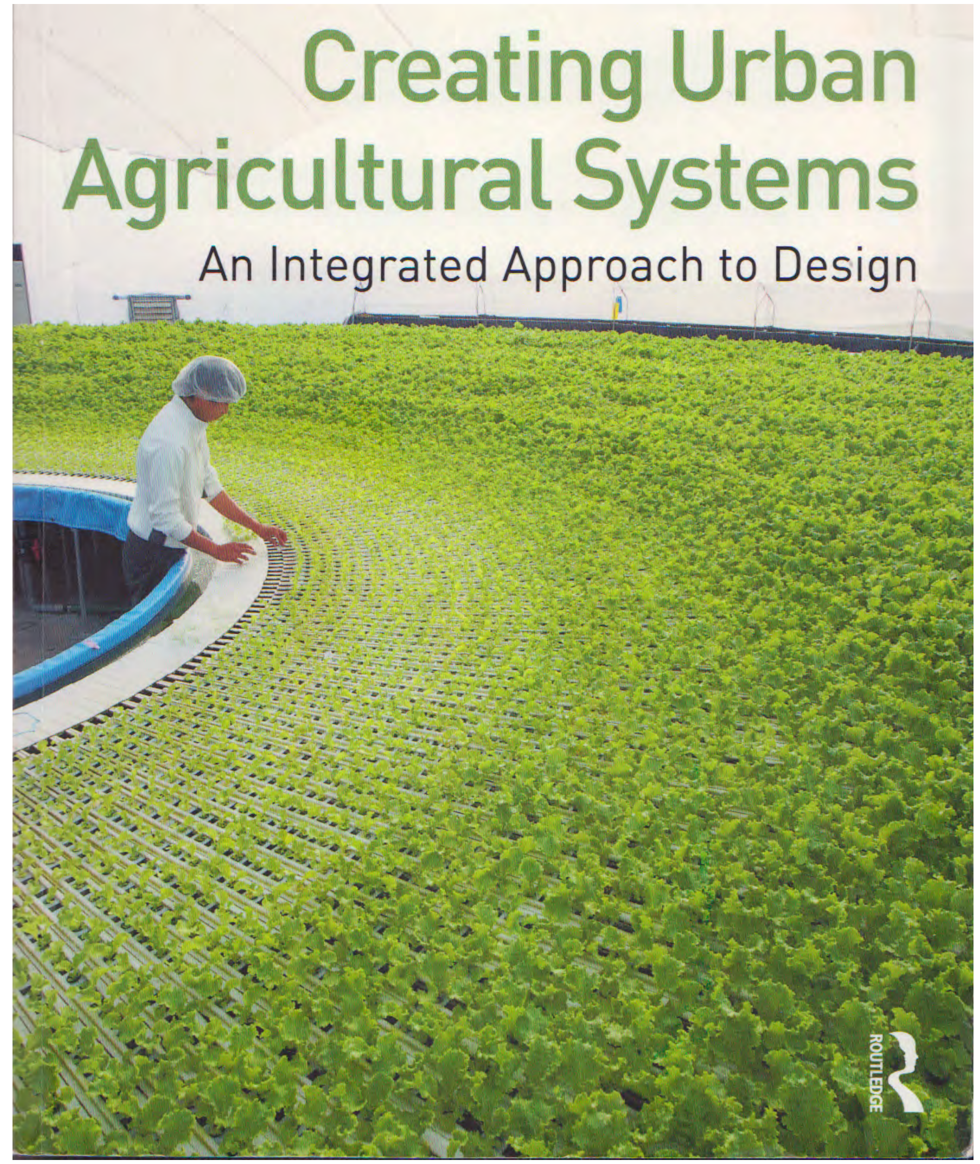


Fig. 29 - Gundula Proksch paints the future of food in the urban environment in a palette of aquaponics, hydroponics, closed loops and a host of greenhouse typologies. The diagrams are clear and easy to understand and care is taken to explain where projects succeed and where they fall short of expectations. Pictured: Granpa Domes, Yokohama, Kanagawa, Japan.
Image: Proksch, 2017, cover image.

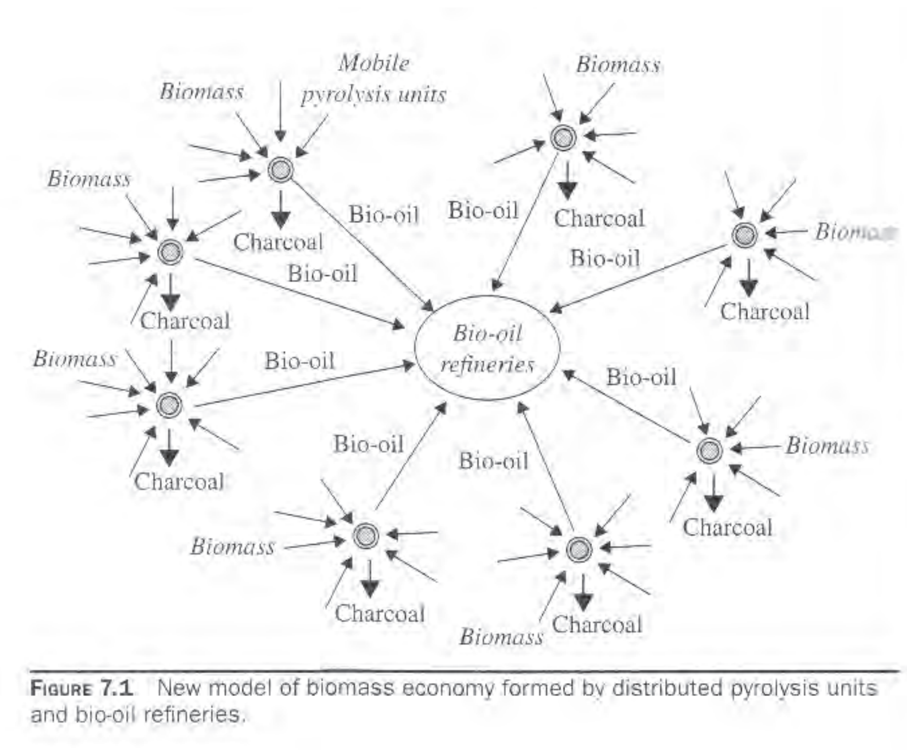


FIGURE 7.1 New model of biomass economy formed by distributed pyrolysis units and bio-oil refineries.

Fig. 30 - What drew me to Nag's Biosystems Engineering initially was the placement of pyrolysis and gasification in the context of agricultural and forestry practices - a concept evident in pre-graduate studies explorations and in the Organ system described below, GUTS. Here, it forms the basis for a new energy economy. A biomimetic typology like the Archinae could act as nodes in a system like the above, producing biochar and fuel in a perpetual act of carbon sequestration and fossil fuel displacement.
Image: Nag, 2010, pp 214.

2.4 Biosystems & Biomimicry

Casting a wide net in order to bring together diverse technologies and processes in order to better design our built environment within the context of the challenges we currently face is a running theme in these readings. In Ahindra Nag's Biosystems Engineering, 2010, a wide array of approaches, techniques, and technologies are brought together with scientific data to support their use and implementation. Machine learning, data analysis, and automation are presented within the same context as soil and water conservation, heat transfer models, GIS-based watershed modeling, water management systems, and biomass pyrolysis. The diversity of subjects is not haphazard; rather, it reflects the complexity of systems which operate and can be integrated into the built environment. Whether looking at farmland or rooftop farms, the systems and resource streams which interconnect us with our food are best considered through exhaustive research and authors like Nag and their contributors provide biosystems engineering as yet another toolkit based upon biological systems and biomimetic design.

Looking beyond the applications of biology integrated into design through systems, Michael French and Yoseph Bar-Cohen provide opportunities to explore how biology and nature provide insight into design and engineering. Geared towards engineering students, these textbooks provide illustrations and examples demonstrating the ways in which engineering and design principles are shown to exist in nature. Their approach is more closely aligned with that espoused by the Biomimicry Design Institute and visualized in the Biomimicry Design Spiral (fig. 4). Janine Benyus, founder of the Biomimicry Design Institute and the consulting firm, Biomimicry 3.8, provides examples and insight into the relevance of biomimetic design in Biomimicry: Innovation Inspired by Nature, 1997.

A toolkit or "seed bank of best practices" has been gathered in Biomimicry Resource Handbook, 2014. Their argument is that the principles which guide the processes by which life operates are exactly the same as those which should be applied to the design of our own systems and structures. The annual conference of Bioneers takes this approach to all kinds of environmental and social issues, as described in the various chapters of Nature's Operating Instructions: The True Biotechnologies, 2004. Here we are introduced to a world in which working with nature, rather than attempting to dominate it, provides sustainable, ethical, and aesthetically desirable solutions. Rather than retelling the myths of an abstract humanoid creator, we are reminded of how our ancestors and extant indigenous societies have and continue to draw from the profoundly deep pool of inspiration found within the non-human communities around us.

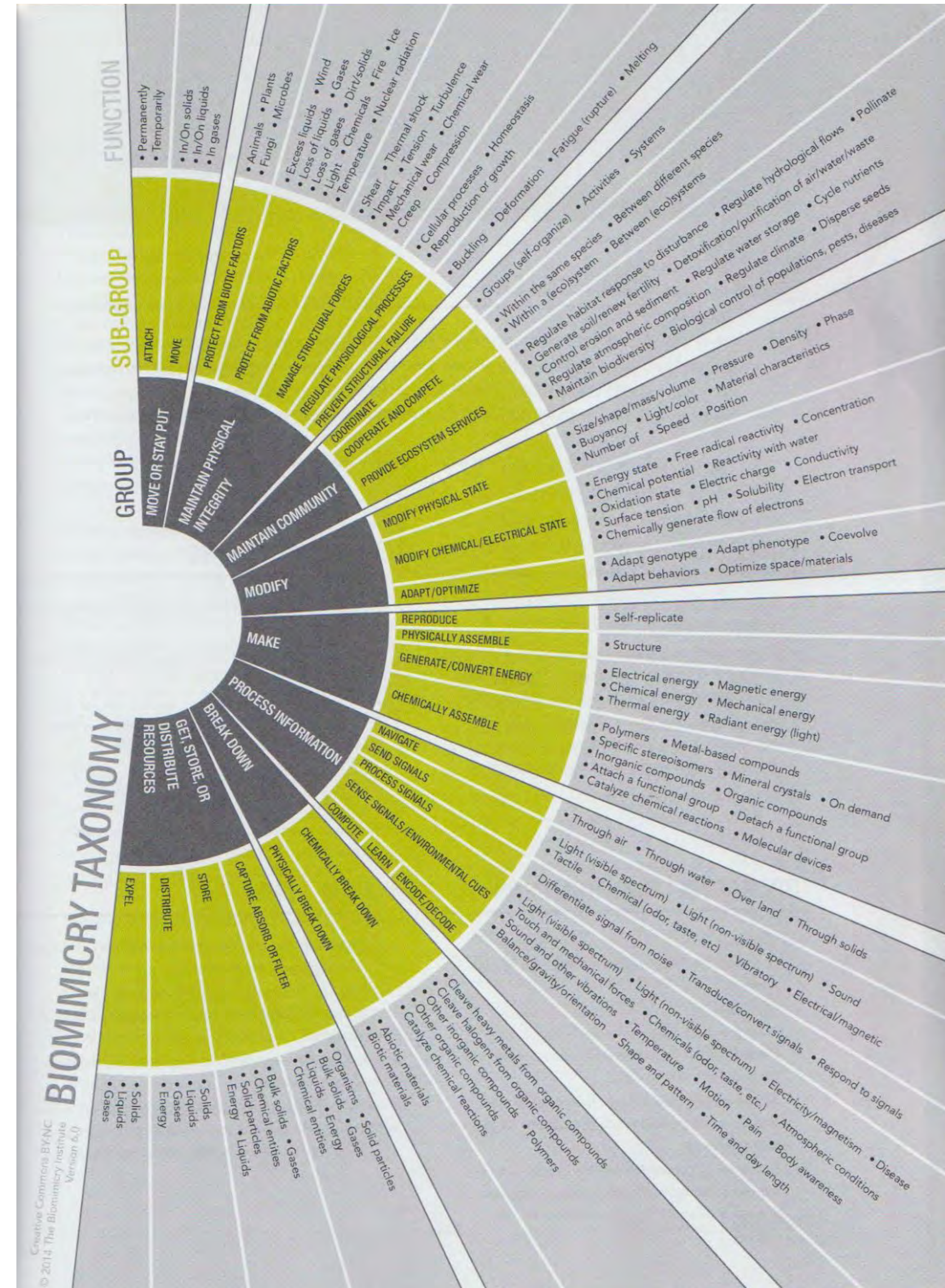


Fig. 31 - The taxonomy of biomimicry is readily recognizable to designers and engineers alike. The Biomimicry Resource Workbook, produced by the Biomimicry Institute, provides many tools for practicing biomimetic design.
Image: Baumeister, 2014, pp 113.

In Invention and Evolution: Design in Nature and Engineering, 1996, French describes the difference between design for function and design for appearance, explaining the former precedes the latter in terms of importance.

> "Living organisms are examples of design strictly for function, the product of evolutionary forces rather than conscious thought, yet far excelling the products of engineering. When the engineer looks at nature [they see] familiar principles of design being followed, often in surprising and elegant ways. Sometimes, as in the case of flight, [they are] inspired to invention: more commonly, [they discover their] ideas are already embodied in some animal or plant." (French, 1996, pp xvii [Edited for gender bias])

In Biomimetics: Biologically Inspired Technologies, 2006, Bar-Cohen goes so far as to describe the concept of A-Life, or artificial life, which "suggests the synthesizing of life from nonliving components." It is closely related to, and followed in the book by artificial intelligence. It is to this furthest extent that this thesis explores the application of biomimetic design on the built environment. What would our world look like if our buildings and infrastructure were recognized and developed as living organisms as opposed to a collection of boxes and pipes? How does this reframing affect our business and behavior? What does the geological era we are stepping into look as we transition away from an anthropocentric view to one where the sustainable and regenerative proliferation of the Archinae take center stage?

Fig. 32 - The idea of a living environment controlled by A.I. is not new and is fast becoming a reality - "minus the paranoia and betrayal." (Dockrill, 2018, pp 1) While science fiction gives us responsive spaceships with personalities, what can a future of habitation on Earth look like with self-constructing homes that show you how they feel and show you that they care?
Image: 2001: A Space Odyssey/MGM.

Fig. 33 - The thin line between artificial and living is seemingly non-existent in science fiction films like Ex Machina. This is A.I. but not necessarily A-Life - sentience and cognition within a mechanized frame.
Image: Ex Machina/Film4/DNA Films

2.5 The Urban-Rural Divide: Tall Tales

I feel that the concept and perception of the "Urban-Rural Divide" is something that requires addressing in this thesis. The question has arisen multiple times - as it did during my final thesis review - as to why I would choose to even look at a rural setting for a thesis, given the urban focus of the UW's Architecture and Landscape Architecture departments. The simple reason is that I no longer view the divide as an accurate descriptor of the dynamic between the hyper urban areas and those we classify as rural, rather that the rural is impacted heavily and inevitably results from urban life, practices and design. In differing ways, the reverse is also true. Bruno Losch argues that this perspective leads to a type of "spatial blindness: stove-piped visions… result[ing] from sectorial approaches but also from a statistical segmentation between rural and urban areas, as if they were completely enclosed entities." (Losch, 2015, 172) This has not only led to a reduction in resilient diversification in "rural" areas in terms of production and knowledge bases, but also sees a corresponding reduction in food system resilience in urban areas.

This overly-reductive approach to our variably occupied ecosystems also ignores the movement of resources between these environments via physically separated family members. "These 'archipelago systems' facilitate greater diversification and risk management, improve the economic prospects of households and offer new perspectives for rural change. They also contribute to the emergence of new 'functional spaces' ignored by public policies."(Losch, 2015, 173)This burgeoning perspective, shared in dozens of papers with a similar title, reveals that viewing the urban, periurban (suburban), and rural environments as separate conditions seems problematic and may be proving catastrophic.

Some of these issues are highlighted by Scott, Gilbert & Gelan in their policy brief The Urban-Rural Divide: Myth or Reality. After addressing specific myths, their takeaways for the Scottish government are that "stereotypes rarely illuminate but obfuscate issues; the countryside is not a single homogenous entity, it is multifunctional and diverse; the institutional response needs to shift from its sectoral past to embrace a more integrated approach that recognises urban-rural interrelationships; the lack of strategic policies across agencies and different governance levels for biodiversity, transport, energy, housing and services means that there is no comprehensive vision for the countryside that all bodies can sign up to; [and that] the identification and diagnosis of socio-economic problems as well as policy prescriptions require the use of different tools at different spatial scales – transgressing traditional urban-rural boundaries;" (Scott, 2007)

The fact is that designing for density and diversity needs to be applied to all of these environments if we are to reduce human impact on our landscapes and offer opportunities at re-wilding. (Ausubel, 2004, pp 17-31 & 92-98) This does not mean designing skyscrapers for the countryside. It does mean designing with practices that:

- eliminate stormwater runoff, mitigate pollutants,
- cycle nutrients while treating waste locally,
- take advantage of structure,
- increase plantable surface area while reducing the carbon/energy/biocidal footprints of farms,
- and incorporate renewable energy into all of these systems - from the heights of the concrete jungle to the end of the dirt road.

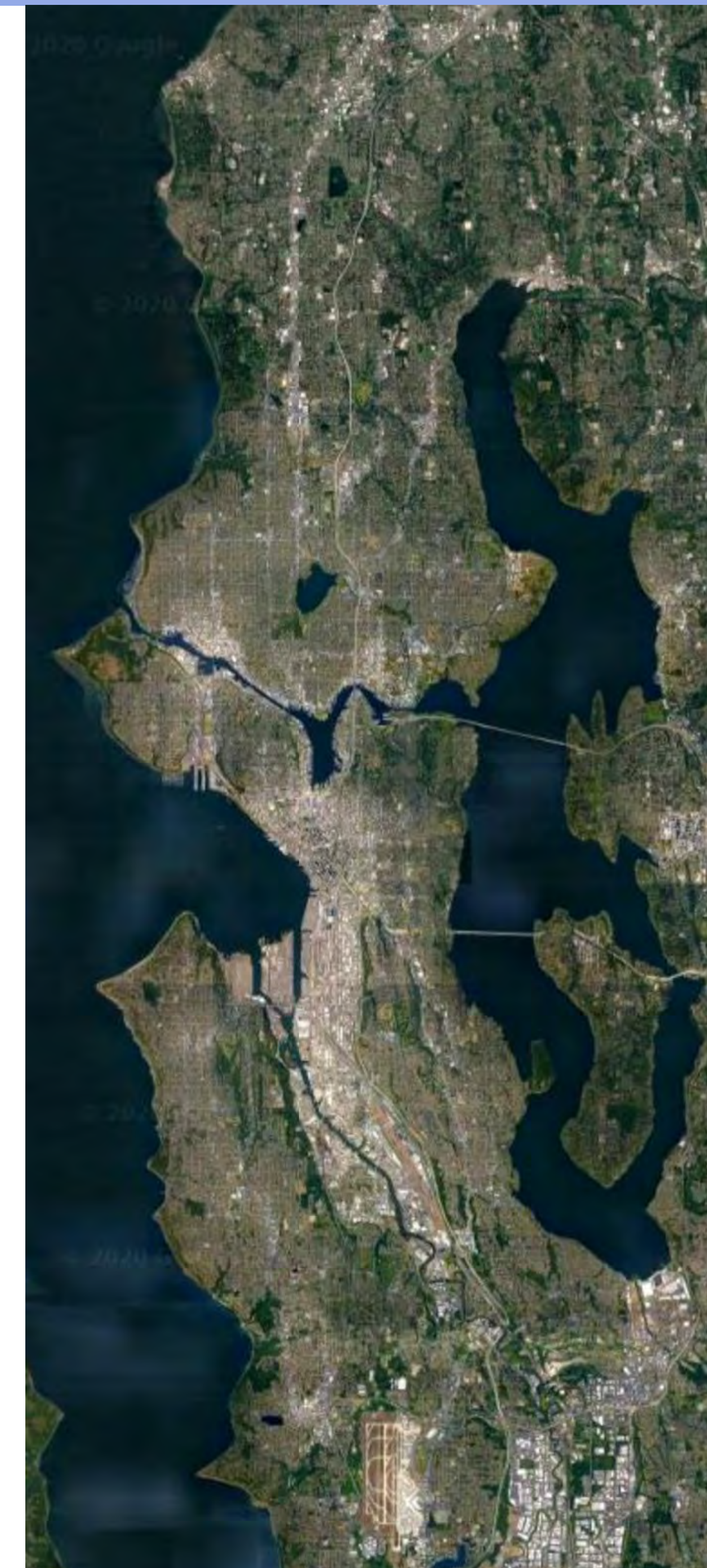


Fig. 34 - The City of Seattle, as seen through Google Maps. Compared to the Waterlines Project (fig. 5), the built environment almost appears as exposed bone or a calcification on the skin. The living tissue of the earth is scraped away and piled upon in a mad scrabble to fit as many people as possible into as sparse a space as we can create. Intentional use of biomimetic design provides solutions to this form of abiotic design at all scales.
Image: Google Maps.

By focusing on the “urban” environment as the areas with the greatest concentration of concrete and asphalt and rejecting design education of the “rural” , we are ignoring the way destructive patterns of growth are being repeated in areas that have been mistakenly viewed as “unused” by colonial, imperialist, and now capitalist interests. Just as the dense hearts of cities which were then destroyed for “urban renewal,” the spaces on the fringe of cities and beyond are being churned over in an orgy of sprawl. The prevailing perception of what is “urban,” in this case - and in my opinion - is carrying on a tradition which does nothing to mitigate the spread of an untenable condition.

Fig. 35 - While there is evidence that the Urban-Rural Divide is a myth, that is not to say that political fractures are not geographical realities in two party systems like that in the United States. Lawrence Jacobs's opinion piece points to the different perspectives of natives of the most densely populated areas of the country and those who hail from sparser areas. (Lawrence, 2019)

Culturally, however, each side has more in common and greater interrelation with the other than divisive politicians and media personalities are willing to admit - the pessimism reflected in the editorial to the right notwithstanding.
Image: Josh Jones from Lawrence, 2019.

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3 SYSTEMS

Applying Biomimetic Design

The application of biomimicry, according to the biomimicry spiral (fig. 4) was established as following the following steps:

1. ***Identify one or more functions that you want your design to perform***
2. ***Translate those functions into biological terms***
3. ***Discover strategies that nature uses to perform those functions***
4. ***Abstract those strategies back into technical terms***
5. ***Emulate those strategies in your design solution***
6. ***Evaluate your design brief against Life's Principles, and then decide how you want to use your next lap.*** (The Biomimicry Institute, 2014)

The functions of the built environment that I want to address in this thesis can be categorized under three general categories of processes: Building/Construction; Waste Processing; and Climate Controls. Translated into biological terms, these are recategorized as: Growth; Digestion; and Transmission. If the B.E. is to be established as a living thing, the functions a design must perform should be based upon those which define life itself. These processes can be sorted into various categories, depending upon the reference used. Some quote four categories while others quote ten. (Blaettler, 2019) Here I have used the kid-friendly set of seven categories from the Oxford University Museum of Natural History, which goes by the acronym Mrs Nerg - Movement, Reproduction, Sensitivity, Nutrition, Excretion, Respiration, and Growth. ("The Living Animal, Mrs Nerg, and the Seven Life Processes!" 2006).

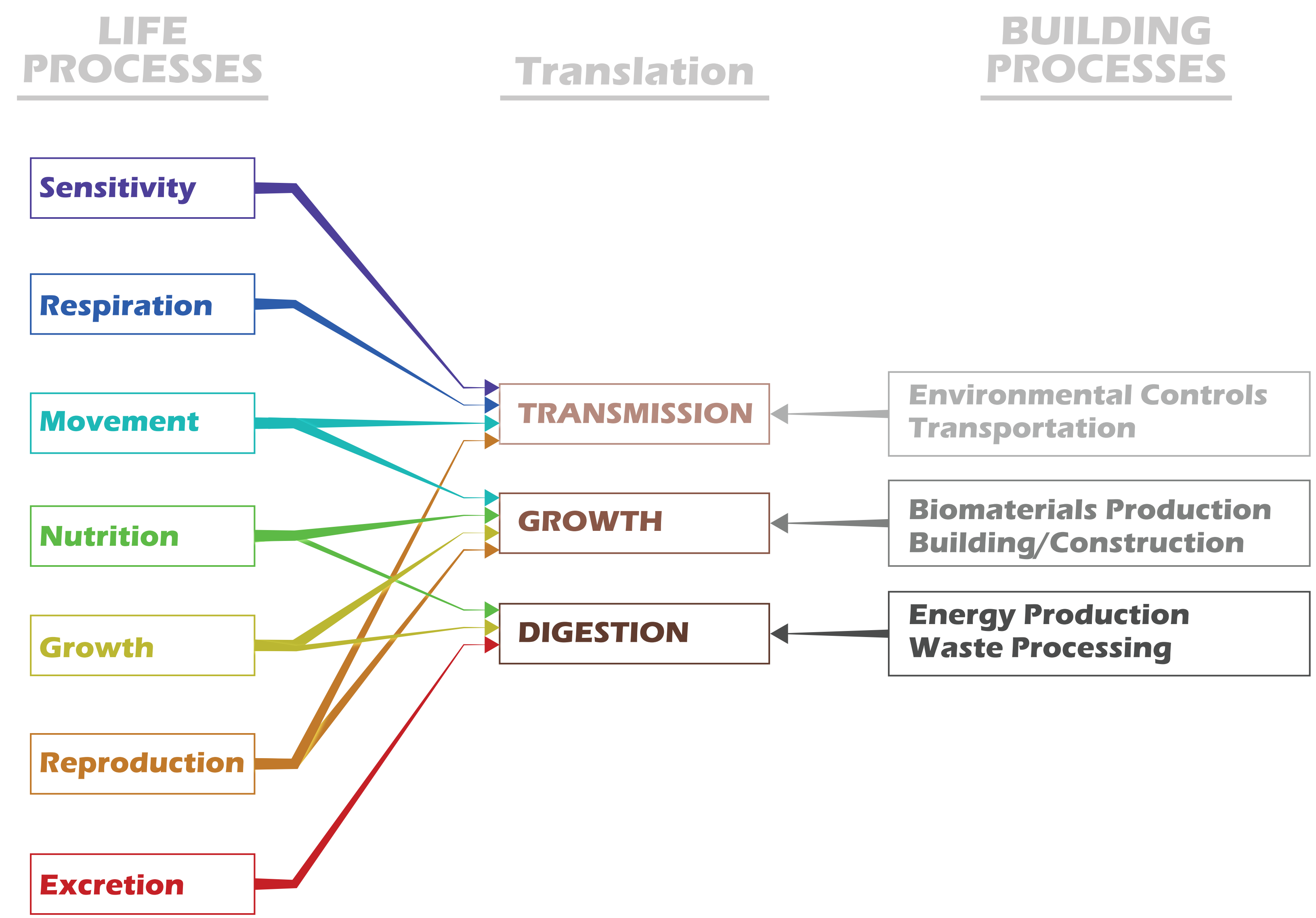

Fig. 36 - The processes which define life can be sorted into various categories, depending upon the reference material. Here seven processes are reduced to three in order to sort the functional systems the B.E.'s "Organs", into an easily remembered set of categories.

Reducing these terms to the previous categories of Growth, Digestion, and Transmission allows for a ready translation back into the functions drawn from the language of the built environment. Transmission comes from the Latin transmittere - literally to "send across." (Online Etymology Dictionary) This denotes passage, movement, and communication. From the passage of information between synapses to the spread of diseases, it is a common biological term. In terms of climate controls it is the movement of air, exchanges of thermal and electrical energy, and the use of sensors and controllers. It should be noted that these processes are interrelated in living organisms, as well as in the context of the "Organs" presented below. For example, Movement can be considered in terms of the response to lateral forces, the adjusting of climate control apparatuses, and the flow of individuals and key equipment within and beyond the site. As the LEAF/LUNG system will show, not only does this system provide transmission of electricity and air, it is characterized by the literal growth of plant matter. Similarly, microbes and fungi are grown in the GUTS and KIDNEY systems.

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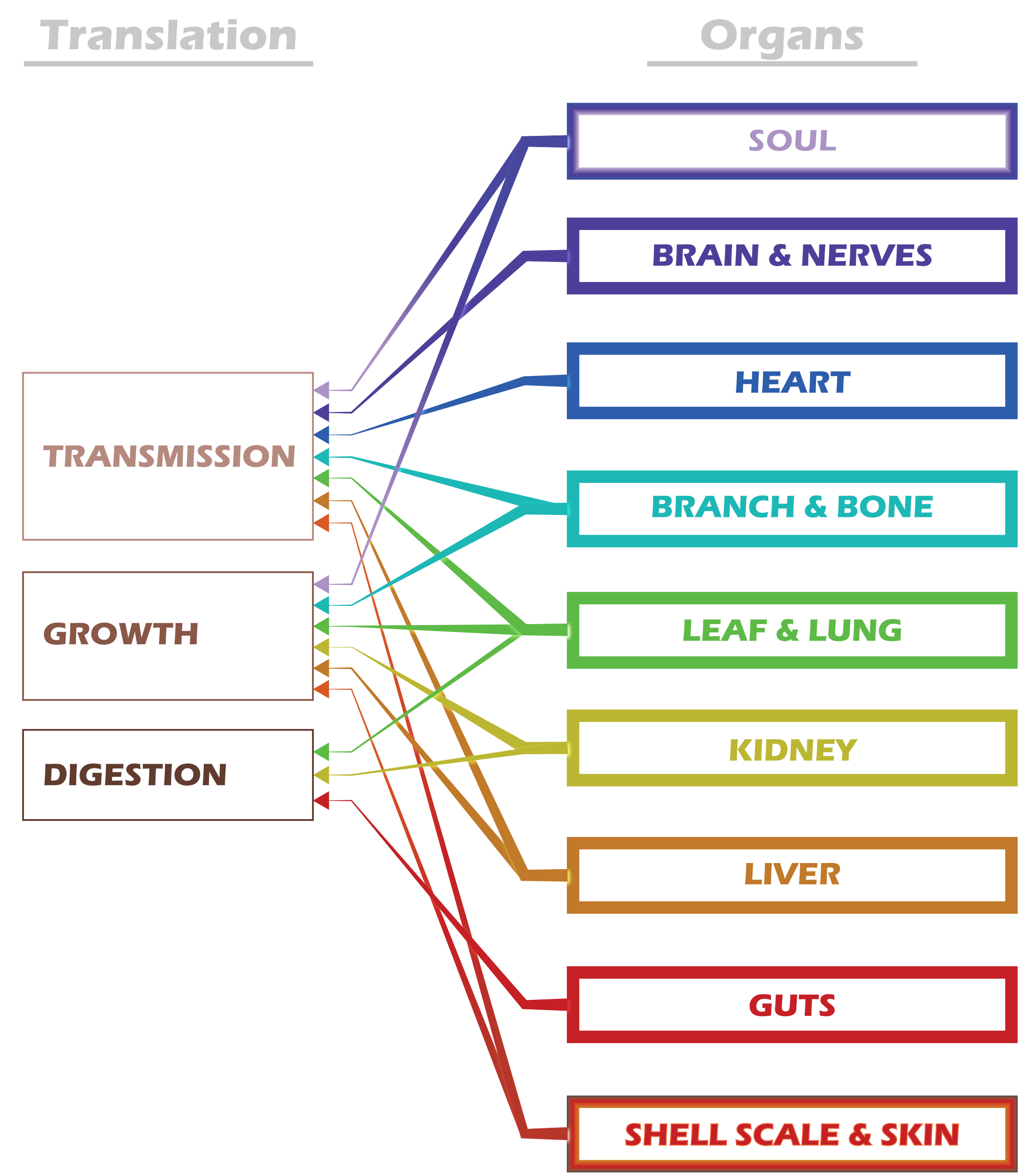

Fig. 37 - The Organs overlap to create a synergistic set of systems fulfilling the basic requirements of life and to be considered alive.

3.1 GROWTH - Alternative Construction Materials

Before there were buildings, life on Earth had to either locate a conveniently sized and protected shelter or to grow the structure which would house their cells, internal systems (organs) and the microbiota within them. Two primary approaches to construction can be simplified as shells and bones. In the former, which includes exoskeletons, materials are combined to form a rigid skin which creates internal microclimates favorable to the organism and its microbiome while providing structural support against external and internal forces. From the microscopic protozoan Difflugia pyriformis (fig. 35), to the now extinct sea scorpion, Eurypterid (fig. 36), the process of growth combines the intake and processing of structural materials and the metabolism of food. Shellfish and insects alike produce their "mobile homes" through processes which operate at ambient temperatures, utilizing readily available materials and elements, and cycle back into the environment through decay - which is to say becoming food for other organisms. However, these rigid structures come at a price, limiting the growth of the organisms themselves due to the sheer weight of the shell or skeleton and the limitations (in the case of insects, for example) of being able to draw in enough air to keep them alive. Termite mounds, which are constructed habitat analogous to these systems, would be skyscrapers reaching a mile high scaled up to human size, but their walls would likely collapse under the load without some kind of reinforcement.

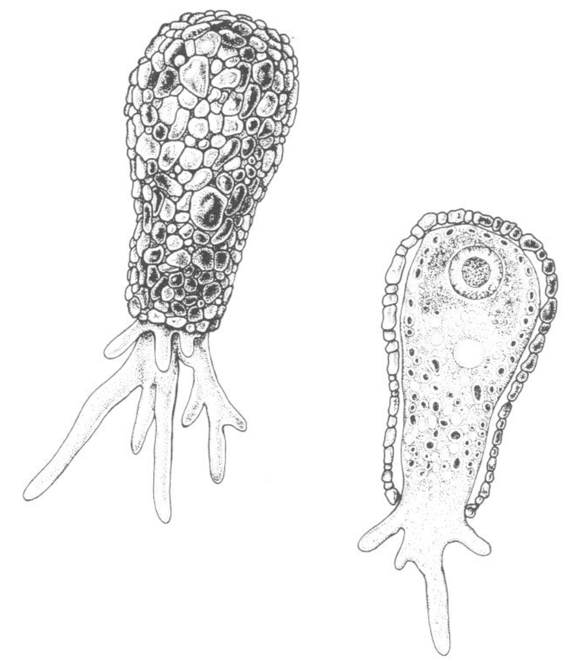

Fig. 38 - Animal as Architecture: Difflugia pyriformis combines indigestible particles with a calcite (limestone) which they make from seawater. Juhani Pallaasma notes that "The grains are very precisely fitted together, and this necessarily implies some system of selection and orientation."(Pallasmaa, 1995, pp49) Unequivocally the world's smallest stonemason.
Image: Frisch, 1974, pp 4.

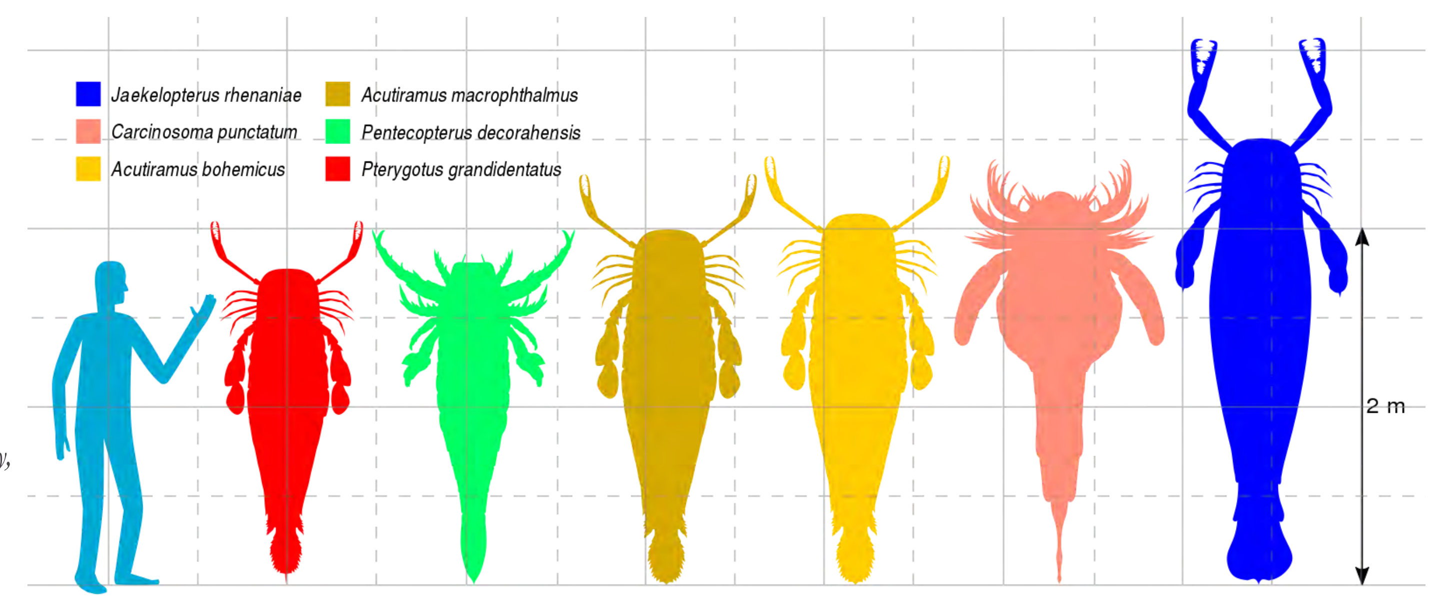

Fig. 39 - Believed to be the largest invertebrates to have existed on Earth, the genus Eurypterid was as tall as the tallest of Homo sapiens. Their evolutionary pathway, however, left them short in the race against animals with skeletons.
Image: Wikipedia, 2018.

When height matters, wood and bone are the structures of choice among the Kingdoms of life. Plants develop woody material, herein simplified to the term "BRANCH" and animals grow skeletons, or "BONE." These composite materials combine rigidity and flexibility while fulfilling other important functions for the individual, species, and ecosystems. Due to their structures of reinforced concrete or cross laminated timber (CLT) columns, beams, slab diaphragms, plumbing and HVAC, our own skyscrapers have more in common structurally with sequoias and giraffes than they do the termite mounds they dwarf in actual scale.

The first systems explored herein are the structural systems. Starting with the latter, BRANCH considers Japanese joinery as a form of grafting, a method used for connecting compatible plant tissues, while BONE looks at composite materials used in structures, emphasizing carbon fiber for its tensile strength, and offers some novel approaches to design and construction of these systems through catenary arches and weaving. SHELL takes lessons directly from the termites and looks at building with earth for its structure and insulating capabilities while SKIN considers cladding and the need for fire resistance in the face of climate challenges specific to the project site of this thesis.

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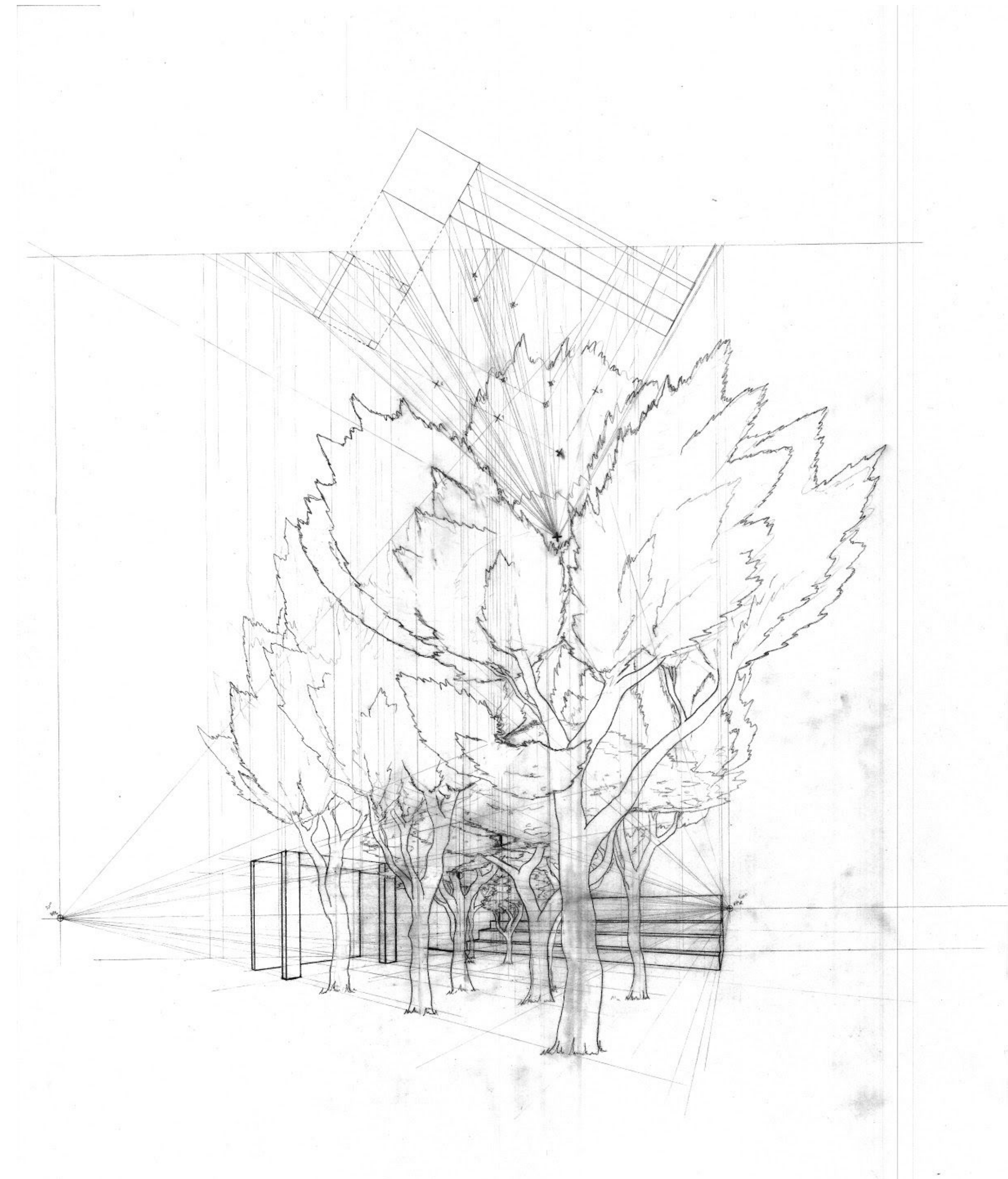


Fig. 40 - The first "built environment" our primate ancestors ever occupied, trees served as protective structures made from air, water, earth, and sunlight.

3.1.1 SHELL, SCALE, & SKIN

Earth, Fire, Fungus

Like bones, skin is multilayered and multipurpose. This reality is reflected in the use of the term in architecture, where cladding systems are often referred to as skin and structural systems are referred to as bones. Skin protects against moisture and sunlight, allows gas exchange, is embedded with sensors, regulates temperature, insulates, and houses conduits for resource flows. Walls, too, possess layers which provide some, and in some cases all, of these benefits to the structure and inhabitants of the building. Wiring and pipes are akin to veins and neurons. Batting or rigid foam insulates against thermal extremes. Thermostats and other sensors provide controls for adjusting heating systems and opening windows. Barriers for vapor, moisture, and rain screens limit and maintain the integrity of the walls and protect inhabitants. As an argument for considering a building as a living organism, the complexity of the skin means that you prick it, it may bleed.

Here, three ideas are explored in regards to skin. First, the notion of skin as structure, as in an exoskeleton. Rammed earth, in particular insulated and reinforced rammed earth, provides many of the benefits listed above. SIREWALL® (Structural Insulated Rammed Earth) is a great example of this kind of system. Reusable formwork, materials gathered from the site itself, rebar from recycled steel, and organic insulation all provide a low embodied energy with the potential for being carbon positive depending on certain variables. Combined with biotechnology such as biocement™, there is the potential to add strength without the need for cement or concrete additives, though this remains to be explored.

Fig. 42 - Structure (framing), barriers, and conduits do for buildings what skin does for us - keeping us dry, comfortable, and free from premature decay. Images: "Parts of a Wall [3 Diagrams of Framed Wall and Layers]."

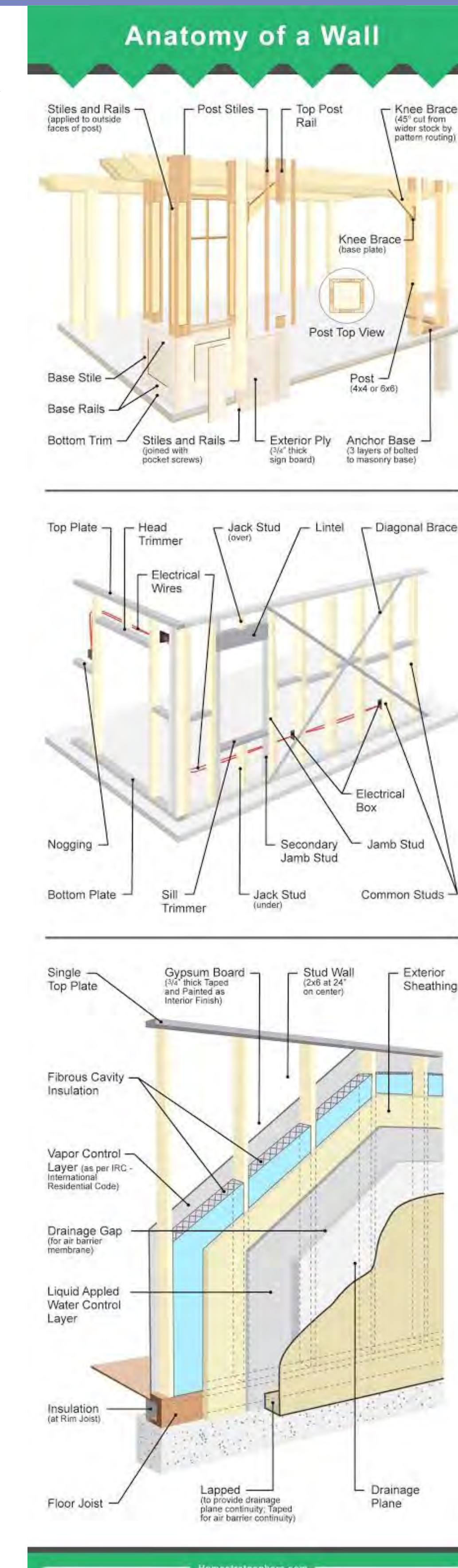
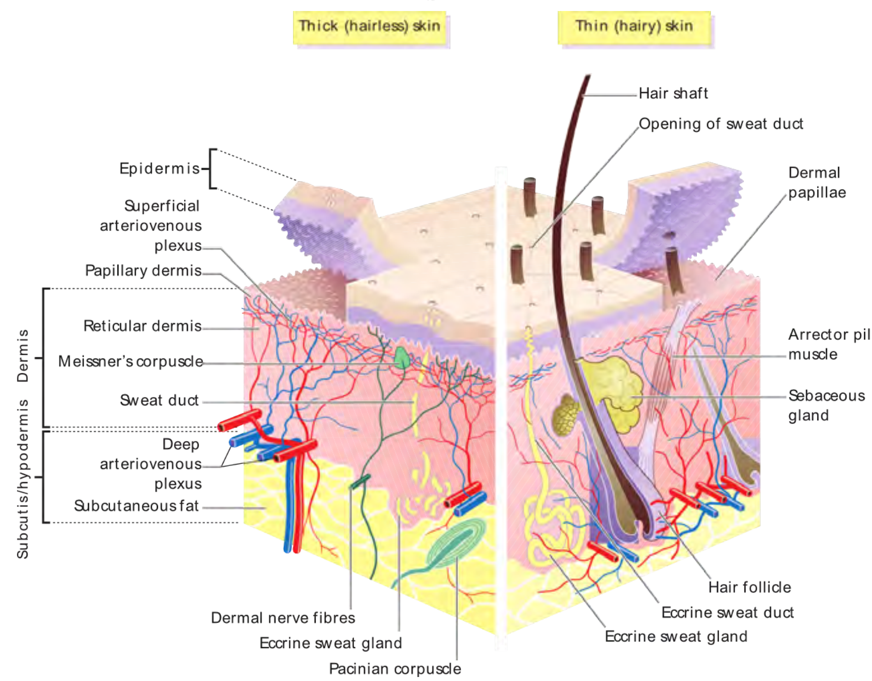


Fig. 41 - The layers and systems found within skin are a direct corollary to the layers and systems found in effective building walls. Image: File:Skinlayers.png.



Rammed Earthworks, meanwhile, has pioneered a rammed earth CMU (concrete masonry unit - commonly called cinder blocks) which can use locally sourced material with a minimized input of cement. Digging deeper, literally, earth-bermed designs such as Earthships can reduce or forego concrete entirely by introducing mechanically stabilized earth (MSE). According to ReinforcedEarth.com, it is "a composite structure consisting of alternating layers of compacted backfill and soil reinforcement elements, fixed to a wall facing. The stability of the wall system is derived from the interaction between the backfill and soil reinforcements, involving friction and tension. The wall facing is relatively thin, with the primary function of preventing erosion of the structural backfill. The result is a coherent gravity structure that is flexible and can carry a variety of heavy loads." (Rammed-Earth.com)

It works well with gabion walls and could pair well with SIREWALL systems. Other benefits include, "Flexibility to accommodate high differential settlement and several feet of total settlement; bearing pressure is distributed over a wide foundation area; extreme wall heights can be achieved; extreme loads can be carried (bridge abutment footings, cranes); high resistance to seismic and other dynamic forces; free-draining, due to granular backfill and open panel joints; form liners or elaborate murals can customize the aesthetics; soil reinforcing strips can easily accommodate obstructions within the MSE backfill volume; special design can allow for nearly any geometry; rapid, predictable, and repetitive construction; superior finished wall alignment; and mechanical connection of soil reinforcements to facing units" (Rammed-Earth.com) Basically much of what you get with concrete and more.

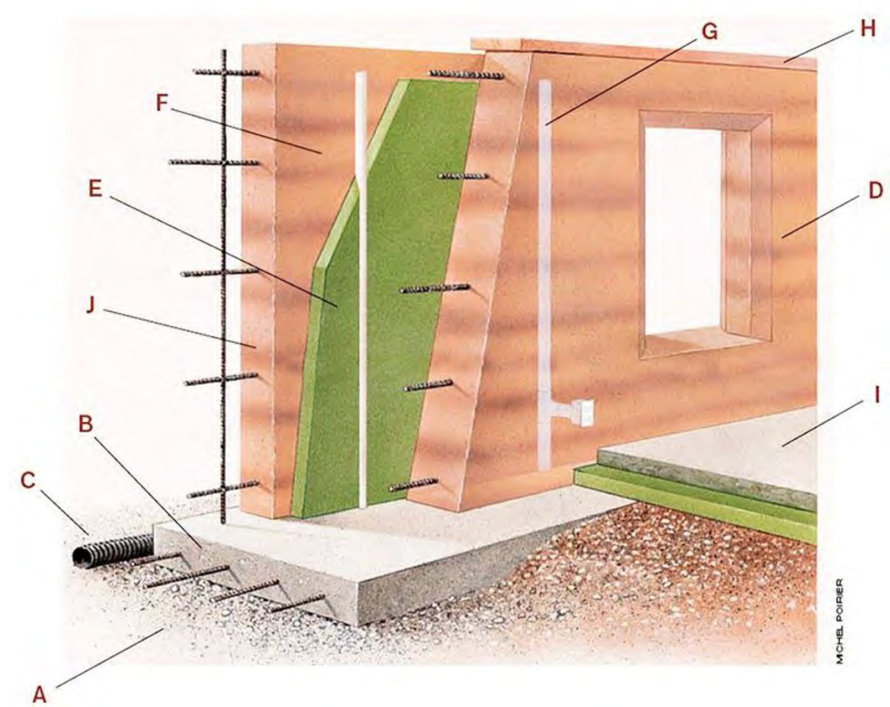


Fig. 43 - The SIREWALL system: A - Rubble trench – 4 inch bed of drain rock; B - Reinforced concrete footing; C - Drain pipe; D - 12 inch interior rammed earth wall, reinforced with steel rebar; E - 4 inch foam insulation; F - 8 inch Exterior rammed earth wall, reinforced with steel rebar; G - EMT pipe to function as electrical conduit; H - Wooden top plate, anchored to wall, ready for roof truss; I - Interior floor; J - Optional anti-graffiti coating. Image and information: SIREWALL.com, 20.

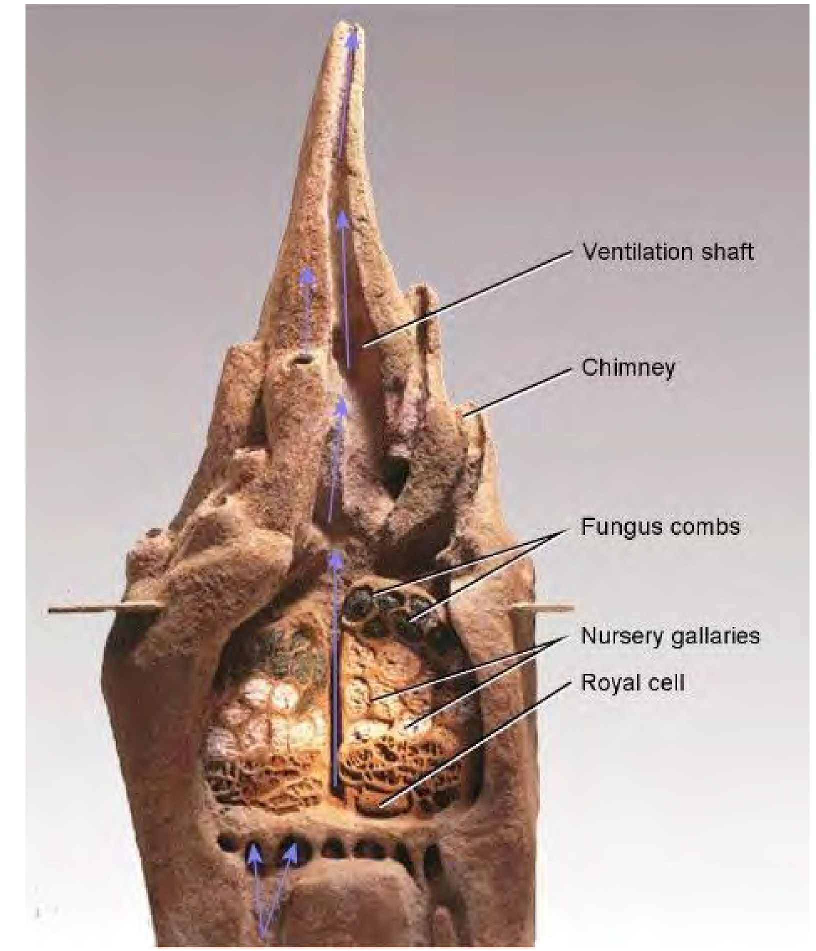


Fig. 44 - Cross section of a termite mound. Natural ventilation (purple arrows) pulls CO2 and excess heat up and out of the structure, maintaining a comfortable environment year round. With a structure made of mud, wood, and feces, termites have already proven you can go big and beautiful by building with earth. Image: Alter, 2018.

Rammed earth also provides the ability to store solar energy and slowly release it during cooler hours in a similar fashion to adobe, a method of building which could have been drawn directly from the activities of potter wasps, the purported source of the indigenous peoples of the American Southwest's own pottery. In the case of African and Australian termites, these species have managed to use this ability to capture the energy of the sun and paired it with the Venturi effect to create a ventilation system which turns their skyscrapers into living lungs. So durable are these structures built of earth and spit that they can last hundreds or thousands of years. By comparison, our own work in concrete through brutalism doesn't only appear brutal, it is mere child's play compared to animal architecture.

Looking at the "skin" of stick frame construction, cladding and rainscreens hold extraordinary potential for sustainable design. Wood cladding can take a huge lesson from traditional practices in Japan. Yakisugi (also called shou sugi ban - a mispronunciation) is the process of treating wood, traditionally Cryptomeria japonica, with fire and oil. ("What Is Shou Sugi Ban and Yakisugi," 2020)The wood is cut into lumber, the surface is burnt, and the charred finish is either treated with oil as it is or some of the char is removed to a desired degree before treatment with oil. This process creates a fire resistant surface with the potential for aesthetic expression through the maintenance of a rough charred surface or a smooth face revealing and highlighting the grain below. In wildfire prone areas, this approach can be used with other fire resistant approaches, to include wildfire resistant planting design, to make buildings near impervious to seasonal fires. Sourcing smaller pieces of wood, say from the construction of cedar fencing, scrap material can be transformed into a fire resistant skin which undoubtedly brings to mind that of a mythical dragon or a scaled serpent.

Fig. 45, 46, 47 & 48 - A variety of yakisugi treatments of wood, to include rough char to sanded and color treatments. Now imagine the beauty of scales and reuse in combining the bottom images. Rigged up with a fresnel lens or utilizing fuels produced through the gasification or biodigestion processes, the charring of the wood itself can be considered carbon neutral..
Photos: (top left, bottom left) "yakisugi," 2020; (top right) Vespa, 2018; (bottom right) Haanala 76, 2020.

An opportunity exists with an innovation called biocement™, which utilizes microorganisms to produce concrete and bricks. According to the company bioMASON, the process has the following desirable (and highly biomimetic features): “Made in ambient temperatures; no CO2 emissions; no waste in manufacturing; additive material performance such as increased insulation; nutrients and minerals required in the process are obtained from natural, renewable sources, but may also be extracted from industrial waste streams;” and it’s “able to utilize waste material resources in production” (bioMason.com)

Fat is essential to insulating the body against extremes of temperature, as well as being energy storage. Currently, insulation for buildings is largely produced through petrochemicals or require high temperatures for production. Some alternatives include the use of wool, shredded cotton (like old jeans), soybean-based rubbers, and hay bales. One particular option of interest being explored by companies like Ecovative is the use of mycelium as an insulating material. Creating formwork and growing the material from agricultural and other wastes (such as coffee grinds) holds the potential for creating a carbon-neutral, and even carbon positive insulation.By tying in this system into a mushroom grow room setup, the potential for simultaneously producing foods and medicines and diverting CO2 from the process into greenhouses can seriously help close the loop and allow for production of the insulation on site, made to order. After curing, the mycelium insulation is rot and fire resistant and remains 100% compostable. (Bailes, 2013) If only my love handles had so many obvious benefits.

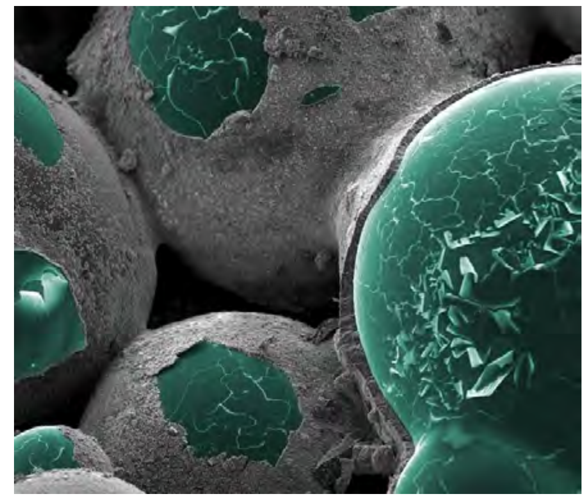


Fig. 49 - Biocement® forming over aggregate with a mix of bM natural bacteria, nutrient mix, water, and calcium.
Image: https://www.biomason.com

Barriers such as Tyvek are widely used but rely entirely on the petrochemical industry for their production. Meanwhile, StrongSeal is a rubber membrane made of recycled tires and is, itself entirely recyclable. Benefits include being made from recycled tires, asphalt free, entirely recyclable, high/low temperature resistance/flexibility, potential LEED points, and a 20 year warranty. (Strong Seal Roof Deck Protection Brochure) This is excellent news and offers another opportunity to give new life to tires. Other reuse options for barriers may include ships’ sails and used billboards, which are tough and waterproof.

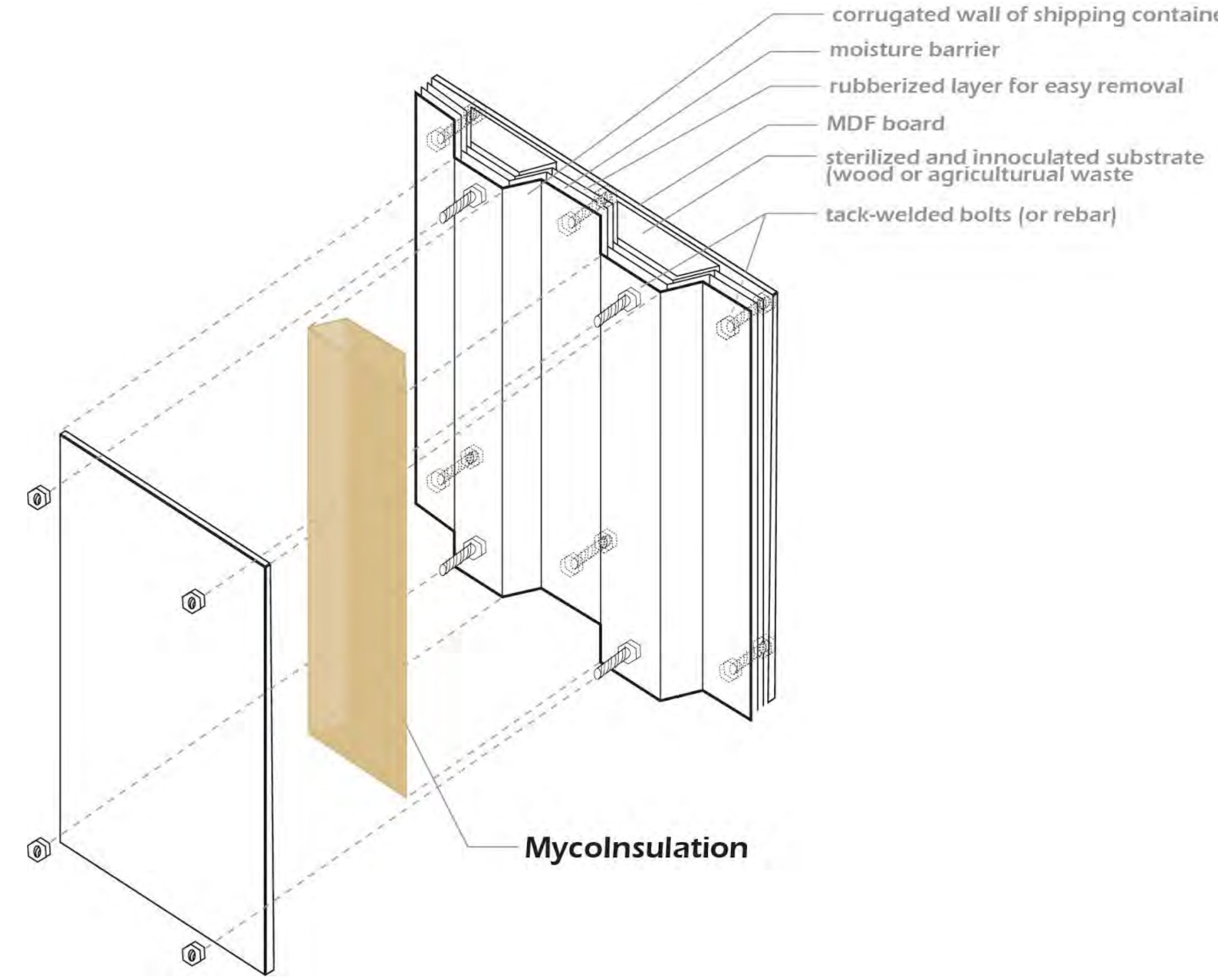


Fig. 50 - Conceptual diagram for mycoinsulation panels form fitted for use in shipping containers. The same principles would apply for growing insulation for other wall types in various forms.

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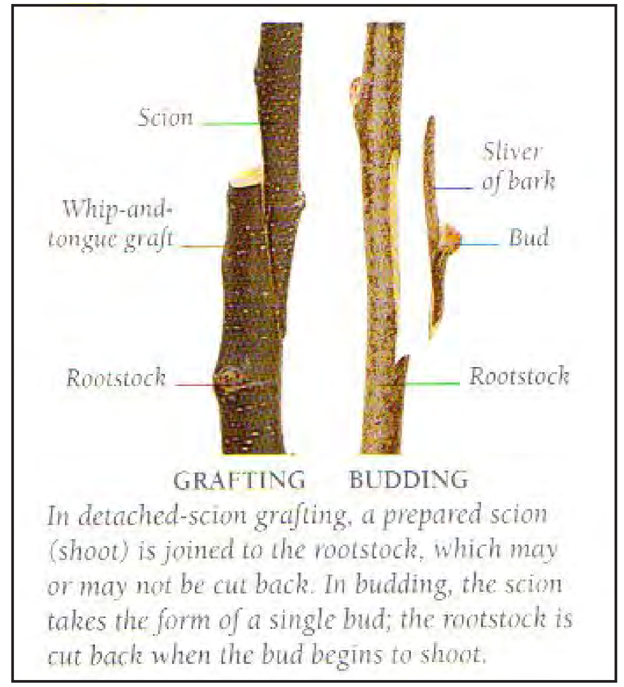
3.1.2 BRANCH & BONE

Grafted OR Grown

Unbeknownst to many people, Homo sapiens learned quite some time ago how to hack the way some plants grow. By taking a healthy plant as "root stock," other plants with other abilities are grafted onto specific points of the plants, allowing for a healthy addition of new genetic material to grow out from this connection. The plant then enjoys the best of both worlds, accessing the genetic resilience of the rootstock and the desired traits of the grafted material, known as a scion.

In similar fashion, Japanese joinery "grafts" wood together into interlocking joints which utilize the grain and size of individual members to increase spans, reduce wood use by joining smaller pieces into larger ones, and actually improve seismic stability of the structures. In a similar, but different means of working with wood, glulam and CLT take smaller diameter pieces of wood and adhere them with glues or epoxy resins, both increasing the size of individual members and simultaneously increasing their strength, thanks to the relative strength of the adhesives as compared to that of the lignin present in the wood itself.

One previously unexplored potential of both of these systems is to design members through 3D modeling. This allows for a high specificity of joint construction without the requirement of a woodworker who is highly skilled in the meticulous work of Japanese joinery. Each member and joint can then be digitally deconstructed into slices, which may then be converted into files to be cut from small diameter lumber through CNC milling.



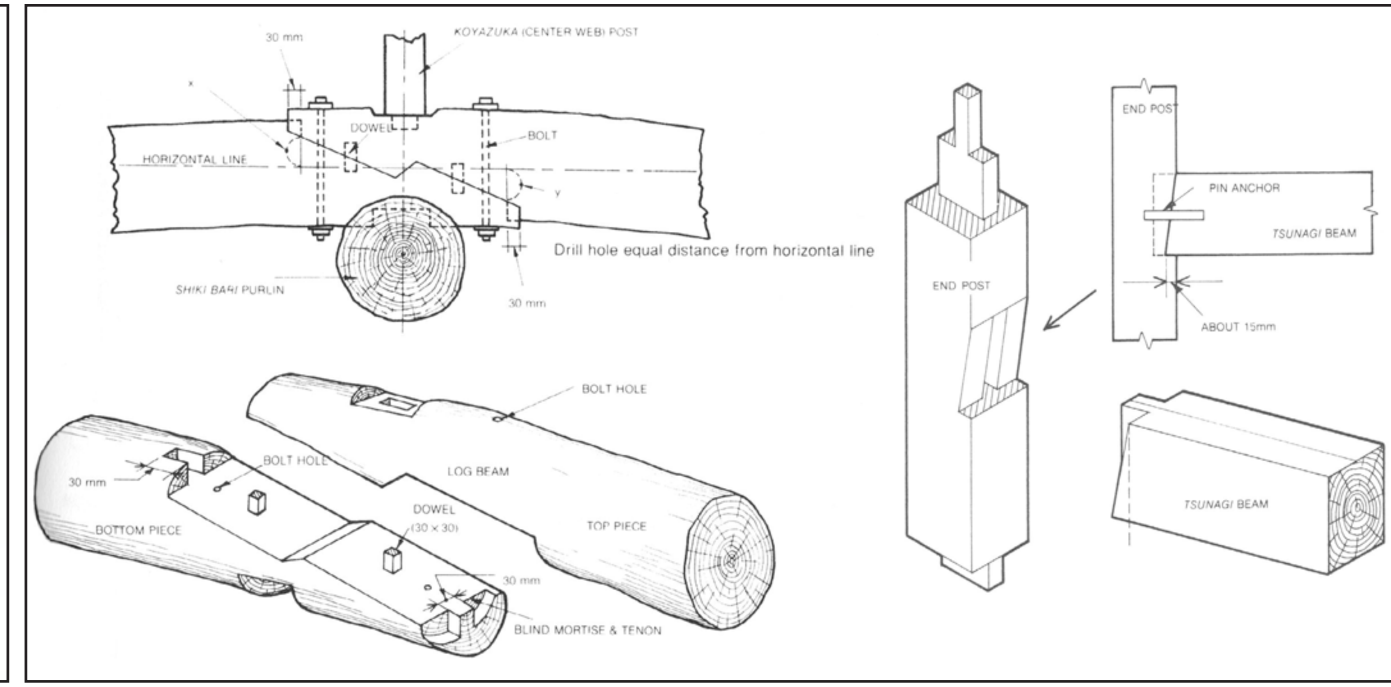


Fig. 51 - (top left) Basic grafts. Image: Toogood, 1999, pp 27.
Fig. 52, 53 - (top middle) The Koyadaimochi tsugi, log beam stub tenon scarf joint is a type of end joint which bears a striking resemblance to detached scion grafting, while ori oki kumi roof framing method (top right) follows that of budding. Image: Sato, 1998, pp 183, 284.

The milling allows for the highly refined designs to be executed with a near equal precision, ready to be glued and assembled on site or flat packed with an engraved numbering system to aid in the construction of the "bones" of the building.

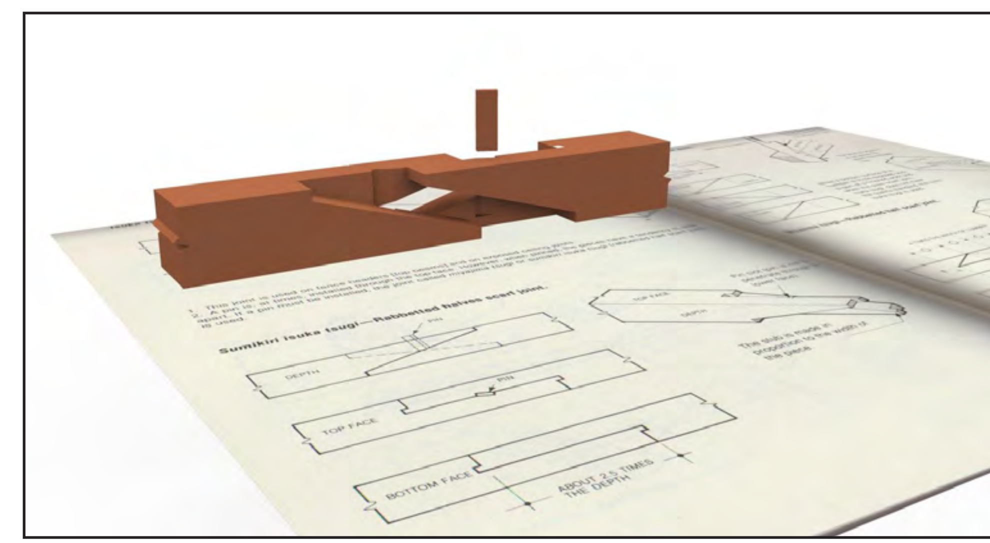
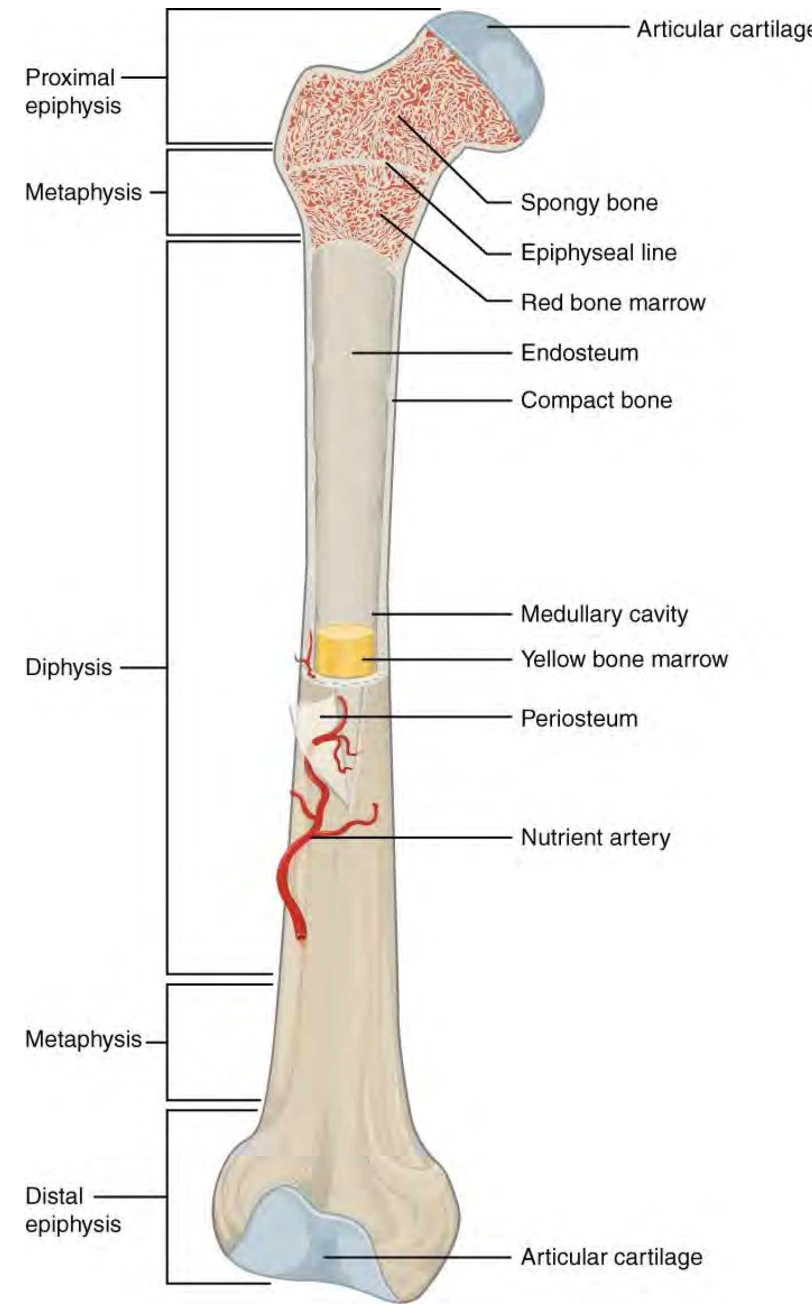


Fig. 54 - 3D model of isuka tsugi, halved scarf joint, rendered in Rhinoceros 6 with Underlying Tsugite-End Joints page from Sato, 1998, pp 184.

Another hopeful and unexplored technology for structural systems is inspired directly by the multilayered nature of animal bones. These layers include the periosteum, endosteum, compact bone, spongy bone, yellow marrow, red marrow, blood vessels and nerves. Each layer and network perform different functions, creating a whole which is significantly stronger, lighter, and capable of self-repair.

To a small degree, the reinforced concrete pillars and beams which define much of modern architecture combine the different strengths of materials to create structures that resist forces which would overwhelm each on their own. The compressive strength of concrete marries remarkably well with the ductility and ability to resist tension in steel. Each of these components is, also, made up of other materials which provide compatible strengths which overcome one another's weakness when carefully and correctly combined. Admixtures, too, can lighten and strengthen the concrete. One of which is carbon fiber.

Looking back to bones, what if, rather than adding a sprinkling of carbon fibers to the mix or gluing a patch on to the surface of a failing reinforced concrete beam, we took advantage of the extreme tensile strength of carbon fiber in the form of braided sleeves. Like the periosteum, a rigid layer of carbon fiber, reinforced with applied epoxy resin, provides a hard, durable layer which is more resistant to tension than steel reinforcement within a concrete member. From there, the interior layers could be a traditional mixture of concrete or site produced rammed earth. With the sleeve supported by formwork, layers could be built up as sleeves are overlapped, filled, and cured successively. This does not address the issue of torsion stress, but it is a start.



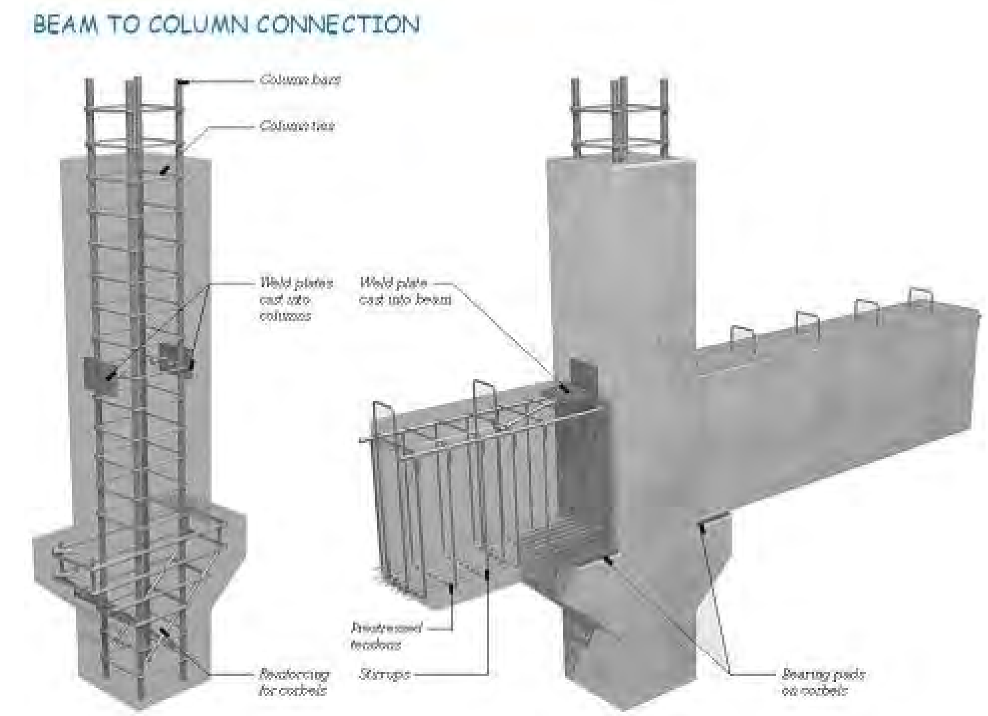


Fig. 55 - (above) Reinforced concrete column and beam connections are common in modern construction and can be cast in place or precast and transported to the site. While concrete is strong against compressive forces, its relative tensile weakness is compensated for with steel rebar reinforcement.
Image: Civil Digital, 2013.

Fig. 56 - (above left) The layered anatomy of a human femur bone is a complex composite material. Bone grows at ambient temperatures, provides structural support, is self-repairing, and its marrow produces new blood cells, fat, and cartilage as well as new bone.
Image: OpenStax College, 2013.

Fig. 57 - (right) Enter carbon fiber. With greater tensile strength than steel and the potential for sustainable production, it is already being used to repair failing reinforced concrete. Braided sleeves add a new dimension for design of pillars and arches.
Image: Fiber Glast.

Pushing this notion further and taking inspiration from the renowned architect Antoni Gaudí, who was himself inspired by nature throughout his life's work, these sleeves could be inverted between frames, filled and cured, before being reversed and placed as catenary arches - made famous in La Sagrada Família. The models for the unprecedented cathedral provide a direct example of how such design work could commence. Though the process requires materials which were undreamt of in Gaudí's time, it would take significantly less time to assemble a structure of significant size and durability than his own masterwork in stone (yet unfinished after 138 years of construction.)

To borrow from the ingenuity of our ancestors who drew from the animal architecture to create basketry, imagine buildings woven of these sleeves, interlocking like nests or baskets of varying complexity. The means of filling, shaping, molding, overlapping, and interweaving are open for discovery and play, the component materials potentially being no more exotic than earth, clay, biochar, and - in the future -sustainably produced carbon fiber. This is a concept which is proposed here but not developed in this thesis.

At present, this last material is primarily produced from byproducts of the petrochemical and natural gas industries. Some companies, such as C2CNT - a startup out of George Washington University, have managed to divert CO2 from "the flue stream of a power plant, cement kiln or other industrial facility, then convert it into pure carbon nanotubes" or carbon fibers using molten electrolysis. (Sweet) Meanwhile, chemists from the Technical University of Munich have managed to engage algae in producing an oil which can then be cracked in a manner similar to our current method of carbon fiber production. (Sweet) From air to structure, just like a tree.

Fig. 58 - A replication of the original model of La Sagrada Familia uses weights to distribute loading of catenary arches which form the structure of the celebrated cathedral. Photo: Anne, 2019.

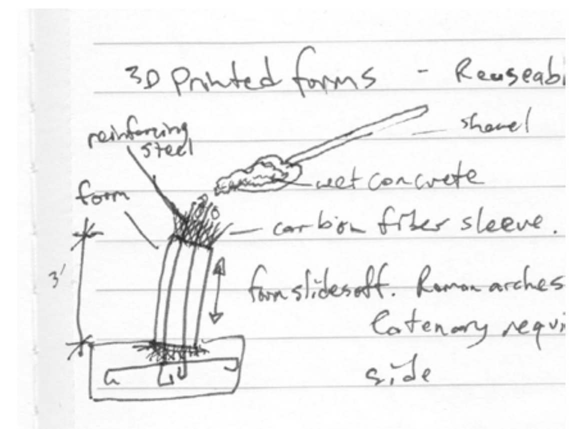


Fig. 59 - A quick sketch exploration of 3D printed formwork for concrete catenary arches within carbon fiber sleeves.

Returning to the notion of bones and their fantastic layers and integration of systems, could not conduit or pipes be integrated as a means of directing resource flows through structure, embedding sensors or even smart materials which could provide a feedback system which could tie in directly as a part of the building's artificial central nervous system? Could mycelium be integrated through renewable feedstocks to form a tough, fire resistant insulation within each "bone," helping to mitigate temperature fluxuations or integrate hot and cold water systems into these quasi-living members? A system of translucent pipes flowing with phosphorescent algae illuminating interiors and feeding the GUTS a steady diet like what the Green Power House and iBison run on? In what other ways does Nature offer ideas for designing better bones for our built environment?

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3.2 DIGESTION - Material Flows

Buildings consume. The premise of this thesis argues that they eat, they excrete. Our built environment relies upon energy in various forms and it invariably produces waste. In Washington State, our electricity largely comes from hydroelectric energy, pumped in from miles (often hundreds) away. Natural gas or oil may heat our homes. Giant wind turbines turn the power of the sun, shifted into the flow of a breeze, into a flow of electrons. At the hyperlocal, perhaps photovoltaic cells pump sunlight into batteries or light is converted for direct use by devices. Each of these mechanistic approaches requires intensive infrastructure and is irreparable but by experts. Chemicals and rare earth minerals, massive amounts of metals and silicon provide the material basis for these mechanical wonders, a biomimicry sin which Janine Benyus is quick to point out.

Buildings excrete. Even as the energy we rely upon invariably produces waste, the waste we produce invariably consumes energy. Centralized waste treatment plants combine sewage from homes, businesses, and industry far from their points of generation. While our bodies do the work of separating our wastes at the source (the septic of fecal matter with the antiseptic of urine), our toilets combine them into a mess which is slow to decompose into anything useful. Septic tanks don't do much better, creating a slow process with the potential for contaminating groundwater and aquifers.

This section looks at material flows in terms of GUTS, LIVER, and KIDNEY. Solids and liquids become soils, water, food, medicine, alcohol, and energy through the alchemy of overlapping biological and mechanical processes.

Fig. 60 - Non-domesticated herd animals turn prairies over in a cycle which builds soil. Before the advent of modern farming equipment, we relied upon domesticated animals to do the same.

Fig. 61 - Prior to colonization by Western cultures, indigenous peoples in the Americas and Australia used fire to bring life. In absence of that cycle, it is wiping it out in unprecedented wildfires.
Photo: Fuller, 2020.

3.2.1 GUTS

A New Digestion

Biomes, like forests and grasslands, have digestive systems. They are the animals, the fungi, and the microbes which digest the fruits, nuts, seeds, leaf litter, and the dying plants. The soil itself consumes the dead and cycles the nutrients into food for the living. In this there is truth to Matthew 5:5 and the claim that "the meek... shall inherit the Earth." (King James Bible) In that we call soil "earth", the meek are literally the Earth. Humans have long been a part of this process with our own digestive systems, adding fire to the mix and building biodiversity in the process. The fire consumes and digests that which is overgrown and so dense that species would otherwise out compete one another and eventually starve. Wildfires are caused by a forfeiture of our species' role in the ecosystem, adding insult to injury with the devastation of wildlife communities by our own in the name of development. (Fuller)

The systems proposed do require some of these same materials, but they do so much more. The base units of the GUTS system are a gasifier/pyrolysis system, biodigester, mycoculture/mushroom grow room, Hugelkultur beds, and compost/vermiculture system. As an ecological corollary, this system mimics the processes of a forest and plains biotopes. The gasifier and biodigesters mimic some of the activities of large herbivores in grasslands, macerating materials before they are consumed and digested, excreting by-products which feed soils, microbes, plants, and fungi. Wildfires bring down trees and turn them into carbon rich soil supplements in a war between the trees and grasses.

In the forest, woody biomass breaks down when it hits the ground, with mycelium and microbes reaching up to digest it along with leaf litter, the refuse of wildlife, and swallowing up their corpses at the end of their life cycles. So too, does composting and hugelkultur mimic these activities, speeding up the process in the former system and extending it in the latter.

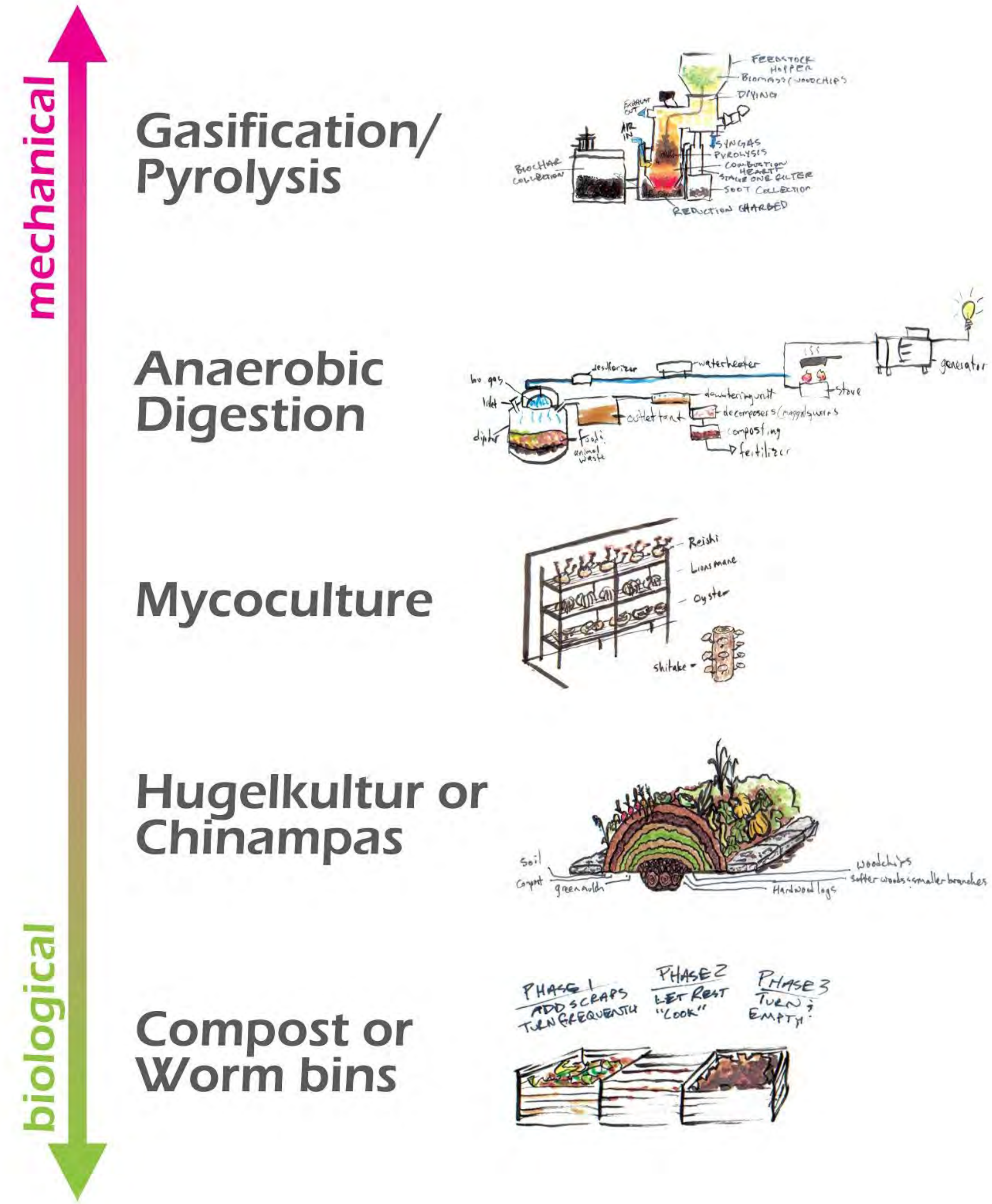

Fig. 62 - The primary GUTS systems ranked from mechanical to biological: gasifier, anaerobic digester, mycoculture, Hugelkultur, and compost.

Specifically, the pyrolysis and gasification system utilizes woody biomass in the form of chips to cycle through at high temperatures without combustion. By omitting oxygen from the process, the wood is broken down into its chemical constituents, releasing water, syngas, bio-oil, and biochar. The system is self-perpetuating, the syngas produced is able to run the process while producing a surplus for direct use or further refinement, as with the bio-oil production. Biochar is an extraordinary soil amendment, providing a remarkably porous mesh of nooks and crannies within which nutrients can be filtered and mycelium and roots can make a home. As a planting medium, it holds promise in hydroponics and aquaponics. In filtration systems it is akin to activated carbon. It really comes down to the nooks and crannies. Surplus water is collected and the heat is diverted into the subfloor heating system. The off-gassed CO_2 and other volatiles are circulated into the LUNGS system to the benefit of the plants therein.

Biodigesters handle the non-woody biomass, taking kitchen scraps, animal wastes, and a number of other organic feedstocks and feeding them to microbes. In a sort of "water into wine" miracle, anaerobic digestion breaks down these "wastes" into biogas or syngas which can be used immediately as fuel for water heaters, stoves, and electrical generators. The solids which remain are then run through a decomposing system of worms or maggots, which convert the mess into high quality fertilizers that are safe for application to food crops. Surplus water and heat follow a similar process as with the gasifier.

Fig. 63 - (left) The PP30 (Power Pallet) by All Power Labs is a compact gasification system which produces electricity, thermal energy via a standard heat exchanger, biochar, and potable water from biomass (woodchips). Image: "PP30 - Basic Considerations."

Fig. 64 - (below) The H.O.R.S.E. (High-solids Organic-waste Recycling System with Electrical Output) by Impact Bioenergy is a compact anaerobic digestion system which produces electricity, thermal energy via a standard heat exchanger, liquid fertilizer, and dry soil amendment. Photos: "HORSE AD25 Series."

Mycoculture allows for the treatment of waste wood, spent grains, agricultural waste, coffee grinds, and more, by fungi. The specific strains inhabit various biomes within the larger ecosystem, as seen earlier in the Stametsian Model for Permaculture (fig. 26). The sterile environment of the mushroom grow room allows for the controlled cycling of air, with the off-gassed CO2 from the fungi to join that from the gasifier in the LUNGS system. Proximity of both these systems to the greenhouse allows for direct conversion of this carbon stock into food for human consumption, even as the mushrooms grown provide another nutritional source for people, livestock, and the fish living in the aquaponics system of the LIVER. The waste products from this system can be used in conjunction with the other systems - such as creating mycelium-based insulation as part of SHELL/SKIN and actively augmenting the microbiomes of the Hugelkultur beds and compost systems (and growing even more mushrooms as part of the process).

By introducing berms and swales to a landscape, the hugelkultur approach can increase soil quality and biodiversity while retaining precious water on site, reducing or eliminating irrigation needs. This is evident in Sepp Holzer's permaculture work in the Austrian Alps, where the climate does not dictate what crops can be grown and biodiversity reigns supreme where microclimates have been created and lovingly maintained. (Sepp Holzer's Permaculture: 2 Films about Permaculture Farming) If applied to a more aquatic environment, chinampas utilize a similar approach which increases farmable land without destroying wetland habitats and simultaneously provides ecosystem benefits. Both systems benefit from wastes from wood, agriculture, mycoculture, kitchen scraps, biochar, and compost. ("How the Aztecs Could Improve Modern Urban Farming.")

Fig. 65 - The ancient past is not so far away. This Instagram post shows chinampas digitally recreated for a modern audience. Essentially a form of aquatic Hugelkultur, this technology could readily be employed today in cities around the world. Image: "Latest News About Climate Change."

Fig. 66 - Compost piles convert organic waste into soil. One often untapped potential is heat capture, as seen here. Photo: "How To Make A Hot Water Heater With Compost."

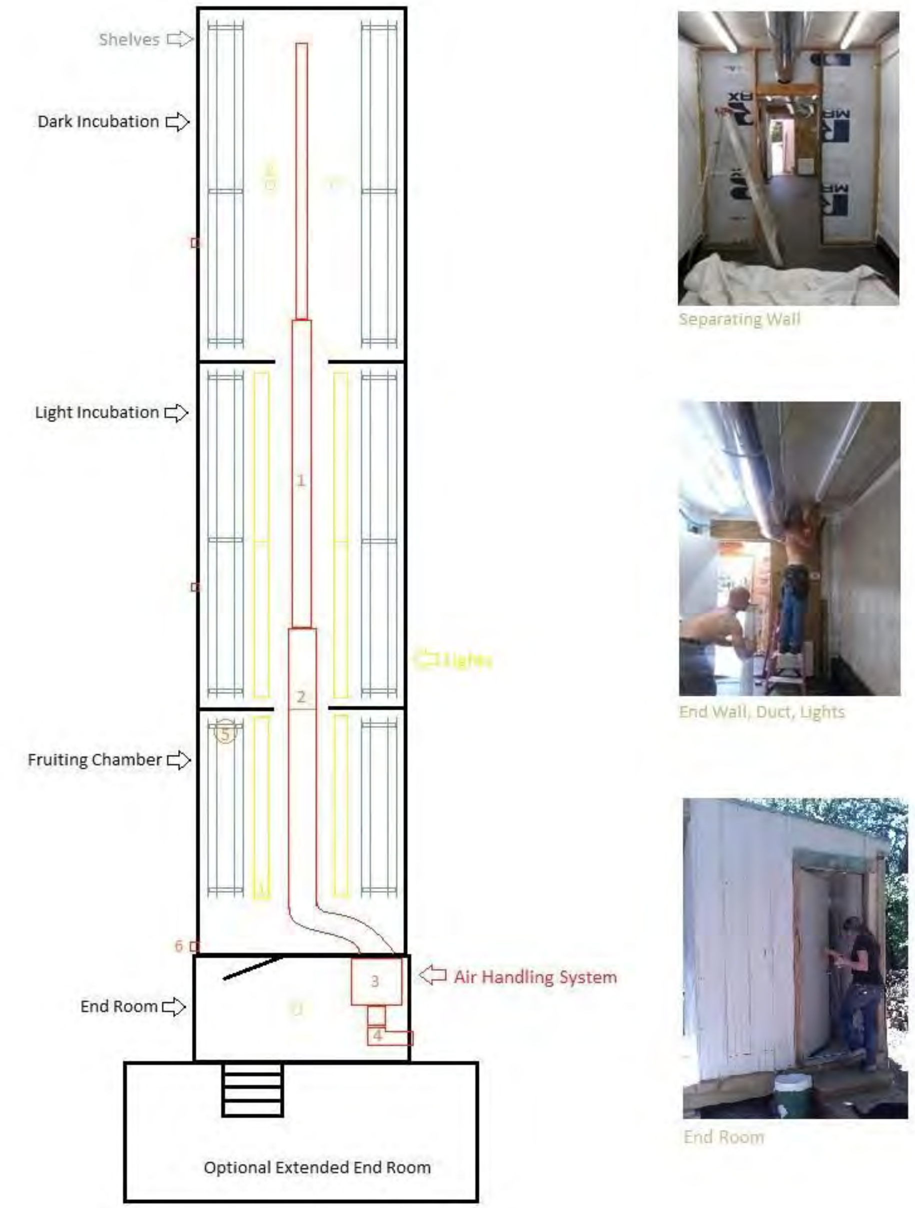

Fig. 67 - Diagram and images showing conversion of an insulated shipping container into a mushroom grow room. Also mentioned in the pamphlet is the potential for venting air directly into an adjoining greenhouse. Image: "Cost Effective Specialty Mushroom Cultivation."

Finally, the compost and vermiculture system allows for a more specialized environment for producing high quality soil amendment for application to the Hugelkultur beds and any soil based planting areas, as well as a high-quality fertilizer called "worm tea." Another benefit may be the generation of biothermal heat for the heating of greenhouses, subfloor heating, preheating hot water tanks, etc. Coupled with the other thermal energy systems in GUTS, there should be no need for external inputs of electricity or gas for heating.

In this thesis, the GUTS draw on the solid matter from the local and global food chain, process it, and convert it to thermal and electrical energy, soil, soil amendment, fertilizers, biochar, bio-oil, food, and distilled water. They are connected to, and form an extension of, our own digestive systems, placing us as microorganisms co-evolving within and between sets of GUTS, enriching the microbiome wherever we are by feeding and excreting into and through each system.

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3.2.2 LIVER

From Waste to Water

Wetlands ecosystems provide a viable model for hydrological cycling and water purification. Within the environs of a wetland, unused nutrients and sediments shift from being wastes to resources for the biotic denizens of these aqueous environments. Constructed wetlands, such as the system built into the Bullitt Center in Seattle, Washington, integrate plant and microbial communities into intentional infrastructure, providing these same benefits with the added effects of increasing biophilic opportunities in the built environment. Those equisetum (horsetail) perched along the third floor of the building provide a brilliant strip of green along the facade, visible through windows and from the street to the north.

Within every one of Michael Reynolds' Earthships exist a similar system, running off of solar power in the south-facing solariums and a steady flow of greywater from each household. Building these beds into the structure of the home provides an opportunity to both remediate precious water, grow food, provide shade, and to humidify air through evapotranspiration. ("Design Principles") As discussed in the LUNG system in this thesis and in the book How to Grow Fresh Air by Dr. B.C. Wolverton, providing habitat for plants is an important, low to zero energy method for filtering "used" air and reducing airborne pathogens, all through the power of roots and leaves. (Wolverton, 1996)

Fig. 68 - Constructed wetlands systems, like the one at Fleming College in Ontario, Canada, comprise an array of different wetlands biomes for the treatment of wastewater. Image: Mclean, 2020.

This kind of green infrastructure can be hyperlocal and odor free, unlike many industrial scale treatment plants. As an Organ, these systems can provide an opportunity to close water related resource loops.

Further opportunities for bioremediation of water are offered through incorporation of fungi, as evidenced in Paul Stamet's Mycelium Running: How mushrooms can help save the world. In experiments conducted near his farm on Kamilche Point in Washington State, Stamets interceded on the behalf of farmed shellfish along the Salish Sea by incorporating hay bales inoculated with Stropharia rugoso annulata, commonly known as garden giants. The cattle, chicken, and pigs he was raising and the rudimentary septic systems for humans in the area were contaminating the shellfish beds with fecal coliform, resulting in a visit from the sheriff. Not only did this result in demonstrably lower levels of coliform levels in runoff from his property, it led to the clever use of the garden giants as feed for salmon fingerlings. The mushrooms floated and fly larvae revealed themselves in an effort to escape a watery grave, only to be met by the hungry mouths of the silver salmon. (Stamets, 2005, pp 61)

According to the Washington State Department of Health, "Greywater is wastewater from bathtubs, showers, bathroom sinks, washing machines, dishwashers, and kitchen sinks - any source other than toilets and urinals." The website goes on to state that "Greywater makes up the largest portion of wastewater from your home...up to 40 gallons per person each day." ("Community and Environment", 2020) For a family of four, the 160 gallons of water they may be using is currently routed into a septic or sewer system, removing the wastewater from any further use on the site. For households that are on-grid, this means that any flushing of toilets, irrigation, or other water use relies upon pumping potable water from other parts of the watershed - or from other watersheds entirely.

Fig. 69 - This kind of green infrastructure can be hyperlocal and odor free, unlike many industrial scale treatment plants. As an Organ, these systems can provide an opportunity to close water related resource loops.

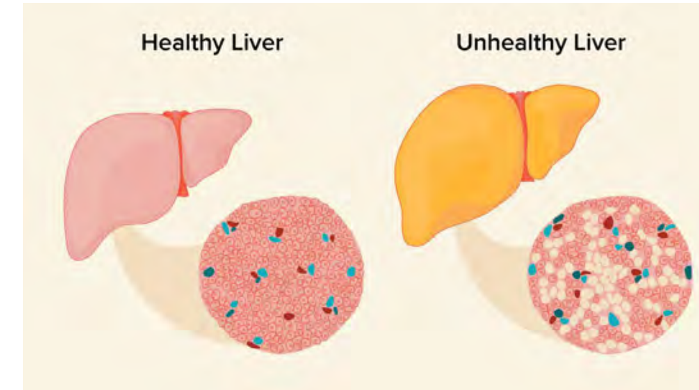

Fig. 70 - This kind of green infrastructure can be hyperlocal and odor free, unlike many industrial scale treatment plants. As an Organ, these systems can provide an opportunity to close water related resource loops.

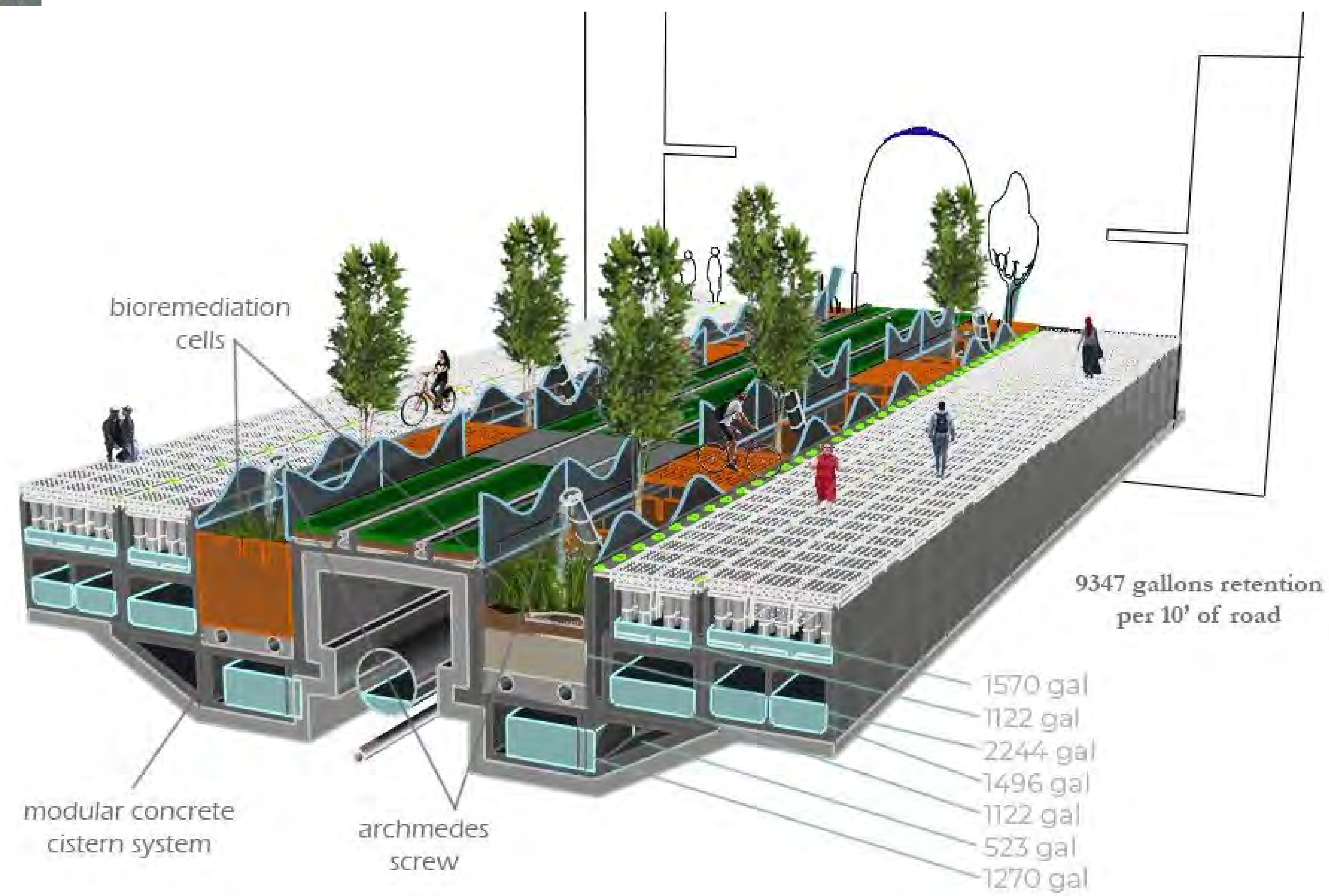

Fig. 71 - Streetscape as an artificial liver. Concept developed by the author during the 2019 Scan|Design Studio with Nancy Rottle & Louise Grassov. Focused on stormwater design of public spaces. This design reduces vehicle acces along Seattle's 15th Ave E, reducing pollution loads, collecting, biofiltering stormwater and simultaneously filtering water from Lake Union, providing cooled, clean water to Chinnook salmon pens where the system reconnects to the lake. People, orca whales, salmon, and numerous other species benefit from the biomimetic and biophilia-inspiring system.

This results in a loss of clean, cool water for biological communities and ecosystems stretching from mountain headwaters to the sea. At present, here in Seattle we are seeing the direct impacts of our reliance upon the Cedar River and Tolt River watersheds upon our apex species, the orca, as their reliance upon Chinook salmon. Not only has our hardening of the environment through impermeable surfaces and removal of streams for the convenience of construction led to less habitat, but the impact of untreated runoff from streets and parking lots, treatment of landscapes with biocides, and the flows of grey and blackwater have poisoned what water does make it into the gills of the food species that we and the orcas alike love to consume. (Mapes, 2019)

Wetlands operate much like the liver does in our own bodies. Turning to WebMD for an illustration (and avoiding any self-diagnosis through the site), we learn that "the liver's main job is to filter the blood coming from the digestive tract, before passing it to the rest of the body. The liver also detoxifies chemicals and metabolizes drugs." (Hoffman, 2019) Our bodies risk sepsis, among other ailments, with the failure of the liver. If we are viewing the built environment, each building and landscape, as a living organism, what are we to make of those which do not treat toxins and pollutants on site? A vision of a patient connected to a dialysis machine seems an accurate analogy for a home which relies upon fresh water being pumped for miles to its doorstep and wastewater flushing away to a wastewater treatment plant. What is worse, these systems are also susceptible to failure, as the millions of gallons which escaped the confines of King County's treatment plant along Discovery Park during a power outage in 2019. (KOMO News Staff, 2019) This was not the first time the Salish Sea has experienced "liver failure" of this magnitude, nor is it likely to be the last.

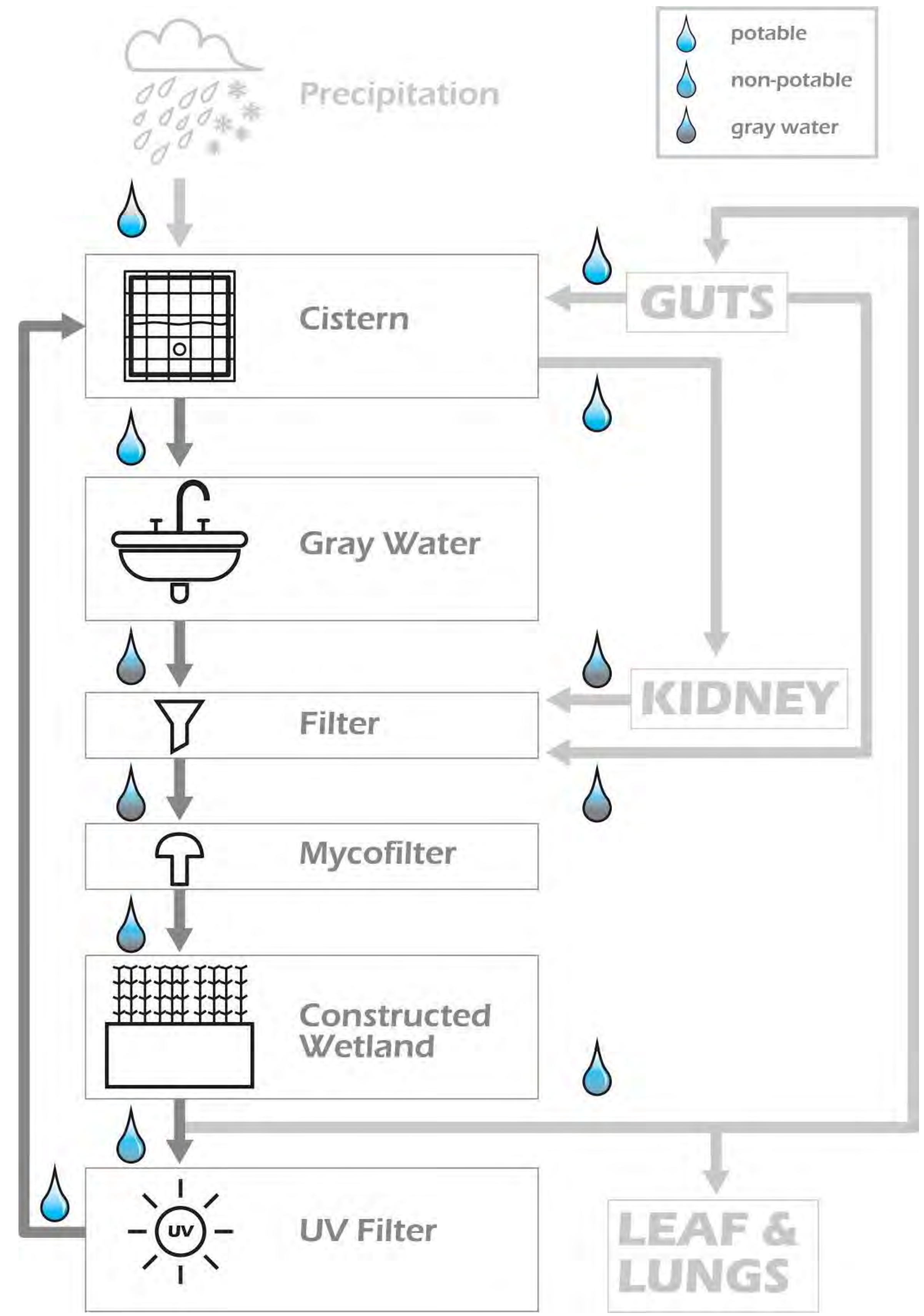

Fig. 72 - The Liver System draws water from precipitation, GUTS (gasifier, anaerobic digester) and filters gray water from sinks and the KIDNEY.

Taking these systems and providing local replacements requires separate treatment for sewage and stormwater runoff. In past studios I explored this as a "prosthetic liver" for the treatment and storage of water. One studio utilized an integrated system of oyster-filled tanks for treating water directly from Elliot vBay and filtering and cooling it before rerelease in the Salish Sea at Pier 48 in Seattle. Another re-envisioned the streetscape of Capitol Hill's 15th Ave E as a pedestrian and bicycle filled space with integrated myco/bioremediation cells, modular cisterns, and dedicated trolley line (fig. 73). Thinking on the porosity of a liver, as well as that of the soils in a temperate rainforest inspired this move to return part of the streetscape to the living.

In this thesis, the concept of LIVER connects to the GUTS, KIDNEY, LEAF & LUNG by taking the building's greywater systems and maintaining their separation from blackwater, preferring constructed wetland and aquaponics systems for the former and composting toilets and urine diverters for the latter. Water is filtered, bioremediated, polished, and UV filtered to remove all contaminants. Fecal matter becomes soil and urine becomes fertilizer and more through the KIDNEY system as described below. Very little rainwater enters these systems and is otherwise diverted into cisterns, where it may join purified and UV filtered water from the LIVER. This water can then be used directly in potable applications, as well as feeding into the KIDNEY system where it eventually connects to our own. Where the LIVER provides habitat for edible species, as with aquaculture, these species loop back to the GUTS, converting sunlight, water, and waste into energy, food, fertilizer, soils, etc. by moving, storing, treating, and delivering water through and beyond the site. The LIVER filters, integrates, remediates, and irrigates with water. The movement of our own water is integrated into the system, a microcosm and microbiome feeding back into the body of the Archinae.

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3.2.3 KIDNEY

From Water to Wine, Back to Fruit on the Vine

Kidneys filter our blood and produce an antiseptic product, urine. Urine itself is more than waste, provided it is given time to age. From there it can become fertilizer and pest repellent, as some farmers have found benefit in the shadows of Mount Everest.(Mallapaty) This is a direct use of actual kidneys in converting wastes into usable products by diverting it before it enters a septic system. In consideration of the filtration properties, the antiseptic uses and potential for fertilizer and feed, this thesis looks at the concept of KIDNEYS as applied to the built environment through the acts of fermentation and distillation of other products such as grains.

As a homebrewer and amateur winemaker, I am keenly aware of the quantities of water required to grow grains and grapes, brew a wort, sanitize equipment, resanitize with each racking (changing of containers), and prepare for bottling. At each stage there is an excess of organic material, from the agricultural waste of chaff and straw or pruning of vines, the spent grains and discarded lees (old grape skins and yeast), and trub (settled proteins, hops, dead yeast) at the bottom of the bucket or carboy. These wastes can be given (and, in larger operations, sold) for nutrient dense animal feed and, in the case of lees, pharmaceutical uses. As the yeast percolates carbon dioxide through the fermenting liquid, the CO2 escapes into the atmosphere through an air lock, keeping the liquid free of contamination and eliminating the potential for explosive release. The carbon dioxide then enters the air and dissipates. Combined with the LUNG system, this becomes a feedstock for plants which turn the carbon into biomass and give the oxygen back to us.

Fig. 73, 74 - (left, middle) The perks of home brewing: An Imperial Breakfast Stout with cacao nibs, vanilla bean, coffee, infused in a select blend of whiskies (left), and a competition brew for a local brewery (middle).

Fig. 75 - (right) The downside home brewing: an infection. Sanitation is important to kidneys and the KIDNEY system, while the LIVER and GUTS handle the heavy work of processing water and organic material.

Fig. 76 & 77 - From basics to the highly refined, my own home brewing is small in scale (left) compared to microbrewing and commercial scales like the production at Old Stove Brewery in Pike Place Market (right).

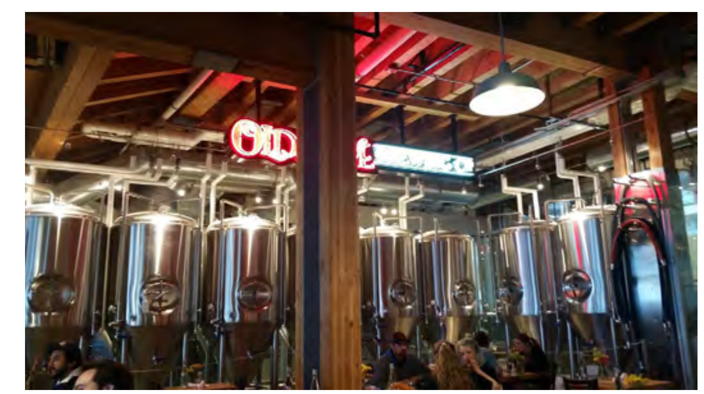
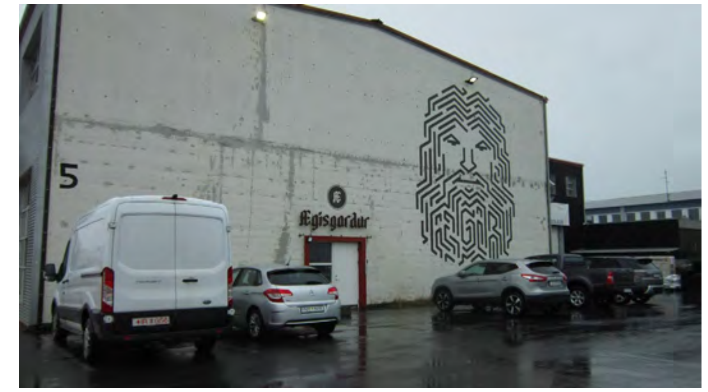


Fig. 78 & 79 - So too, stills, such as these in use for decades by a family matriarch I met in Croatia (above), are dwarfed in stature and complexity by this beautiful copper still at Copperworks in Seattle (right).

When visiting Friðheimar in Iceland, I interviewed Helena Hermundardóttir, the botanist who turned a greenhouse operation into a top tourist destination. They grow a variety of tomatoes, herbs, and flowers with a carefully controlled hydroponics system and the assistance of imported bumblebees. She has partnered with Ægir Brugghúsi, the Reykjavik brewery headed by Ólafur S.K. Þorvaldz to create a tomato based beer from the fruits of the vine produced at Friðheimar and served during their daily tomato soup buffets. I had chanced upon the brewery the day prior and spent a few hours chatting up the house manager and Ólafur about the history of the brewery, their methods, and market. It had occurred to me that the brewery produces a significant amount of waste material in terms of spent grains, gray water, and off-gassed CO2. At the end of my interview with Helena I asked her if they had considered the potential for partnering with breweries like Ægir or building their own setup in order to take advantage of the waste CO2. Friðheimar already purchases this from outside sources, arriving in gas tanks which slowly release it into the air to the benefit of the greenhouse crops. While Helena found the idea compelling, she conceded that they had not yet considered this approach.



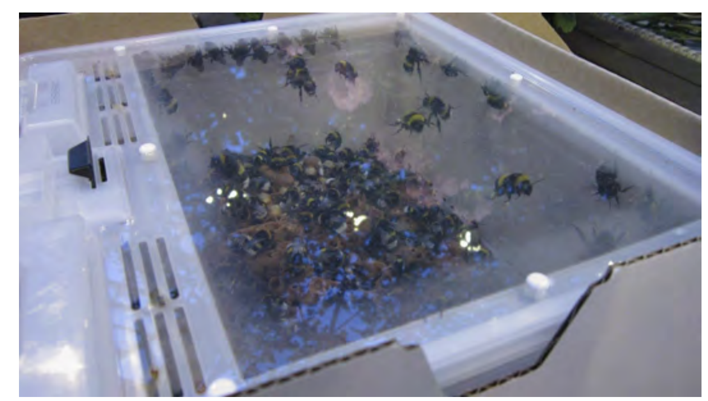


Fig. 80, 81, 82, 83, 84, 85, 86, & 87 (clockwise from upper right) - Tomato Beer served at Friðheimar; the buffet books up in advance; tomato soup, fresh baked bread, and housemade relish; a thicket of tomato vines; wee baby tomato plants; bumblebees boxed up and buzzing; geothermal heating minimizes impacts of heat loss and lamps supplement the sun; Ægir Brugghúsi- where the beer began.

In this thesis, the KIDNEY does its work by drawing distilled and clean, potable water from the GUTS and LIVER systems, combining it with fermentables and flavorings, and feeding it to members of the kingdom of Fungi. Some of the fermenting mixture (grapes, grains, fruits, honey, sugar, potatoes, etc) and flavorings (hops, oak, herbs, flowers, etc) is grown on site, if not all. Some may be produced from the LUNGS and all plants are fed by the GUTS or LIVER. Liquid is extracted into a clean container and excess solid matter goes into the GUTS system to produce energy, fertilizer, and soil. Clean water is used to clean and sanitize, connecting at the input end of the LIVER for remediation.

Different products ferment for different periods of time and either are bottled for aging and later consumption before being digested and diverted back into LIVER or into a urine diverter for storage and aging. After 6 months, this becomes a zesty cocktail for plants, with additional use as an organic pesticide which does not poison the earth, delivers nutrients to plants, fungi, and beneficial microbes, boosting desirable growth. As the fermented liquid has gone through a distillation in our own bodies, some of the fermented liquid is distilled in still, drawing apart evaporated alcohol from evaporated water, leaving behind the heaviest solids and sending some components out with the water. Water and undesirable components are evaporated out through subsequent distillations, finding its way into the GUTS or LIVER, depending on the requirement for thermophilic biodigestion. (Gebreeyessus, 2016) The accumulated alcohol is then bottled, casked, or added to another product. Within the last few months of the pandemic, we've seen that alcohol production for drinking and for sanitizing has made it's access a near apparent human right.

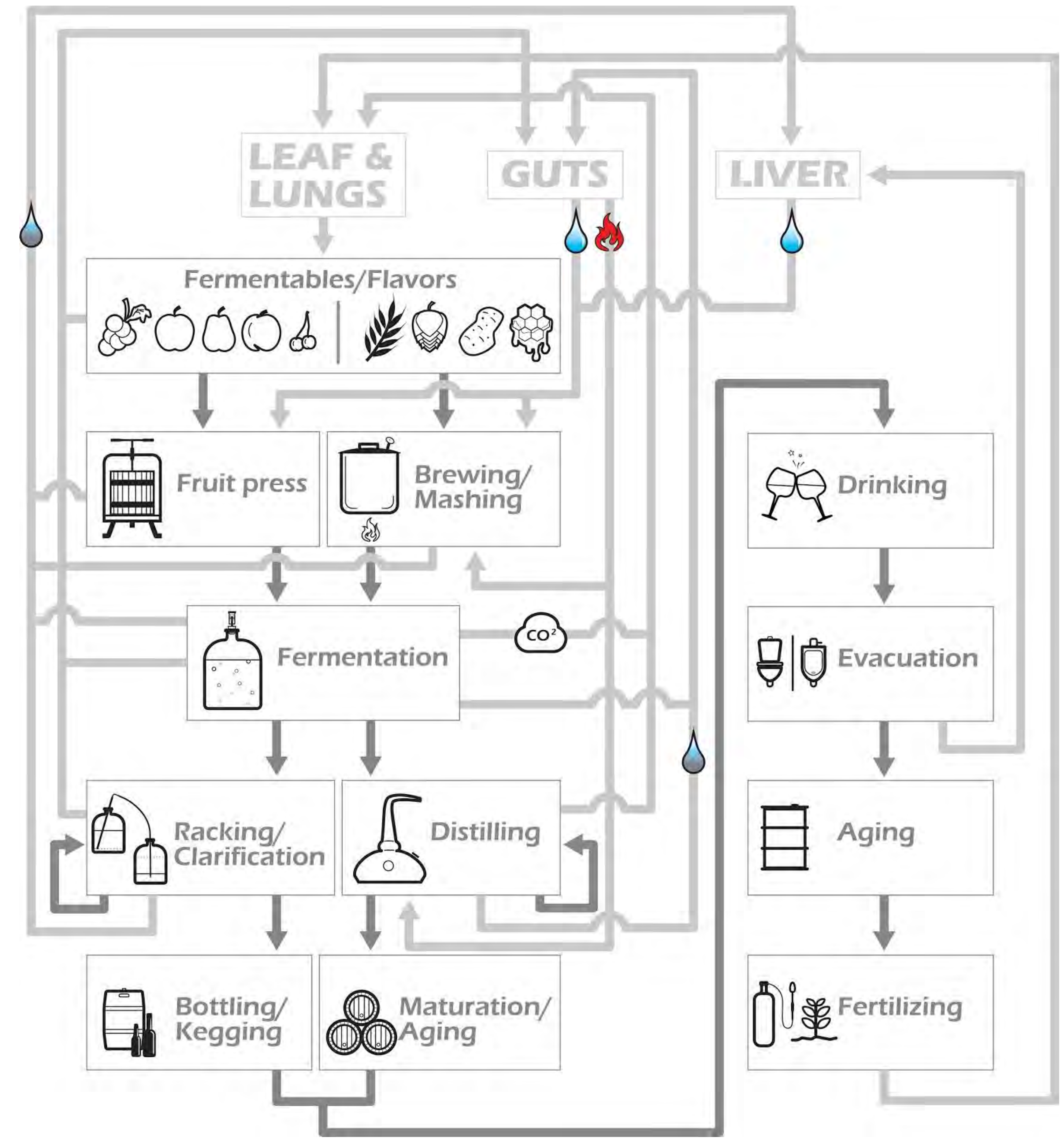


Fig. 88 - The KIDNEY System turns water into wine, bringing in fermentables grown in the LEAF & LUNGS, combines them with water from GUTS & LIVER, and the Kingdom Fungi (yeast) to produce alcohol.

This may be further refined through distillation powered through the surplus heat and fuel production of the GUTS. Homo sapiens further processes the alcohol into fertilizer.

The KIDNEY of this beast of the kingdom Archinae is tied to our own, an extension of our own bodies and a healed connection to the species upon which we depend. It is also a deterrent and, if one ever settles on Islay, it will even mark its territory by the bacteria in the air and the scents of ferment and malted grain. The excess heat from the KIDNEY system is transferred into the HEART, providing subfloor heating, preheating for the gasifier and other systems, and may power an optional heat pump. The CO_2 and other volatiles move with the air flowing into the LEAF & LUNGS, sequestering or bioremediating these resources in place of releasing them as pollutants while boosting plant growth.

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3.3 TRANSMISSION - Energy & Information

Capturing the thermal energy of the sun through passive solar offers an opportunity to move water captured and purified in LIVER without mechanical parts through the building and site in HEART. Heat capture and energy production from the GUTS coupled with electricity generated from photovoltaics from LEAF and LUNG provide power for pumps, sensors, lighting, electronics, and an internet of things connected via a mesh network and/or wifi and fed to a monitoring and control system, the BRAIN & NERVES.

3.3.1 HEART

The Diurnal Heart

At first glance, I considered applying the notion of a heart of fire in the form of a pyrolysis gasification system. The heat and electrical energy produced in such a system could power a pumping mechanism for water. Upon closer examination, it became clear that this system is more directly applicable to digestion, which provides the fuel by which the heart pumps. Taking a step back, however, and reconsidering transmission and circulation through the lenses of hydrology and reptiles, I began to reconsider the concept entirely. The heart unifies the body, it moves energy and resources from head to toe to fingertips and every cell between.

Reptiles are almost exclusively cold-blooded. They rely upon the light of the sun in order to provide a boost of energy to get them moving and active. What if a building did the same? The sun rises, so too do temperatures. What if heat collected in water, lifting it up, assisted by a PV powered pump, storing its energy up high and allowing it to flow down, around, and under the structure.

Tied into the energy system represented by GUTS, the surplus heat and electricity produced by the gasification and biodigestion processes can be directed into the system, augmenting the solar power to create redundancies in the system which could ensure that on even the coldest, cloudiest days, the system continues to circulate heat energy and water through and around the structure. This process is generally known as thermosiphoning and is entirely feasible. ("Thermosiphon," 2020)

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Fig. 89 - An iguana basks in sunlight. Reptiles generally rely on sunlight to energize themselves and get their blood moving. While the GUTS system provides ample heat to keep the flow of water moving through the structure, the diurnal HEART provides a useful redundancy in this system, moving water to higher elevations via heat pump rather than electricity. Photo: "Brown, Grey, Bearded, Dragon, Iguana, Watch, Lizard, Reptile, Animal, Scale," 2020.

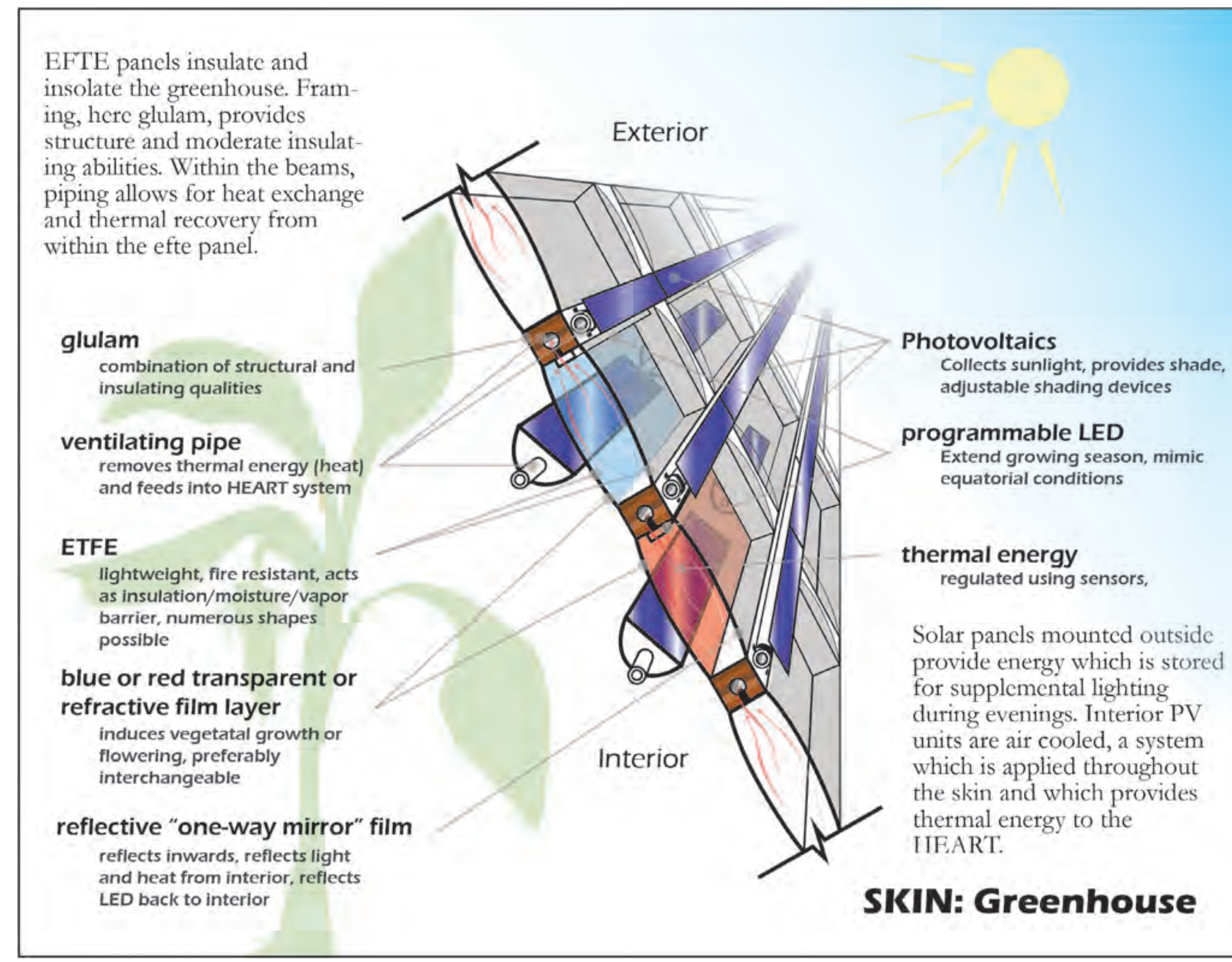

Fig. 90 - EFTE panels can take many forms and are an excellent option for parametric architecture. They can act as a thermal barrier while allowing light to penetrate interior spaces. Here they are paired with systems for collecting solar energy as heat and electricity, pumping energy through the HEART, LEAF &LUNG.

Further opportunities for heat exchange exist with composting systems. Smaller systems and larger windrow systems built over PEX tubing can connect to insulated piping which runs directly to the building, creating a biothermal circulatory system which extends into the landscape. If this system allows heat from the above systems to flow into the composting systems and is paired with an aeration system, their heat levels can be kept higher with less need for manual turning over of the decaying material to maintain high levels of heat. This kills off pathogens and could speed up the creation of high quality soils. Incorporating drainage and diverting runoff into the LIVER system allows for water to be cycled back through the filtration and purification process, redistributing nutrients to beneficial organisms along the way.

Beyond the solar and biotic opportunities for thermal energy capture, geothermal energy provides at least one more means of integrating heating and cooling with a potential for a passive systems approach using heat pumps and heat exchangers.

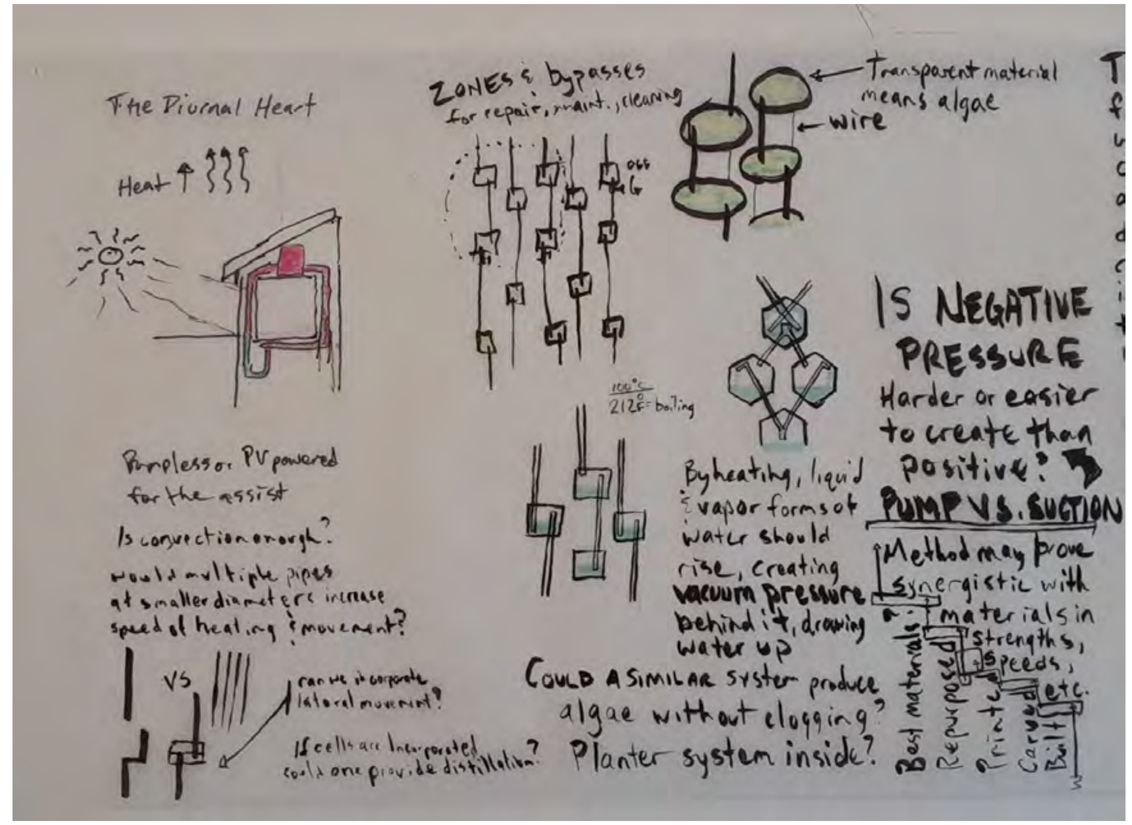

Fig. 91 & 92 - Early conceptual sketches began to consider how heat might be drawn up and through a structural arch system, as well as through a modular screen of translucent containers. The latter would operate based on evaporation and could host algae production as a source of biofuels.

Endnotes

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3.3.2 LEAF & LUNGS

A Breath of Fresh Air: Green walls, moss carpets, growing electricity

We breathe oxygen. Plants breathe carbon dioxide. Our relationship as animals and plants are synergistic in this way, the breath of one fueling the growth and survival of the other. Bereft of this dynamic, our built environment invariably poisons the air we all breath, whether it is through the release of toxic chemicals meant to ease construction and maintenance or by providing habitat for a microbiome which attacks our organs and can even kill us. This has been described as "sick building" syndrome. (Joshi, 2008) Being ignorant of what wasn't visible, namely the microbes and the invisible networks of exchange between living organisms, many designers and builders of the built environment have created spaces that were profoundly unnatural, if such a term still has any meaning. The truth is we cannot be separate from nature and natural processes, as our very bodies are integrated biomes which feed into the world around them. Even as our own lungs are an integral part of our bodies.

Fortunately, the design world and public acceptance of a reassessment of the relationship between our species, the kingdom Plantae, and the kingdom of the built environment - the kingdom Archinae - is widely underway. Green walls adorn interiors and exteriors while green roofs extend the ground plane into the sky. Coupled with effective ventilation, our interior environments are ever less likely to make us sick or to omit entirely the presence of our photosynthetic cousins. Industry and architecture provide wide windows and allow for wide spanning atriums and light wells.

Artificial lighting supplements restrictions in daylighting and irrigation provide relief from some elements of maintenance, wasteful watering practices, and - paired with effective sensor systems - can regulate the delivery of nutrients to the planters which can and should populate ever more of our built environment. In these ways the B.E. becomes recognizable as a L.E. (living environment) again. Sterility is managed, rather than being an assumed or default state.

Fig. 93 - (top left)The tree covered Bosco Verticale (vertical forest) in Milan by Stefano Boeri Architetti promotes biodiversity, "'regulates' humidity, produces oxygen and absorbs CO2and microparticles" (Stefano Boeri Architetti, 2020)
Photo by Gaetano Virgallito.

Fig. 94 & 95 - Green walls and columns bring greenery and improve air quality indoors.
Photos: (top middle) Wikilivre, 2017;
(top right) GSky Living Green Walls, 2020.

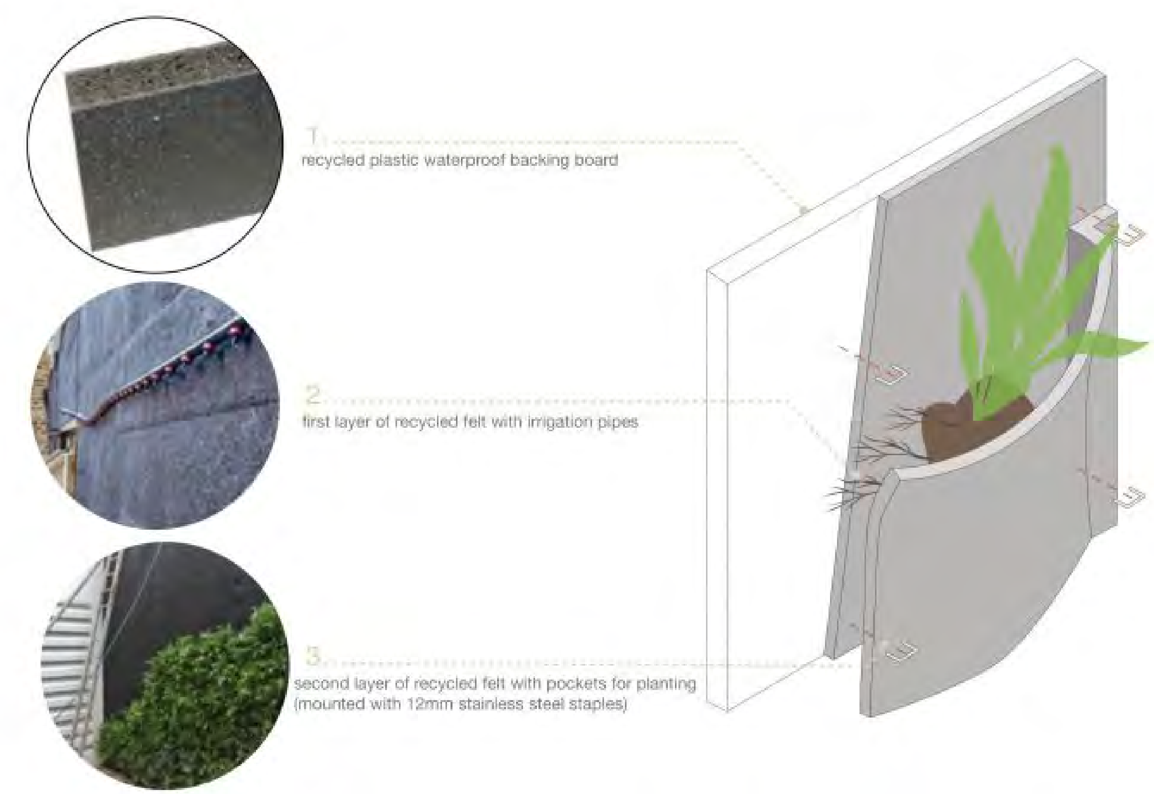
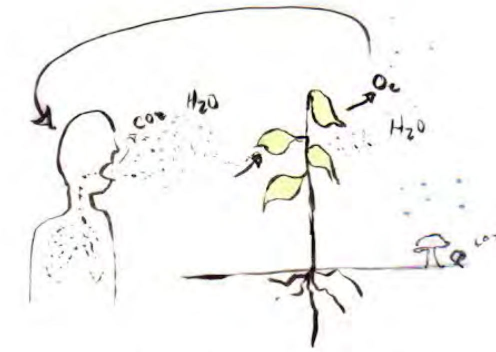


Fig. 96 - (right) Rather than utilizing a modular system of planters, Daniel Bell Landskap utilizes recycled plastic and felt to create their irrigated planting systems.
Image: Daniel Bell, 2019.

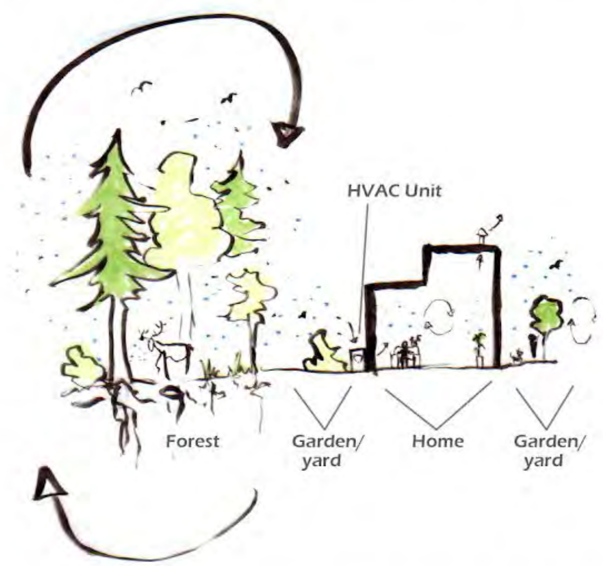
Fig. 97 - (above) Nection Design's moss carpet captures water from drying feet while pulling CO2 from the air.
Photos: "Moss Carpet," 2016.

Proposed here are systems which exist already. While HVAC may continue to serve certain purposes for specific environments, the opportunities for reducing mechanical inputs serving singular uses (intake, filters, returns, exhaust) are improved with the recognition and prioritization of the roles plants play in these systems already. Tied into sunrooms and greenhouses, our exhalations become food for plant matter which can refresh our air, reduce airborne pathogens, feed us, and can integrate into the digestive system laid out in this thesis thereby exchanging solar power into other forms of energy we rely upon through biodigesters and composting. The diagrams are more complex than certain HVAC systems, but that is ignoring the inputs required to build and maintain these relatively dumb systems.

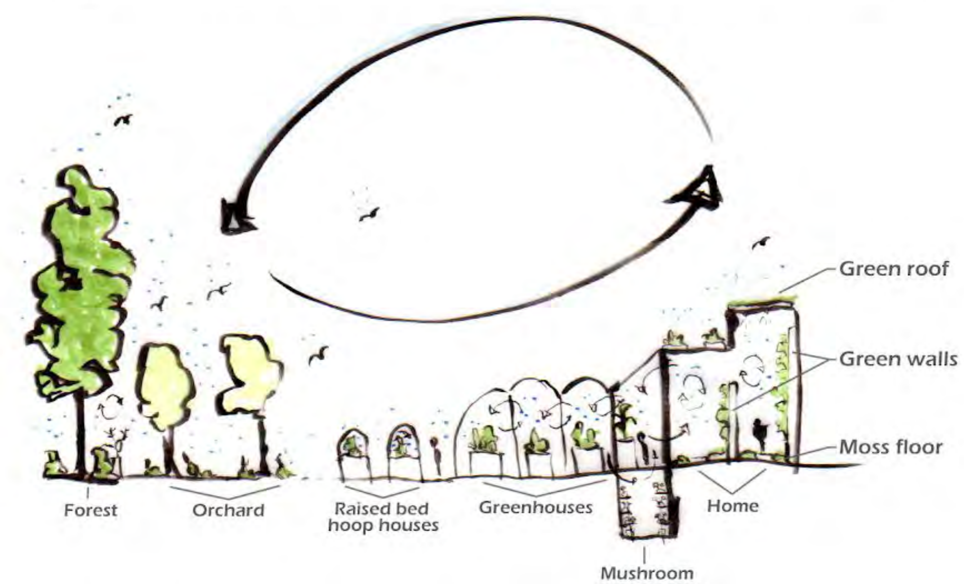
The other side of the leaf is the photovoltaic system. In greenhouses, custom PV systems act as shading and cooling devices from the interior, providing passive environmental control. A small amount of the power that they generate is fed into the self-adjusting system, like leaves turning towards the Sun. Other automated louvres can be similarly powered by the PV system. Surplus energy gets directed into the BRAIN & NERVES battery, with overflow being redirected into the grid or to neighbors, as explained below. In this thesis, the LEAF & LUNG converts sunlight and excess CO2 into energy, food, biomass, and fresh air while supporting the LIVER in its treatment of water through phytoremediation and evapotranspiration. It breathes in our waste and feeds Homo sapiens (among other species) back the oxygen. It is a self-filling oxygen tank for Spaceship Earth. All planting areas are considered a part of LEAF & LUNG, to include greenhouses, green walls, green roofs, and solar arrays.



Natures Lungs: Gas Exchange Between Plants, Fungi, and Animals



Contemporary Standard of Housing Design for Rural Dwelling



Proposed of Housing Design for Increased O2 & CO2 Cycling and Food Production

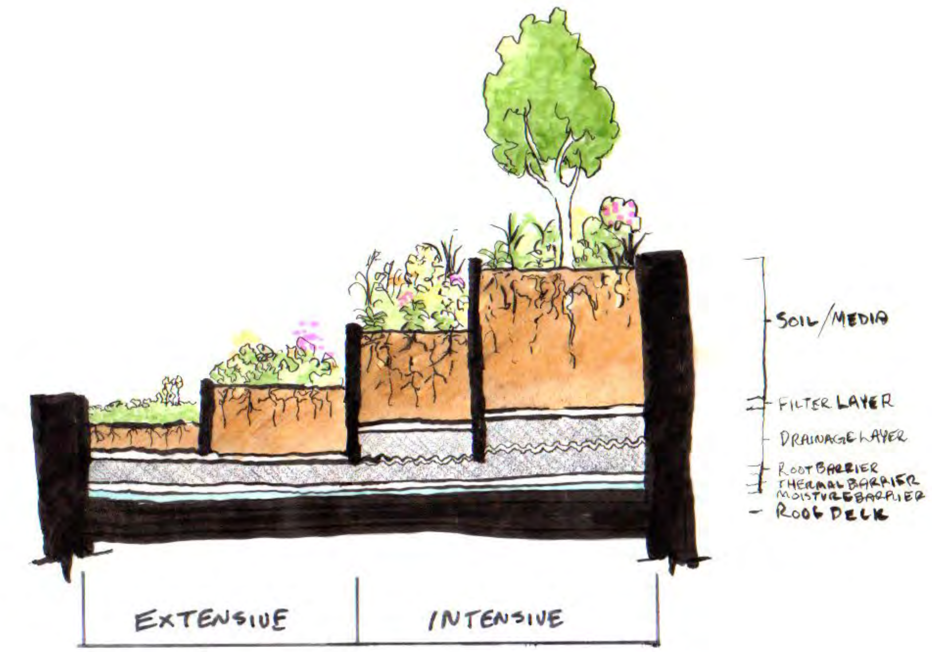


Fig. 98 - (above) Rooftop gardens come in two flavors: extensive and intensive - essentially shallow or deep. Both provide surface area for plants to grow, rainwater to be retained and filtered, and as an insulated barrier against climate extremes.

Fig. 99 - (left) Our atmosphere relies upon a balance of plants taking in CO2 and other gases and exchanging them for oxygen, which aerobic organisms like us, fungi and various microbes. Presently, the B.E. relies extensively on forests and algae which are rapidly displaced for the development of the B.E. and industrial agriculture. Presented here are ideas for increasing surface area dedicated to plant life and biodiversity, which promises to improve air quality, provide food, sequester carbon and mitigate climate impacts.

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3.3.3 BRAIN & NERVES

Intelligence, Efficiency, Power, and An Internet of (Living) Things

Not every living thing has a brain. Fictional scarecrows aside, many creatures survive with minimal processing of sensory input, their requirements for survival restricting complexity of sensors and the systems with which information is processed. Slime molds are go getters without a centralized nervous system, while your brain was thought to have as many neurons as stars currently exist in the Milky Way (though the number may be closer to 20-40%, that's still just you and a few friends putting your heads together). (Voytek, 2013) So too, our built environment ranges in degrees of complexity.

From the region to the inside of a room, our spaces are more responsive and interconnected than ever. Systems and sensors bring information to nodes where information is gathered, then it is analyzed and systems kick in or off. A smart thermostat is a huge jump in "intellectual capacity" as compared to a teepee. Yet the latter manages to cycle fresh air, evacuate smoke, and maintain highly desirable conditions despite climate extremes. There are no electrical wires running through its walls as neurons through skin. It is passive technology, fitting into the resource streams which surround it and providing a very comfortable habitat for our species - within certain extremes. There are no sensors, nor are there meters to read, wire to run, or fossil energy consumed. Humble construction does not equate to lack of habitability.

Fig. 100 - The Mycelium of fungi are made of hyphae which connect to make intricate distribution networks, as discussed in The film Fantastic Fungi. Photo: Griffiths, 2015.

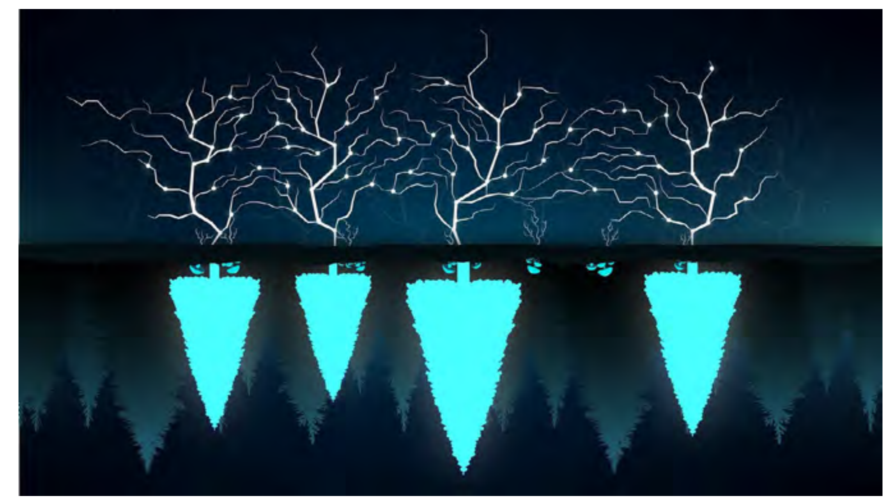

Fig. 101 - These networks connect plants directly, sending information and nutrients - a biological precursor to the internet. Image: Covacich, 2019.

Fig. 102 - The division between the neural network of our minds and circuitry which increasingly connects us to each other and our environments is blurring. Image: Nakod, 2019.

That said, climate control can help mitigate the furthest extremes. I've heard UW Architecture professor Rob Peña refer to it as "Sailing the building" dozens of times. It's a good analogy. We are a part of the brain of the building and built environment, in this way. Increasing complexity of systems requires increased complexity of monitoring and feedback mechanisms in organisms, as well as in the built environment. We sail the ship with our minds as much as the sail and motor, if not more so. The less we have to focus on at any moment, the easier it is to just tweak the way air moves through and over it and we find ourselves cruising along at a comfortable temperature. Quite a feat when we think of the vastness of space.

The intelligence present in our own minds as we set thermostats or open windows is now being enhanced at all scales by technology. We see this in our homes, outfitted with smart appliances which communicate via the invisible network of wifi and the physical network of power outlets and electrical grids to optimize energy usage based upon the habits of the organisms which use them. It simultaneously optimizes our own time and energy by reducing wasted thought, effort and money. The internet-of-things, despite its security flaws, promises a future in which electronic devices, lighting and heating systems, and security systems all offer improved energy savings, remote monitoring and control, and advantages of data recording for further optimization. (Banfa, 2019)

This was barely imaginable only a few decades ago, when the Jetsons promised robot housekeepers (Rosie, meet the Roomba), easy access to video communications (this thesis was made possible, in part, by Zoom conferencing), and flying cars (yes, these exist, but there are still regulatory hurdles and pesky powerlines to contend with.) They even forecasted the ongoing trend of useless jobs, with George designing the next sprocket, a mechanical wonder with nearly zero use. The dream was living high in the sky, far from the feel of earth beneath one's feet, let alone under their fingernails.

Fig. 103 (above) - The Internet of Things promises an interconnectivity between appliances, devices, sensors, environments, and more with a potential for radically increased optimization
Image: Banfa, 2019.

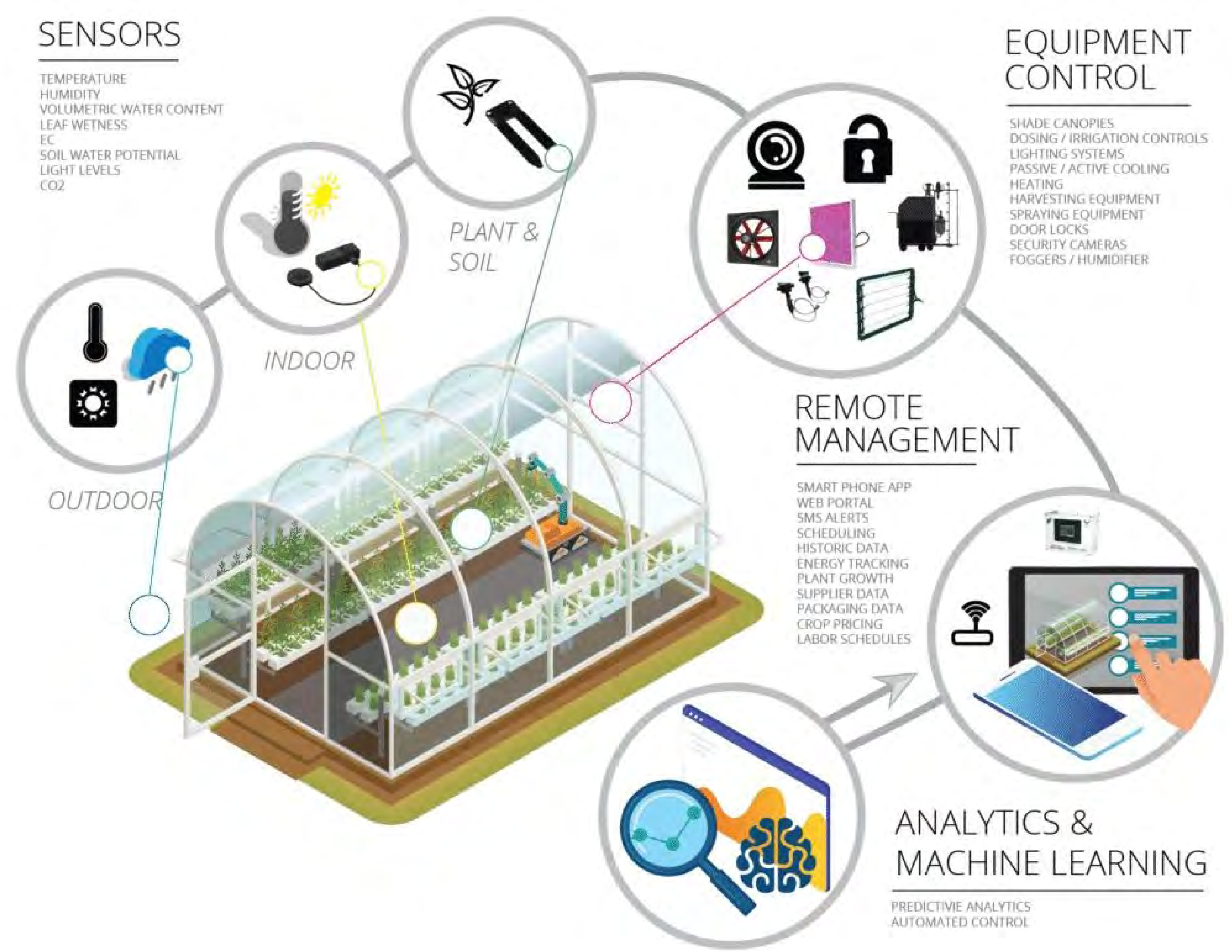

Fig. 104 (left) - Smart greenhouse systems are already on the market, promising improved control and optimization of indoor growing environments. Image: "Smart Greenhouse: 2019 Guide to Best Sensors and Remote Automated Monitoring Software," 2019.

Science fiction has offered many windows into a future of increasing automation and an ostensibly intelligent environment. The voyages of the Starship Enterprise and those of its ilk came to rely upon an intelligence built into the ship itself. Sometimes we forget that ships straddle that fine line between built environment and ecosystem, but that is exactly what inspires Buckminster Fuller in his branding of our planet as "Spaceship Earth" and of Michael Reynolds's Earthships. These are more passive systems that can be adjusted. Where opening the windows (or automating them) is like trimming a sail.

Revisiting the dreams of intergalactic travel and deepsea colonization, we find various examples of biomes equipped with sensors and artificial intelligence, providing means for regulating the life-promoting systems of these enclosed environments without human intervention, as well as mechanisms for people to interact directly with their environment. Horror stories like HAL 9000 aside, the potential for such systems to provide higher quality of living for entire biomes - not just our own often self-centered species - is more than just a pipe dream.

What seems to be missing from many of these stories, however, is biodiversity. Star Trek offers a promise of a world where foods are made from the raw materials of reorganized atoms and biophilia is experienced on the Holodeck. Despite its massive size, the Battlestar Galactica is a dark maze of metal clad corridors and filters, rather than filled with a forest or algal ponds, providing breathable air. Unsurprisingly, when these systems fail, the ships soon promise to become coffins.

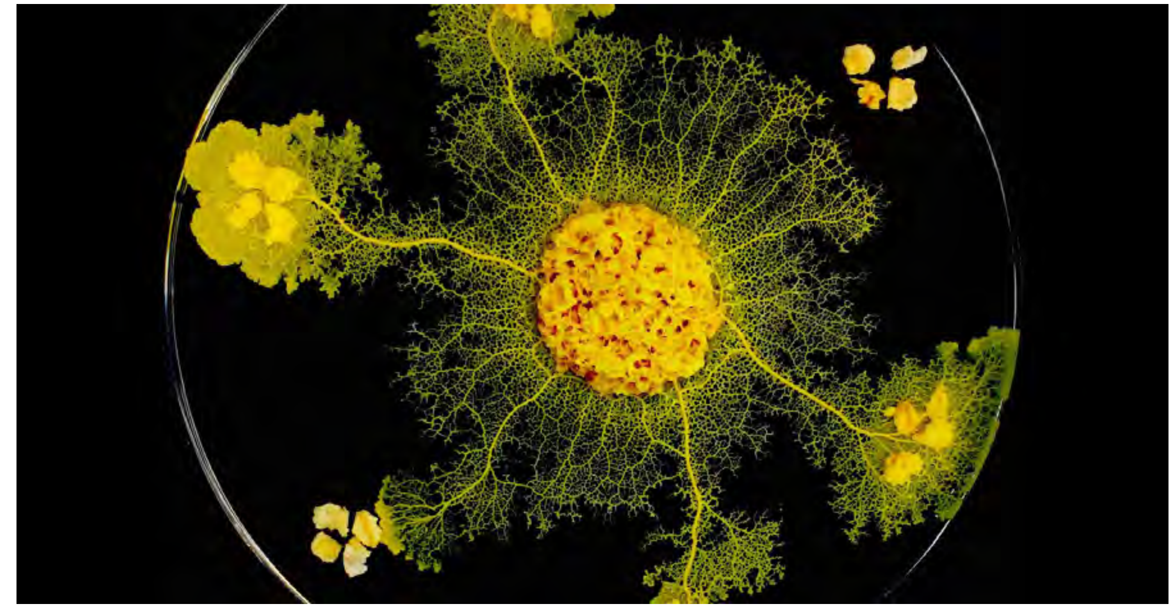

Fig. 105 - Physarum polycephalum is a species of slime molds which have proven "capable of solving maze problems and laying out distribution networks as efficient as ones designed by humans (in one famous result, slime molds recreated the Tokyo rail system)." (Moskvitch, 2018) "The Blob" as it is often referred, is a natural inspiration that goes well beyond the horror movie genre. Photo: Moskvitch, 2018.

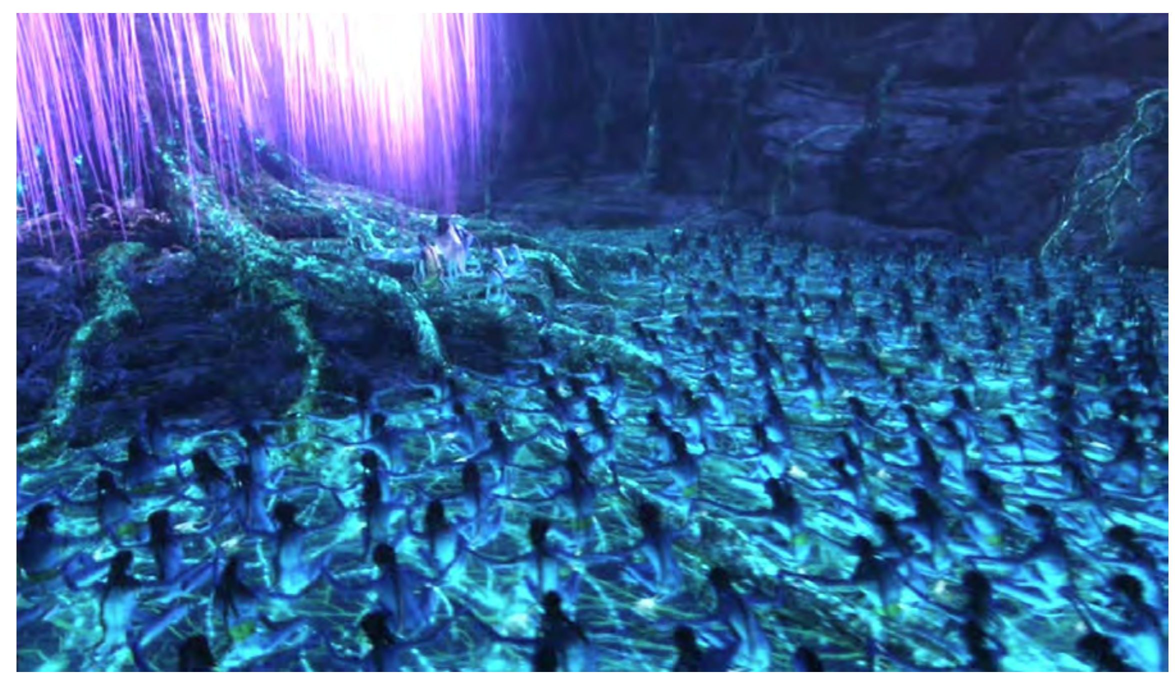

Fig. 106 - (below) Inspired by indigenous cultures and belief systems, sci-fi worlds like Avatar provide a retelling of our own story, with a call for greater connectedness with the L.E. which guarantees us a future while connecting us to our past. In the case of the Tree of Souls, that connection is quite literal. Image: Avatar, 2009.

Our ship's life support systems are failing. The slime mold of our society is starving out or consuming the living flesh of the planet. Something new has to evolve out of it, and that can only come through sensory feedback. It has been key in driving evolution thus far. Driven by the long game of science and the occasional theoretical or technical leap, our world is already being wired up. Sci-fi just guesses at where that will lead us while reflecting on where we stand socially.

Films like Avatar paint a vision of what this kind of organism or society can look like when it has a tangible way of connecting with and respecting other organisms as a part of our own cycle. Their home is literally a skyscraper tree. They have an afterlife thanks to another tree. They literally plug into their ground and air modes of transport - they just happen to belong to the kingdom Animalia. This is a retelling of our own stories, the cultures which allowed our own ancestors to turn barren earth into a boreal forest or islands into paradise. That's a smarter slime mold.

We cannot survive without biodiversity. If our systems and infrastructure aim to remove all lifeforms but our own, they become timebombs which will inevitably go off and leave life to repopulate where we once proliferated. The networks built of and by biodiverse systems represent a sort of intelligence which is reduced precipitously with trophic cascades and other catastrophic events. We need our built environment to work smarter, not harder.

In this thesis, renewable power generated by GUTS and LEAF is stored in a battery system for off-grid applications, with surplus feeding into the local electrical grid for credit or pay. Car battery systems work, but other options include the TESLA battery, kinetic batteries (storing energy in mass moved to a height and dropped through a turbine or stored in a flywheel), or any other effective and safe technology.

The BRAINS use and regulate the usage of energy, providing access to real time data from modular, arduino based systems. Processing power via Raspberry Pi provides feedback mechanisms by which servos can be controlled by the arduino array, automatically adjusting any number of mechanisms, input and output flows. Used smartphones or tablets connected to a mesh network can provide basic data while remaining disconnected from the internet and direct attack from hacking. The mesh network also allows the arduino system to connect remotely to a central node, which may connect to other nodes. These nodes can then share a one-way data stream which can provide real time status updates via the internet to smart devices. As an Organ, the BRAIN & NERVES are the conduits for advanced sensing and communication.

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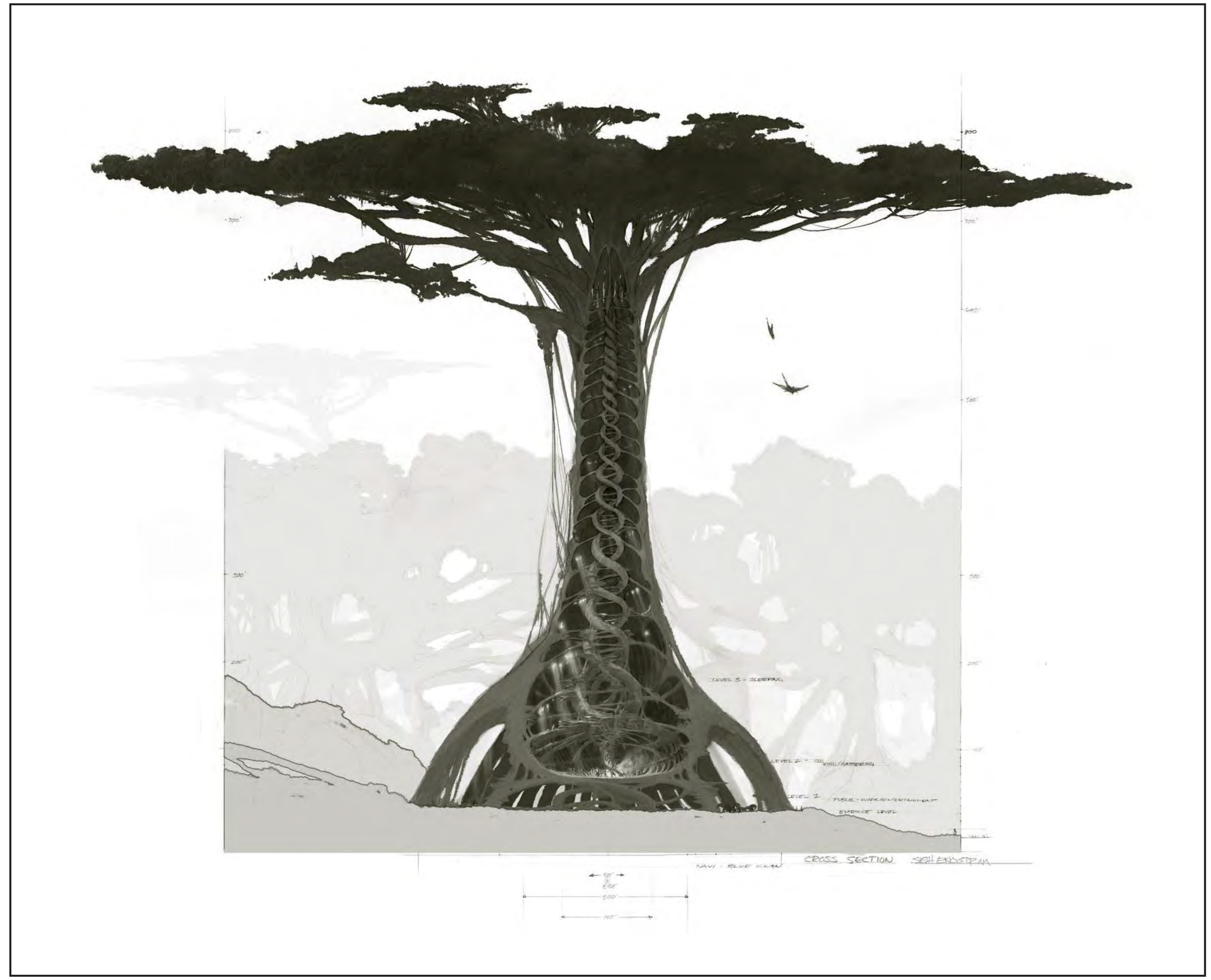

Fig. 107 - Imagine a world that grows in tune with its people. Literally. Concept art of the Home Tree of the Na'vi from the film Avatar. Image: Engstrom, 2010.

3.3.4 SOUL

Story: The Organ of Immortality

Not every living thing has a brain. Fictional scarecrows aside, much of life manages to live out their existence without one. For those of us with a brain, a mind, and a level of sentience to contemplate the matter, we still recognize that each of those lives does, indeed, live. As we tell stories, we literally breathe life into species that can't speak for themselves, to include some that are partially or wholely imagined. Harari points to the life of a Limited Liability Corporation as one example. (Harari, 2015) Inclusion in a compelling story, whether a legal fiction, a scentific discovery, or the memories locked in the *genius loci* of place, has proven enough for us to literally move mountains and to send our lives and stories towards the stars. Story is an driver of Life, and SOUL is its organ.

As designers we use images and words to give our buildings and landscapes life in the minds of others before clever hands and brute force carve them into reality. The documents we produce convey abstractions of the reality we wish to see created and they always fall short of capturing any aspect of outcome entirely. Like a holy book or sacred text, they are a mix of poetry, history, perception, truth, misinformation, and are open to interpretation. As with any concept of heaven or hell, there is immense power in the idea of the place that takes roots in the minds of people exposed to the stories being told in the design and those stories that grow after onstruction. People hate it. People love it. People have a distinct sense of *being there* in built and natural environments which move them or by which they have been encouraged to be moved. Some places feel holy, others distinctly not so and the stories we tell ourselves before, during, and after our stay - physical or imagined - give that place a life beyond its location.

Simply, I put forward that this unseen but widely manifested Organ of the *Archinae*, SOUL, can be seen in the functions of story telling, place-making, marketing, tourism, travel photography, and in every building that was ever built. They may not all be beautiful, but our built environments all of stories. Stories that allow them to live beyond their actual years, like Seattle's Kingdome or the Tower of Babel. It is encouraging to see a story like that of the Bullitt Center grow from the notion of a tree take root in a city, becoming office spaces that are beautiful, well lit, comfortable, and are supported by renewable energy and onsite waste water treatment. For our buildings and landscapes to help grow a better, more biodiverse world, their very SOULs will need to be of diverse biological origins.

In the case studies that follow, the biomimicry is at the heart of each innovation. Beyond the technical and biological, the life of these projects relies on more than their organs, as their names and communities will attest. These projects have SOUL.

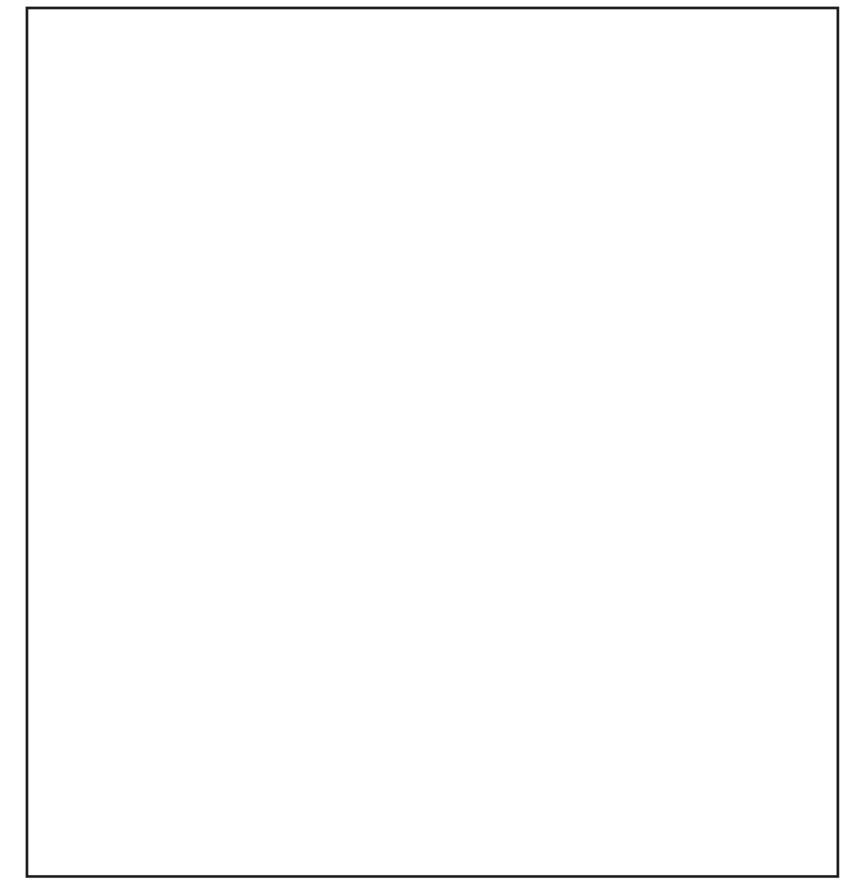

Fig. 108 - Intentionally blank. This space is yours to fill with story or to leave disregarded. The stories you tell about it determine whether it will live on.

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4 CASE STUDIES

4.1 OVERVIEW: Systems Thinking

In terms of simple economics, each of the Organ types described in the preceding chapter conductS resources in time and space, apply certain processes in order to break those resources down to raw components or bring them together for a value added product which is then exchanged or accumulated. Viewing everything is a resource which can either be traded or tended is something all living things do. There is always give and take, with hands exchanging circularly or passing down the line.

With biomimicry, we travel the spiral out and first identify, then we translate, discover, abstract, emulate, evaluate, and then identify the next opportunity. Applying the Organ types to each of these businesses reveals new systems which could be added, or grafted, onto the existing physical and business structures. Using the metaphor to classify types allows us to fit systems together, each processing resources through or between them.

A biochar system takes woody debris, but it doesn't take green waste, sludge, or fecal matter and convert it to syngas, bio-oil, and clean water. It takes a biodigester to get those, as well as a great fertilizer. That's nutrient density that is digestible by the soil, which feeds it back to the plants over time rather than washing away and flowing from fossil fuels. But you need a gasifier if you want those first three things in addition to biochar. Biochar is a soil amendment that adds surface area to soils at an insanely small level (pores that are 10 µm or smaller). (Batista, 2018, pp 3).

That happens to be the size of fungal hyphae, the threadlike tubes that help them explore (Field, 2019). They are masters of extracting nutrients, minerals and water and releasing it for use by other organisms. And the combination of biochar and fertilizer means that many more storage spaces for the fungi and plants which inhabit the soil to access. When a gasifier and biodigester get to live together, along with a compost heap, mushroom grow room, there is a cycle through which biomass is converted into electricity, gas, oil, filtration media, fertilizer, soil amendment, and soil. Between the electricity and fuels, technology can feast. With the fertilizer, soil amendments and soil, the living can feast.

Combining processes into a system of interconnected relationships powered by sunlight and the hydrological cycle is a fundamental approach for agriculture and the basis for renewable energy. The following case studies begin to close many of these loops. Applying the thinking behind the Organs to them, there are few technologies I would choose to add. Some might consider a gasifier superfluous, for instance, but access to biochar provides an incredible opportunity to provide a high level of filtering while using discarded material as the bases of soil beds. The more porous, the more space for life to take hold and get at what's there that's not being used. Beyond biochar, these systems provide additional streams of electricity, fuel, thermal energy for heating, and distilled water for plants and people alike.

Beginning with water, the case studies covered here, in brief, begin with the Living Machine. As a basic component for wastewater treatment, these constructed wetland systems use basic filtration, pumps, tanks or planter systems, and an army of plants, micro-organisms, and animals to provide bioremediation of contaminated water. This is a great lesson in basic biomimicry - get Nature to do the heavy lifting.. Which is what we see in the Green Power House, where the efficiency of algae at converting CO_2 and sunlight into biomass is married to a high tech take on an ancient technology. Pyrolysis, a step in the gasification process, breaks down organic matter into its component carbon, oils and gases. As noted before, additional byproducts include clean water, thermal energy for heating, and a greenhouse environment for growing other plants for food, medicines, and beauty.

Finally, we land at The Plant, where an anaerobic digester fulfills many of the same steps as Green Power House's gasifier. The feedstock for the biodigester comes from a set of businesses housed in a former meat-packing facility in a remarkable case of adaptive reuse. An indoor aquaponic farm shares space with two breweries (beer, kombucha), a commercial kitchen, and other small businesses, bringing financial opportunity and local organic food to an area that has been sorely in need of both. To each of these systems, I take existing diagrams and overlay components that were left out of the drawing and other systems relating to the *Archinae* Organs which are the basis for this thesis.

4.1.1 Living Machine

The Living Machine is based on the knowledge that wetland ecosystems can purify polluted water. "In the 1940s and 50s, despite the belief then that higher plants can't withstand polluted waters, Dr Käthe Seidel from The Max Planck Society discovered that bulrushes don't just survive polluted conditions, they restore them." (Laylin, 2010) Ecologist H.T. Odum set up guiding principles for the process and Dr. John Todd invented the first Living Machine. Installed at Findhorn Ecovillage in Scotland, the system has been replicated and expanded at various sites around the world. (Laylin, 2010)

Waste water, to the exclusion of black water, is pumped through a series of tanks hosting beneficial communities of organisms. These organisms down contaminants and their own waste. What doesn't break down settles to sludge which then is cycled or removed for further treatment or disposal. I have overlaid a network of additional components which may enhance, augment, or benefit from integration with a Living Machine.

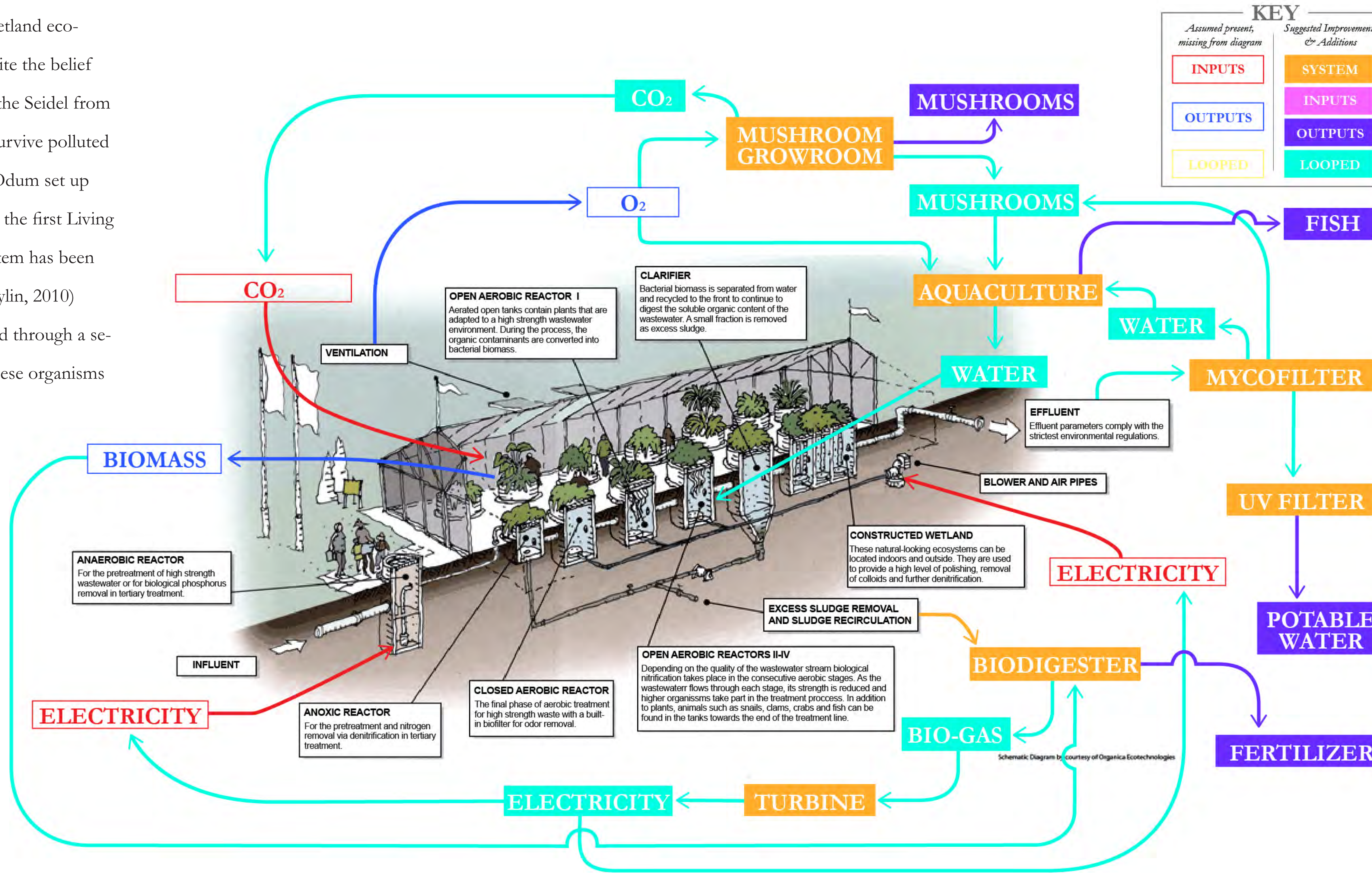

Fig 109 - The Living Machine creates distinct environments to maximize biodiversity and thereby increase the the means by which the water may be remediated. Wetlands ecosystems have long provided these necessary services as a part of the hydrological cycle.
Base diagram: Laylin, 2010

4.1.2 Green Power House

The Green Power House combines three subcomponents in order to close the loop on waste products from an adjacent sawmill in Columbia Falls, MT. The system utilizes the waste wood to fuel a generator (Organic Carbon Engine, or OCE) which produces thermal energy, biochar, bio-oil, and surplus CO2 and N2O. The heat and gases are piped into a greenhouse where algae production and edible food plants are grown (Photo Bioreactors, or PBR), providing a comfortable and productive environment for them. The algae are harvested and the biomass is run through an anaerobic digester (Anaerobic bioreactor or ABR/iBuffalo) which produces methane and nutrient solids. The methane goes back to fueling the OCE and the nutrient solids are combined with the biochar to create soil amendment and fertilizer. (Green Power House, 2013)

I have added a constructed wetlands component for treatment of wastewater from the sawmill, a mycoculture component to enhance this filtration process and process some of the sawmill waste into foods and medicines, and an aquaculture component to produce food and enhance the cycling of water and nutrients.

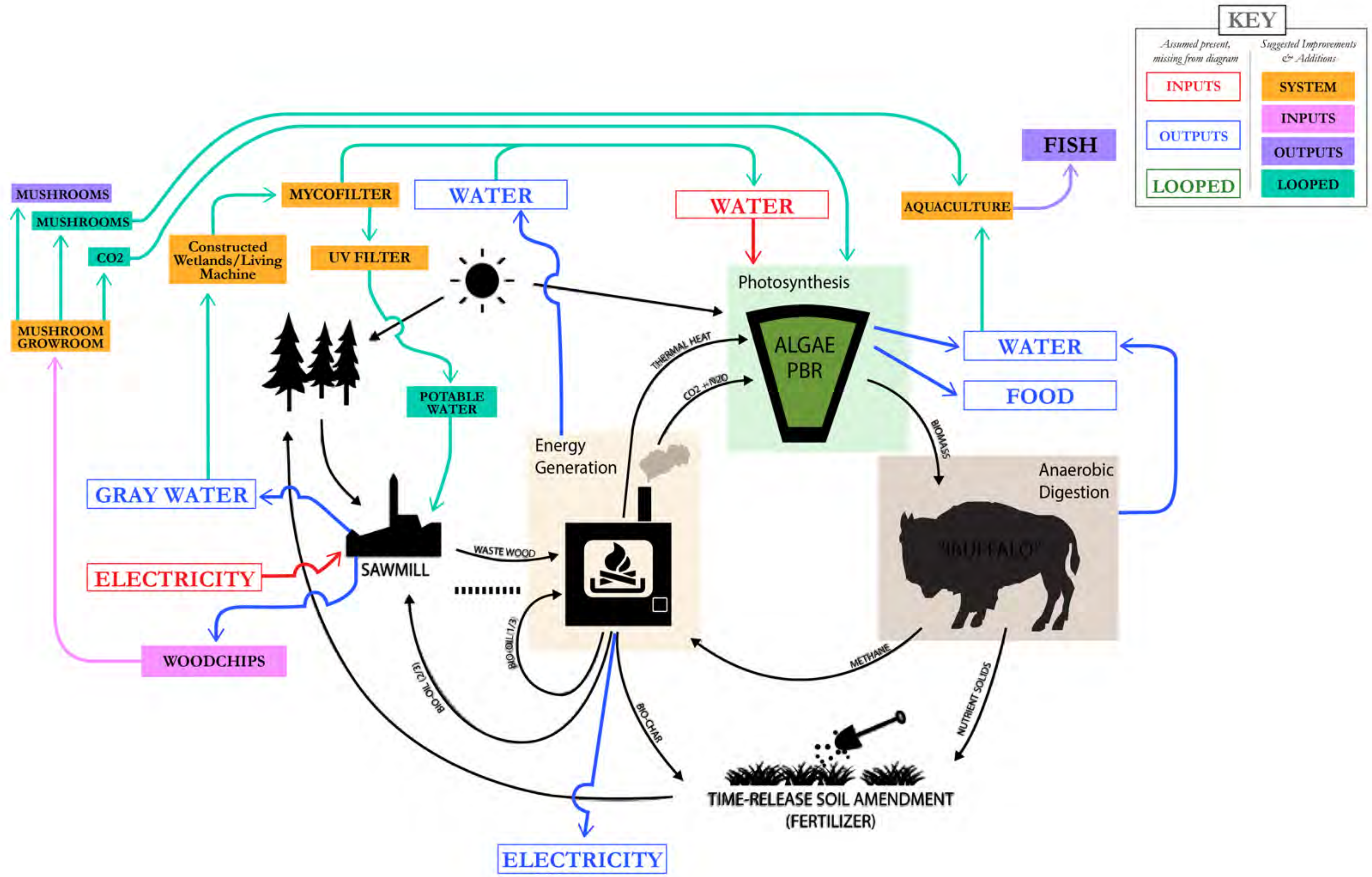

Fig 110 - The Green Power House also provides protected environments for desired biodiversity. Integration with the sawmill provides considerable ecological benefit as the algae continue to pull carbon dioxide from the atmoshphere. This even morey true if the lumber is regeneratively managed and sustainably harvested.
Base diagram: Green Power House, 2013.

4.1.3 The Plant

The Plant is a "net-zero vertical farm and food business incubator" in Chicago. (Proksch, 2017, pp 194). An example of adaptive reuse, the former meat-packing facility includes hydroponics, aquaponics, beer and kombucha breweries, a commercial kitchen, and anaerobic digester which turns waste biomass into electricity. This energy powers lights for the greenhouse operation and heating and cooling.

In considering the diagram below, I added inputs, outputs, and looped resources which were not included in the original diagram. Systems that were then added on include a gasifier system for supplementing energy production and producing biochar for the greenhouse system, as well as a constructed wetlands system for the treatment of wastewater into potable water. Additionally, I recommend cycling waste CO2 from the brewing and mushroom growing processes into the greenhouse.

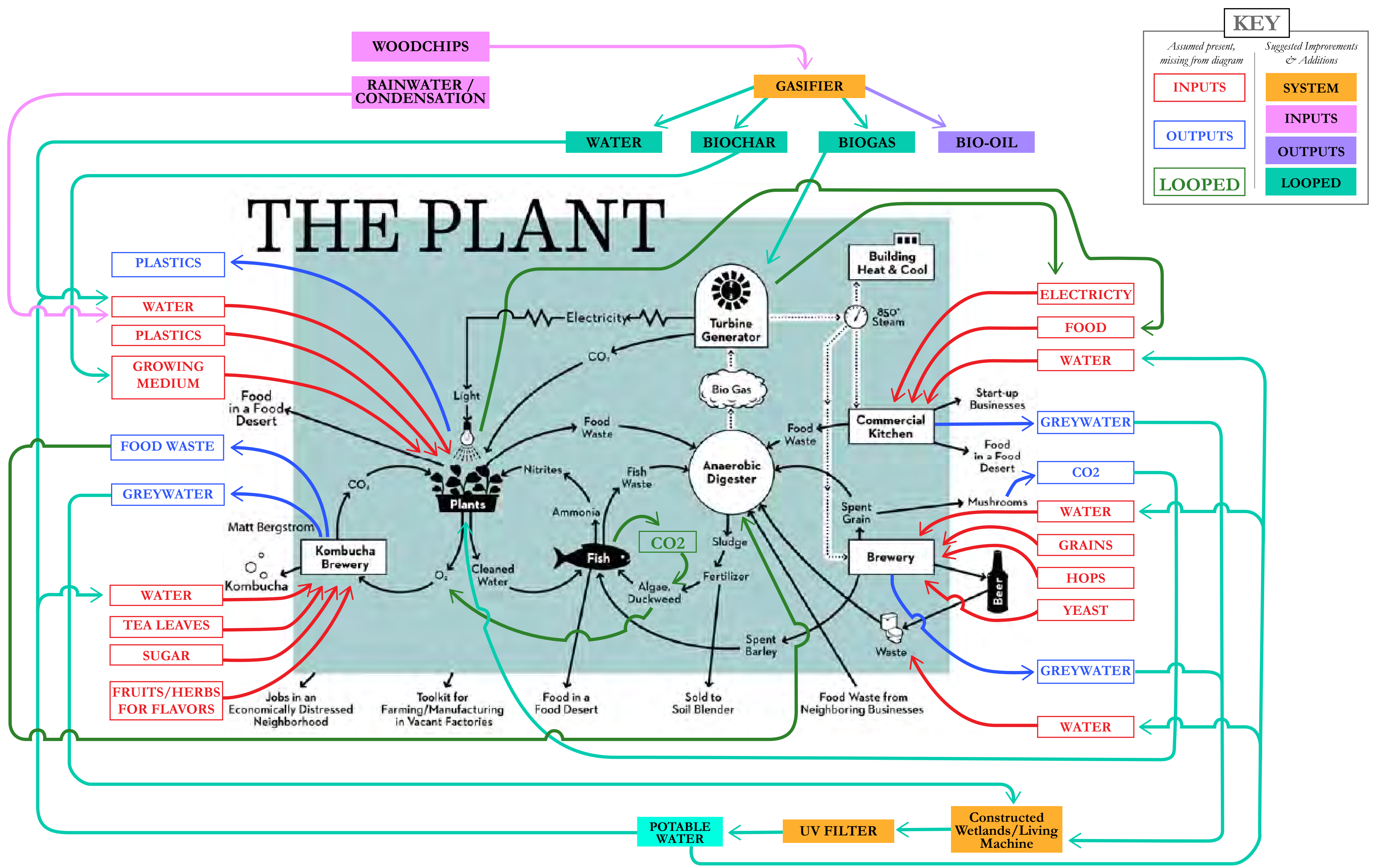

Fig 111 - The Plant incorporates a wider range of strategies for energy production and resource cycling than other two case studies. Still, it is arguable that there is room for even more growth and adaptation.
Base diagram: Thiel, 2011

Endnotes

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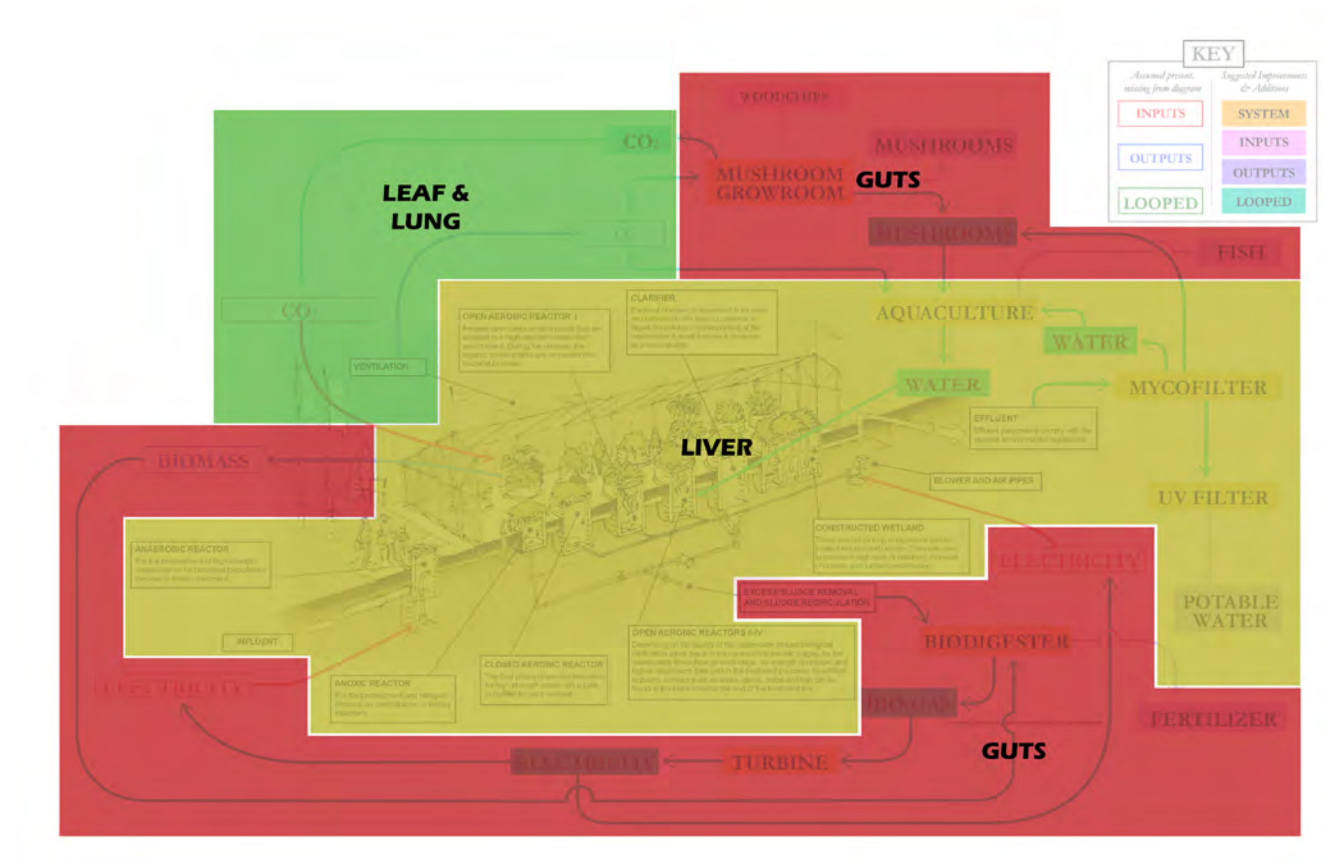
4.2 SYNTHESIS

Synthesizing the ideas discussed in the Framework, Literature Review, and Systems sections of the thesis with the Case Studies and Design is hereafter diagrammed through the *Archinae* Organs, Principles, Symbols and Systems. In the next Chapter, site analysis and design iteration layout a snapshot of a current effort to design and grow a new species of Archinae outside of a remote town in Washington State..

4.2.1: Organs

I went on to look at the final, augmented drawings and overlayed labels and color coding to identify where each of the *Archinae* Organs are revealed.



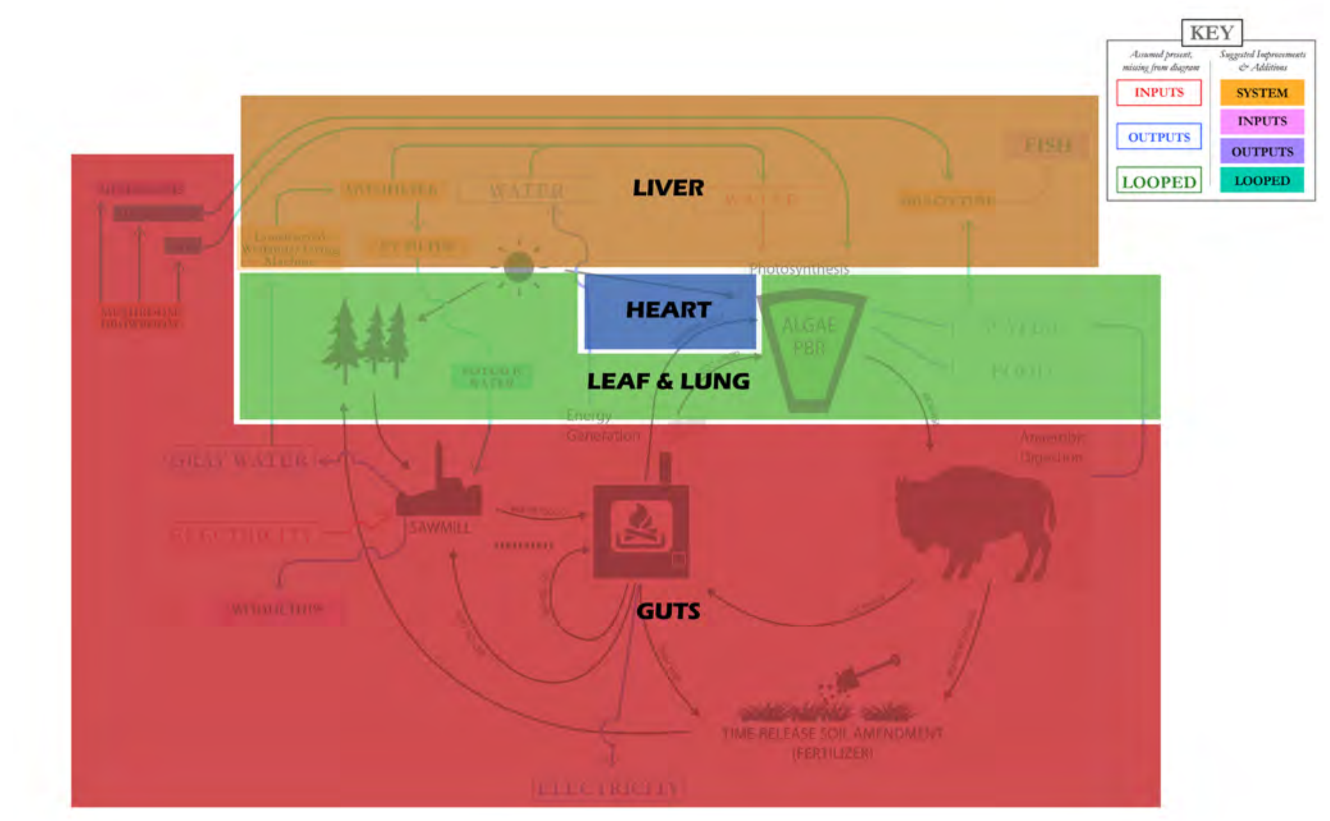


Fig 112 & 113 - The case studies with augmented systems are overlaid with color coded groupings into the Archinae *Organ systems.*

4.2.2 Principles

In synthesis we can again employ the biomimetic process: Identify, Translate, Discover, Abstract, Emulate, and Evaluate. I have identified a list of "Design Principles from Nature" from Janine Benyus, which I want my design proposal to emulate. Added to this list is an additional set of biomimetic principles which inform my design proposal.

Identify one or more functions that you want your design to perform

Translate those functions into biological terms

Discover strategies that nature uses to perform those functions

Abstract those strategies back into technical terms

Emulate those strategies in your design solution

Evaluate your design brief and Life's Principles, and then decide how you want to use your next lap. (The Biomimicry Institute, 2014)

Design Principles from Nature

Rules according to Janine Benyus & the Biomimicry Institute:

"Nature uses only the energy it needs and relies on freely available energy.

Nature recycles all materials.

Nature is resilient to disturbances.

Nature tends to optimize rather than maximize.

Nature provides mutual benefits.

Nature runs on information.

Nature uses chemistry and materials that are safe for living beings.

Nature builds using abundant resources, incorporating rare resources only sparingly.

Nature is locally attuned and responsive.

Nature uses shape to determine functionality." (Baumeister, 2014)

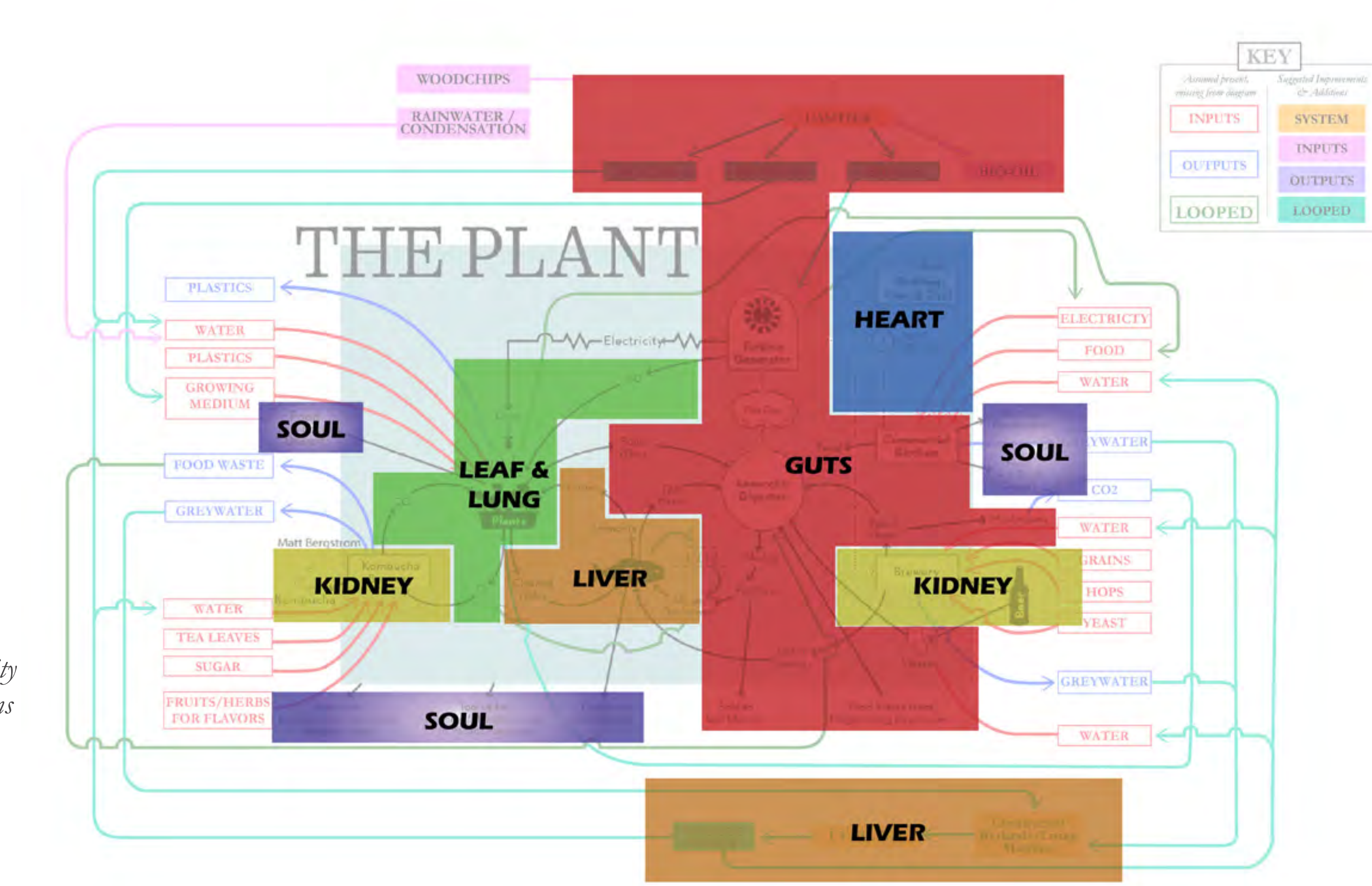


Fig 114 - The Plant shows an integration of more of the Organs systems, which compliments the increased diversity of services provided by the organizations that call it home.

Endnotes

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4.2.2 SYNTHESIS Principles

Some Additional Principles

A biomimetic approach and the range of research performed for this thesis has revealed a few other gems. The following approaches are my own takes from the field of biomimicry:

- Minimal effort, maximum effect
- Composite materials - no magic bullets/one-size-fits-all
- Surface area may be increased for
- Strength (ridges, etc)
- Friction/resistance
- Habitable space/biodiversity
- Directing forces/flows rather than fighting against (smooth vs rough, channels, berms/swales, etc)
- With materials and fuels (food), more transport = more energy, thus local > global, and reducing movement can increase sustainability
- Grow locally, sell locally.
- Separating at the source (sorting, filtering, processing on site) saves energy and reduces waste
- Processing at ambient temperatures is nature's way. Avoid "heat/beat/treat"
-
- Life works on a framework and fill regime. Processed materials make a lattice for the sorted. Chemical and mechanical, biological and built.
- Basic construction strategies: burrowing, stacking, weaving, mechanically and chemically adhering
- Less $$ does not necessarily mean cheaper - the costs are subsidized somewhere and lives are always impacted.
- Complexity is built of simple things.
- Fractals are a template for continual growth.
- Species migrate around, through, and beyond the abstract definitions of site. Control should be limited.
- DO NOT DEGRADE THE SOIL. BUILD IT.
- The structures grown and constructed by species always provide several useful functions, not just one.
- Microclimates are essential for biodiversity
- Camouflage can be useful and beautiful

4.2.3 Symbols & Systems

Abstraction through symbols and words can provide a means of organizing complex ideas and providing an intuitive understanding of relationships. The trick is to not ignore the complexity for a love of simplicity. Here, the relationships between the different systems and their primary elements are depicted around and within an octagon, representing the eight systems presented herein. GUTS, for instance, has inputs from all of the elements, but most strongly depends upon plant matter, woody biomass, soils, and metals - represented by Earth and Wood. The heat required for and generated by the composting, biodigester, and gasification systems within are most directly related to the energy of Fire, seen in the interior Energy diamond. This is not a perfect model, rather it offers an intuitive understanding of the holistic connections between these systems.

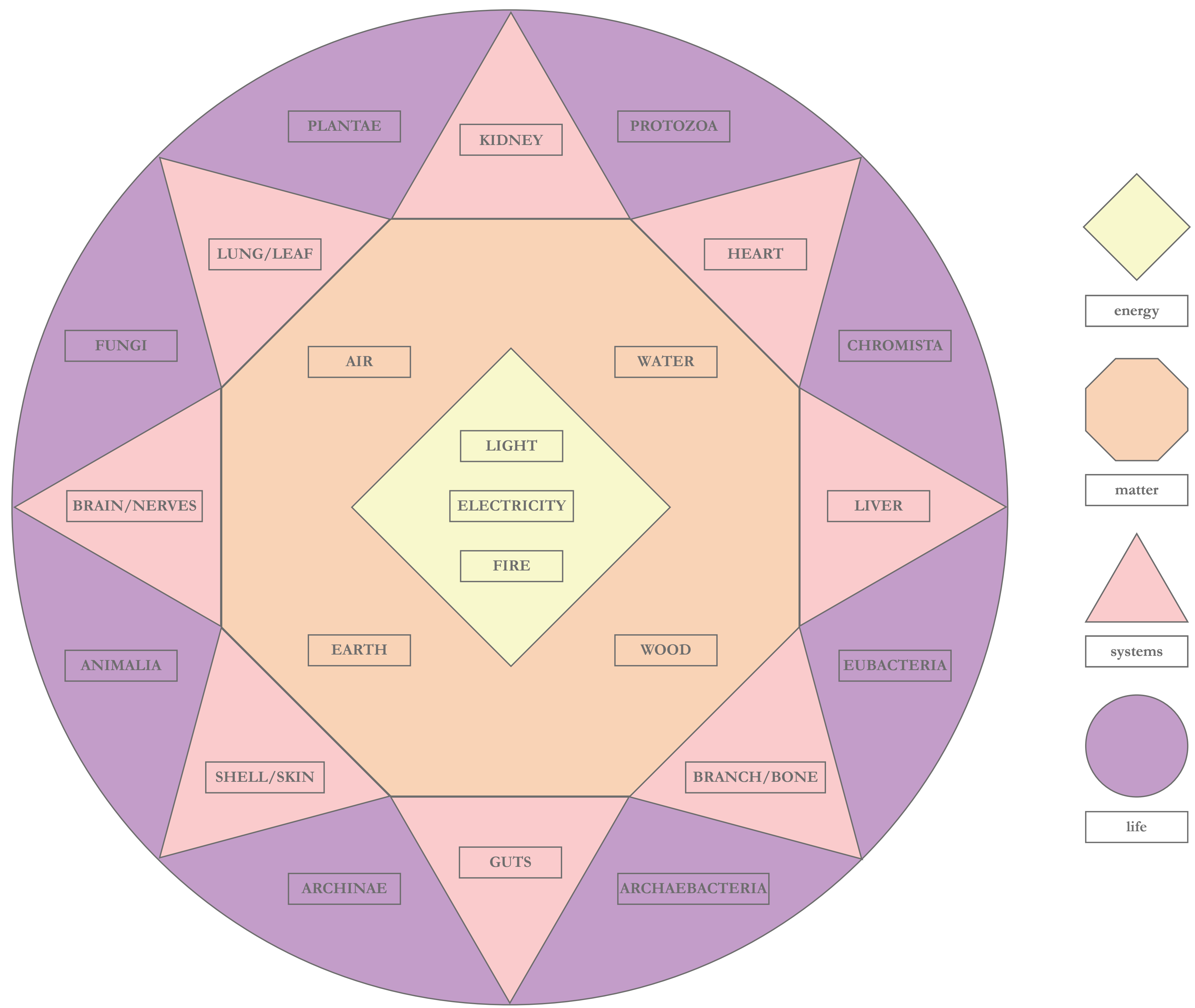


Fig 115 - Early conceptions of the building blocks of life were abstracted into "elemental forces" of Air, Water, Earth, and Fire. These were expanded to include elements such as wood and metal.

Here the complexity of the overlapping systems is revealed in terms of resources. With the exception of electronics, certain plastics, and re-cyclables, “waste” becomes an entirely irrelevant term and is replaced by “feedstock” which is looped through the various systems. A lack of arrows indicates INPUTS from outside sources or marketable OUTPUTS, in dark purple. At the center of this resource diagram, Da Vinci’s Vitruvian Man holds a wireless device in one hand and a piece of fruit in the other, indicating the roles of organic systems of the individual and community within the larger set of systems.

Compared to the previous figure, the image to the right appears vastly more complicated and/or complex. Yet this in itself is an abstraction of yet more complexity and interdependence between actors, systems, waste and resource streams. This diagram alone may convince future architects to continue the overly simplistic practice of building boxes in the air. For myself, I remain inspired by the opportunity to tease out the secrets to a long and healthy life for the built environment and all of its denizens from the complicated web of relationships our very existence precipitates.

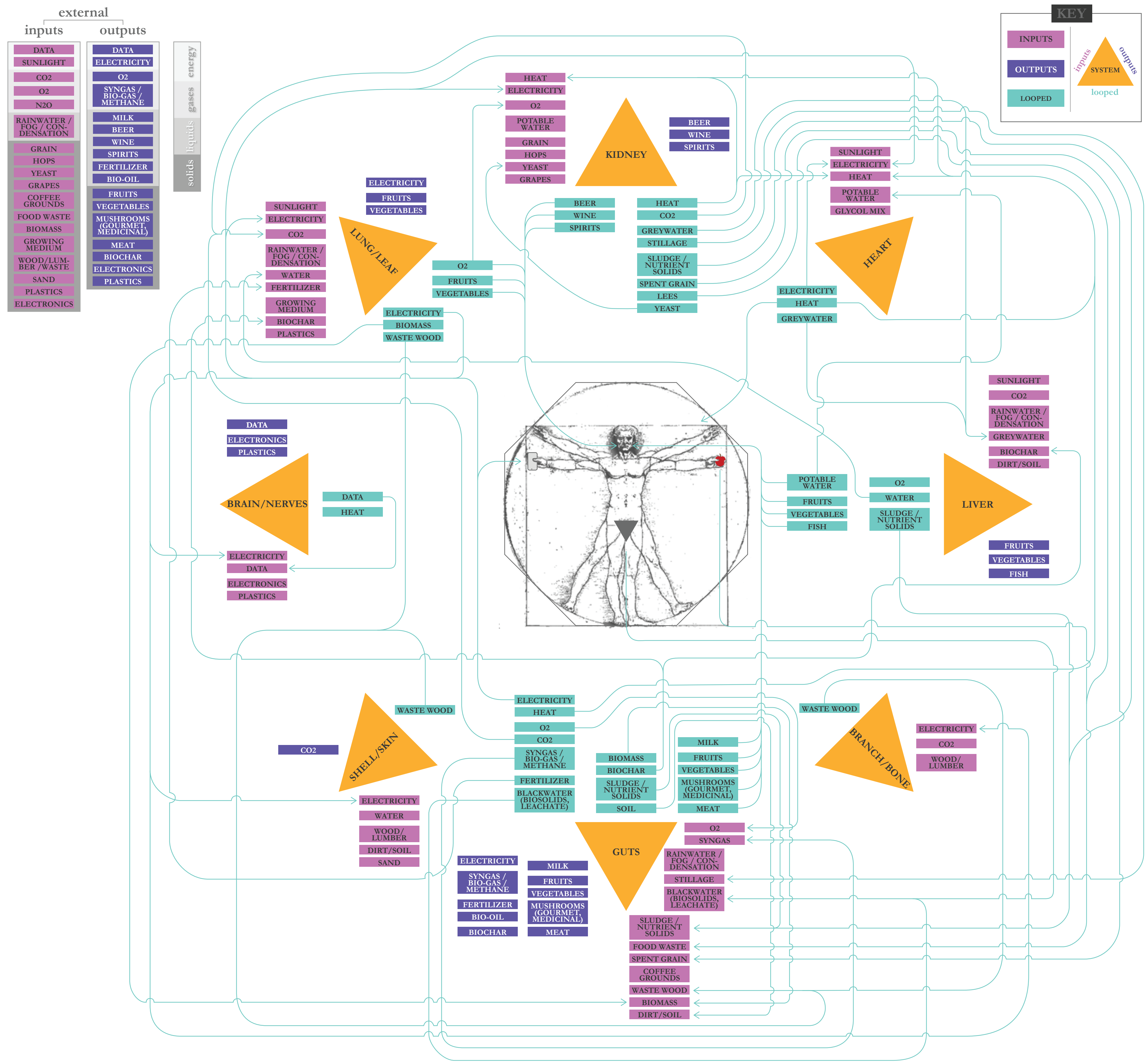


Fig 116 - An anthropocentric view of these systems makes them all appear much more complicated.

5 DESIGN

5.1 OVERVIEW

The design chapter covers the overall vision for the site development in accordance with the design principles discussed in Chapter 4; the program developed to embody this vision; context and site analysis for the specific location chose for the design; a description and images of the design process which preceded and followed these steps; plans for the site and building/organism; sections; and renderings. For the ease of translation, I will generally use traditional terms building and landscape to describe the larger hybrid organism which is the hopeful outcome of this line of exploratory design. Not all Organs were fully developed during this iterative phase of development.

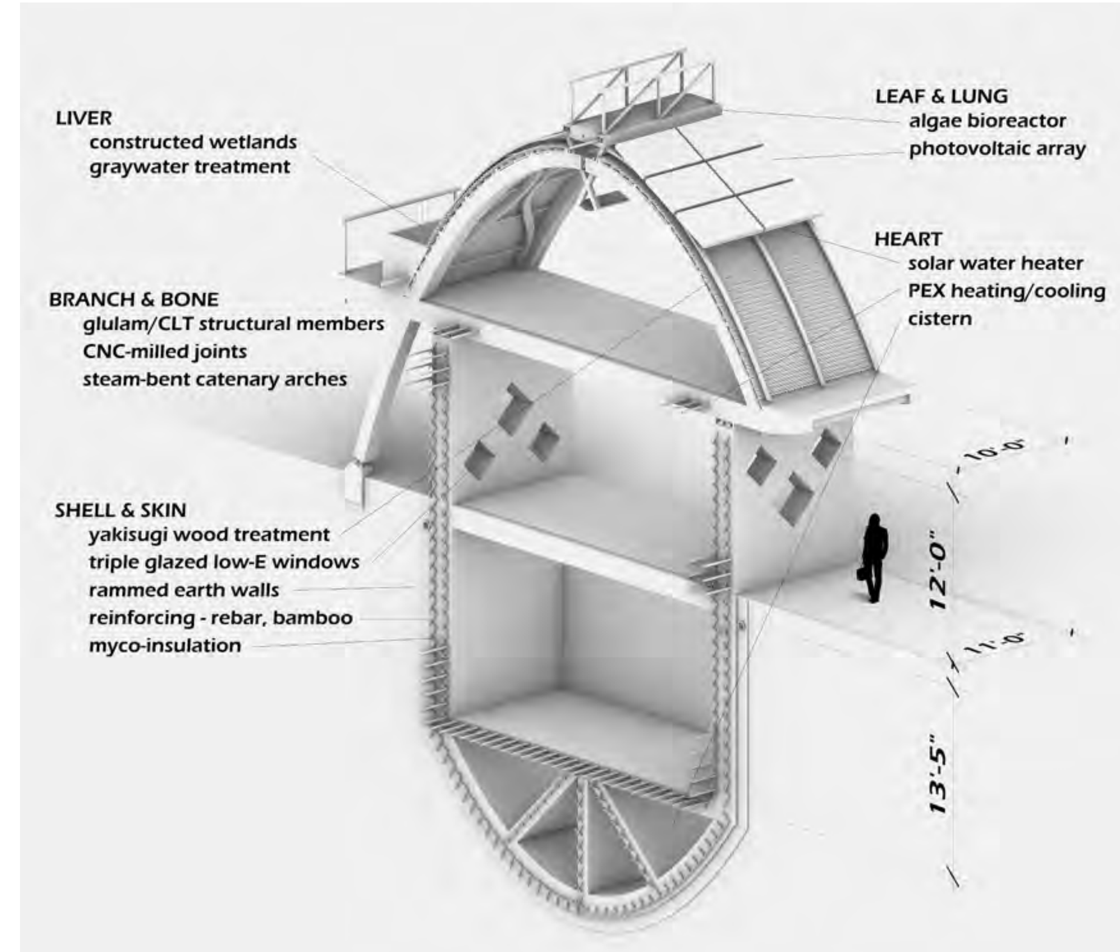
5.1.1 Vision

The design vision for this project is to develop a general master plan for a retreat center focusing on holistic health practices, natural medicines, organic food production, and arts events. The intention is to build and grow community and collective resilience through this site, providing templates for other members of the community to do the same on their own land. Mimicking nature's processes of phased growth and metamorphosis, this project develops over the course of different phases, a network of systems that are zero-energy, zero-waste, carbon positive (sequestering), and which increase native habitat while diversifying the landscape through berms, swales, and the cycling of organic wastes and water into and through built infrastructure and landscape features. Materials brought onto the site will generally only leave the site as value-added and upcycled goods.

Use of machinery will be limited to that which is most efficient, increasingly run on the renewable energy produced on the site. Onsite energy production of electricity and fuels is targeted to exceed the needs of the site and residence, with the surplus of electricity being sold to neighboring homes and/or put back into the grid. Fuel production in the form of syngas or biogas, which will rely upon biomass produced onsite and material imported from restaurants, farms, etc, is anticipated to grow dramatically over time and will be sold once the capacity exceeds the needs on the site.

The Methow Valley is the cultural hub of Okanogan County. It is populated with many artists. Performance groups are regularly invited into the area to perform at various locations, to include on personal property for public performance. This project incorporates opportunities for arts and performance, to include the construction (in a later phase) of an amphitheater space, dance studio/dojo/interior performance space. As actors, Isis King and I are connected to the community in Seattle and in other cities, to include New York, which would undoubtedly benefit from these spaces. As a fine artist, I intend to create a gallery space for exhibition of my own works and of others, offering yet another venue for display to artists within and beyond our personal networks.

Health and wellness are intimately tied to the notion of community, being considered both in the production of food, herbs, and medicines, as well as the development of sensory garden spaces. Designation of some garden areas in a P-patch style will provide opportunities for area residents to take advantage of the increasing fertility of the site for their own benefit, in particular those who are unable to farm their own land. Classrooms offer



opportunities for classes and lectures on food production and sustainable design practices.

In creating a location with such a diverse range of programming and opportunities, the goal is to attract people for day-visits and overnight stays who are:

- From around the world and who are interested in holistic healthcare and regenerative agriculture
- From within the state and who are interested in the local arts and music festivals
- From the local community and who are interested in all of the above, as well as employees and community partners.

To facilitate this, while controlling the numbers of people and, more importantly, vehicles, on the site, funding would be sought to purchase a small bus or van for bringing people from Twisp to the site. Fueled by the GUTS, this would negate much of the carbon footprint associated with transport to and from the site. Future improvements to the dirt roads would also allow for easier access via bicycle

Fig. 118 - A view from the communal kitchen looking west past the courtyard toward the amphitheater. Out of frame to the left is an entrance to the greenhouse and cafe seating.

Fig. 117 (previous page) - The resulting design takes a base module of bamboo-reinforced rammed earth walls, glulam arches and beams, yakisugi shingles and integrates photovoltaics, subfloor and interwall heating and cooling, and treats gray and storm water as a matter of course. This image reduces some of that complexity and emphasizes form over generative function.

5.1.2 Program

The program is intended to benefit from the biomimicry design spiral mentioned earlier in Fig. 4. (The Biomimicry Design Institute, 2014) The first two steps in the biomimicry spiral were to:

1. **"Identify one or more functions that you want your design to perform" and then to**
2. **"Translate those functions into biological terms."**

In developing the Organs as a biomimetic response to the installation and maintenance processes of Building/Construction; Waste Processing; and Climate Controls were translated into the biological terms Growth; Digestion; and Transmission. The 8 organs cover the essential functions of a complex living organism. Within their environments, these organs in themselves provide opportunities for a range of interconnected, overlapping, and redundant functions and complex systems. These are lessons learned from looking at how nature interacts with itself in terms of growth patterns, dynamic relationships, and resource flows. Each allows us to:

3. **"Discover strategies that nature uses to perform those functions"**

Viewing the built environment as living organism, the forms and functions of Organs are defined and refined by their growth patterns, dynamic relationships, and resource flows. They are also defined by spaces which hold quantities at specific distances and in particular mixtures through structures. The flow of solids, fluids and gases is directed and regulated according to intention and a recognition of constraints, cycles, sanitation or hygiene.

4. **"Abstract those strategies back into technical terms"**

All of this can be found abstracted in our built environment in the forms and proximal relationships of things like furniture in a room, spices in a cupboard, water in a toilet bowl, etc. In architecture, we take that abstraction to the extreme in our conception of solid and void. What we do with space, how we shape it and fill it, these provide fascinating images and moments that can leave us spellbound, even affected for life. But space isn't just space. We're being biomimetic over here. So we return to the analogy of Organs.

Organs also make room for other beneficial organisms or find themselves occupied by the harmful and damaging. So too our living spaces must be built for Homo sapiens, our cast of domesticated species, and the wildlife that can cohabitate. It must also be designed for the numerous species which are chosen to direct, regulate, and process the flow of resources which invariably flow into, through and beyond the biomes our species occupies. If we do all of that in a way that is elegant, beautiful, and provides space for the desired activities, odds are it will be populated and cared for. Which is to say, next we:

5. **"Emulate those strategies in your design solution"**

Emulation, here, can begin with the program, which lists familiar names from the Organs and adds some items aligning with the Vision explained above. It is an ambitious program which assumes the building will grow over time and that the structure and form will allow for this.

The program for the site includes:

Public Areas: main entry/welcome area, bodywork rooms (massage, reiki), classroom, kitchen, guest rooms

Living areas: bedrooms, bath, kitchen, entertainment area, library/office), wine cave, dry goods storage, garage, weight room, workshop/makerspace, bodywork area

Art & Performance: amphitheater (150 person or 50 "socially distanced"), outdoor sculpture spaces, art gallery space

Energy production: solar panels, windmill, controller/inverter room, gasifier room, biodigester, gas storage

Water capture: cisterns, greywater treatment, blackwater treatment, fog capture,

Small scale agriculture: mushroom grow room, fermentation room, integrated greenhouse, aquaculture, chicken coop, goat pens, beehives, tool storage, food preparation area, outdoor abattoir, classroom space, tree copses, hugelkultur beds

The final step in the biomimicry spiral proves iteration to be the mantra of nature and the designer alike:

6. "Evaluate your design brief and Life's Principles, and then decide how you want to use your next lap."

Before we can take that next lap around the biomimetic design spiral, we need to know something about the biome we're entering.

5.2 CONTEXT & SITE

Elemental Influences

Located approximately 200 miles by car from Seattle, Washington, the selected site of this study is located near Twisp, in north central Washington State in Okanogan County. A site analysis was conducted, to include geography, geology, hydrology, wind, sun & shade, wildfires, vegetation & wildlife, and history. These correspond to the elements listed on Fig.119: EARTH, WATER, AIR, LIGHT, and FIRE. As they would affect a living organism, the abstraction of their relationships in the diagram is meant to begin an exploration of the Organs. The relationship of these elements to the site must influence the parameters of the Organs, as environments would any other organism.

5.2.1 EARTH: Geography & Geology

At 8000bce, the Okanogan lobe of the large Continental ice sheet stretched into and beyond the Methow Valley. Ice, snow, and water covered the volcanic and sedimentary rock below, grinding it down and churning it up as the glacier stretched and retreated. Under this immense pressure, portions of this upper crust was depressed into what would become valleys when the ice gave up its hold. (“Graben,” 2020)

Soils on the site of the proposed project are primarily composed of a thin layer of glacial sediments directly over bedrock which is either sedimentary or volcanic. A single test excavation of one cubic meter at the highest point on the property revealed medium brown colored soil with low organic content and several large cobbles and one-man boulders. Surveying the site reveals potential outcroppings of bedrock or very large boulders, of which several are visible along the gravel road running through the property.

Fig. 119, 120 - The flows of molten earth, the grinding of ice, and carving of water made this place. Base images courtesy Google Maps.

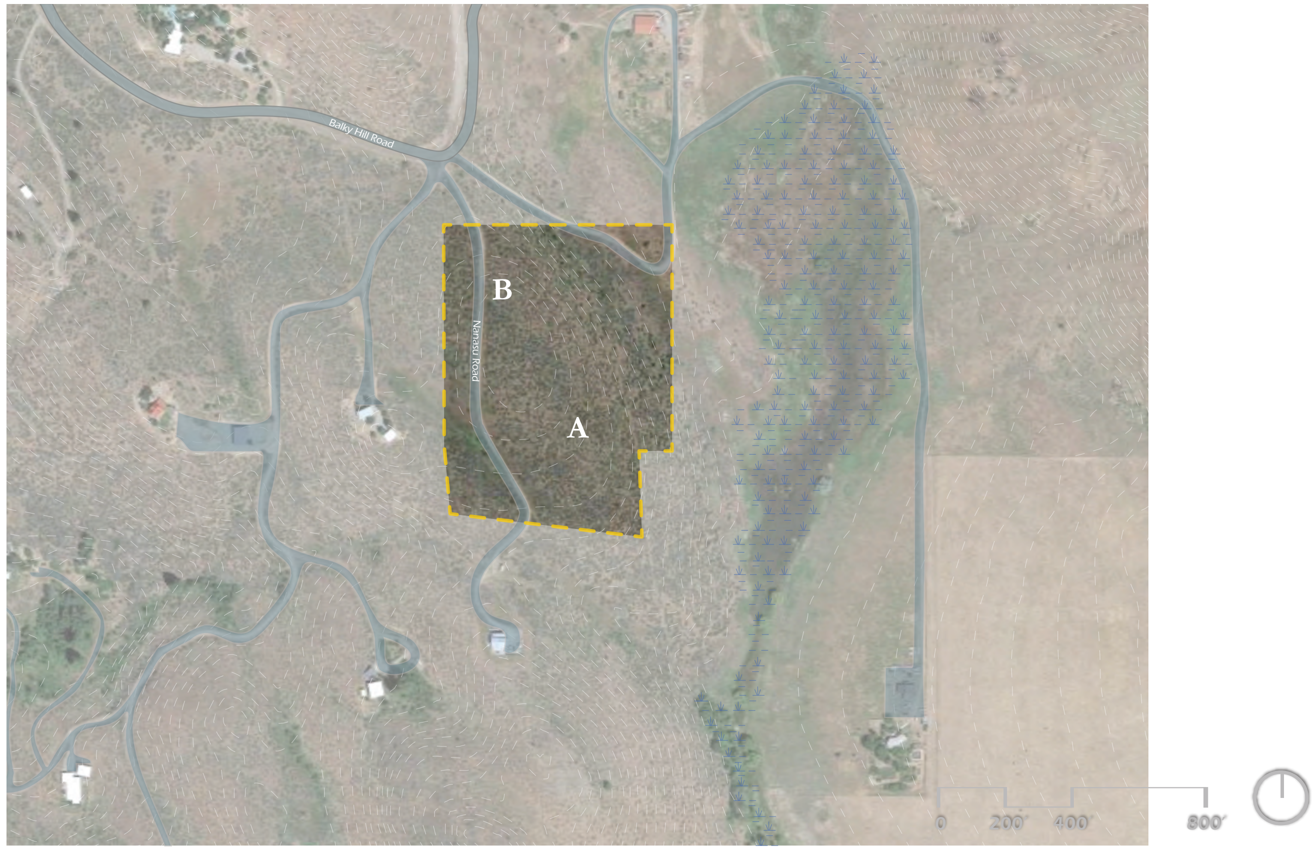


Fig. 121 (left) - Direct overhead view of site with contour overlay. Site encompasses over 11 acres.
Base images courtesy Google Maps.

Fig. 122 - (right) Aerial view of site with boundaries overlaid in yellow.
Base images courtesy Google Maps.

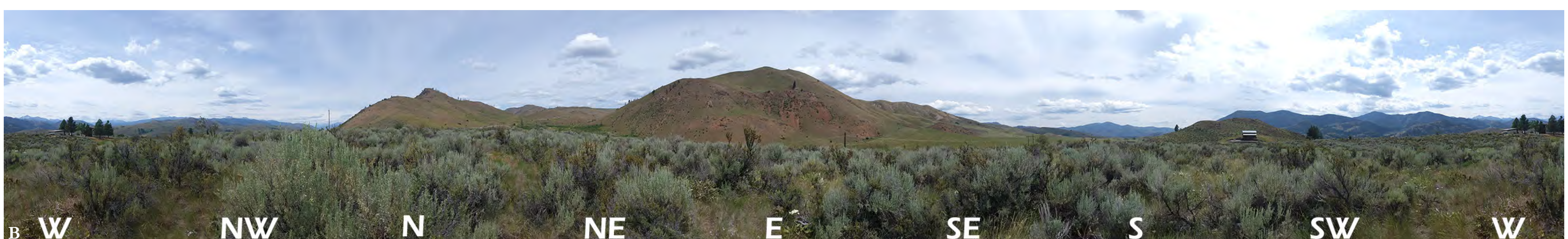


Fig. 123 & 124 - (left) 360° panoramic views from the top of the proposed site. Positions noted on Fig. 126 & 127.




Fig. 125, 126, 127, 128 - It is currently uncertain as to how deep soils run on the proposed construction site before hitting bedrock. Recent test excavations revealed no bedrock at 6' deep.

Endnotes

Baesecke, Heike, Jennifer A. Bountry, James S. Hadfield, David Hopkins, Edward S. Lyon, Todd Maguire, Robert McAffee, et al. RECLAMATION - Managing Waters In The West: Methow Subbasin Geomorphic Assessment Okanogan County, Washington, § (2008). https://www.usbr.gov/pn/fcrps/habitat/projects/uppercolumbia/reports/methow/geomorphicassessment/geomorph2008.pdf.

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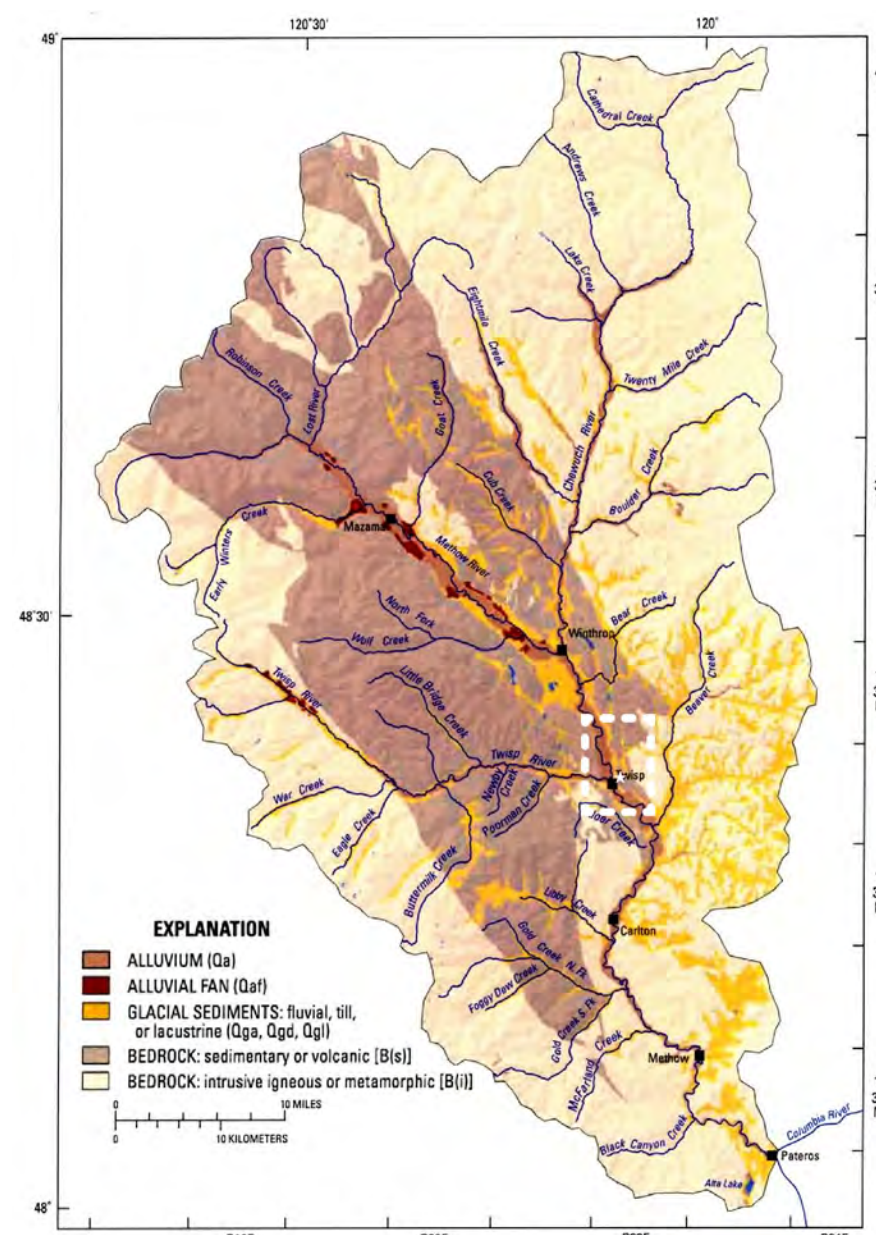

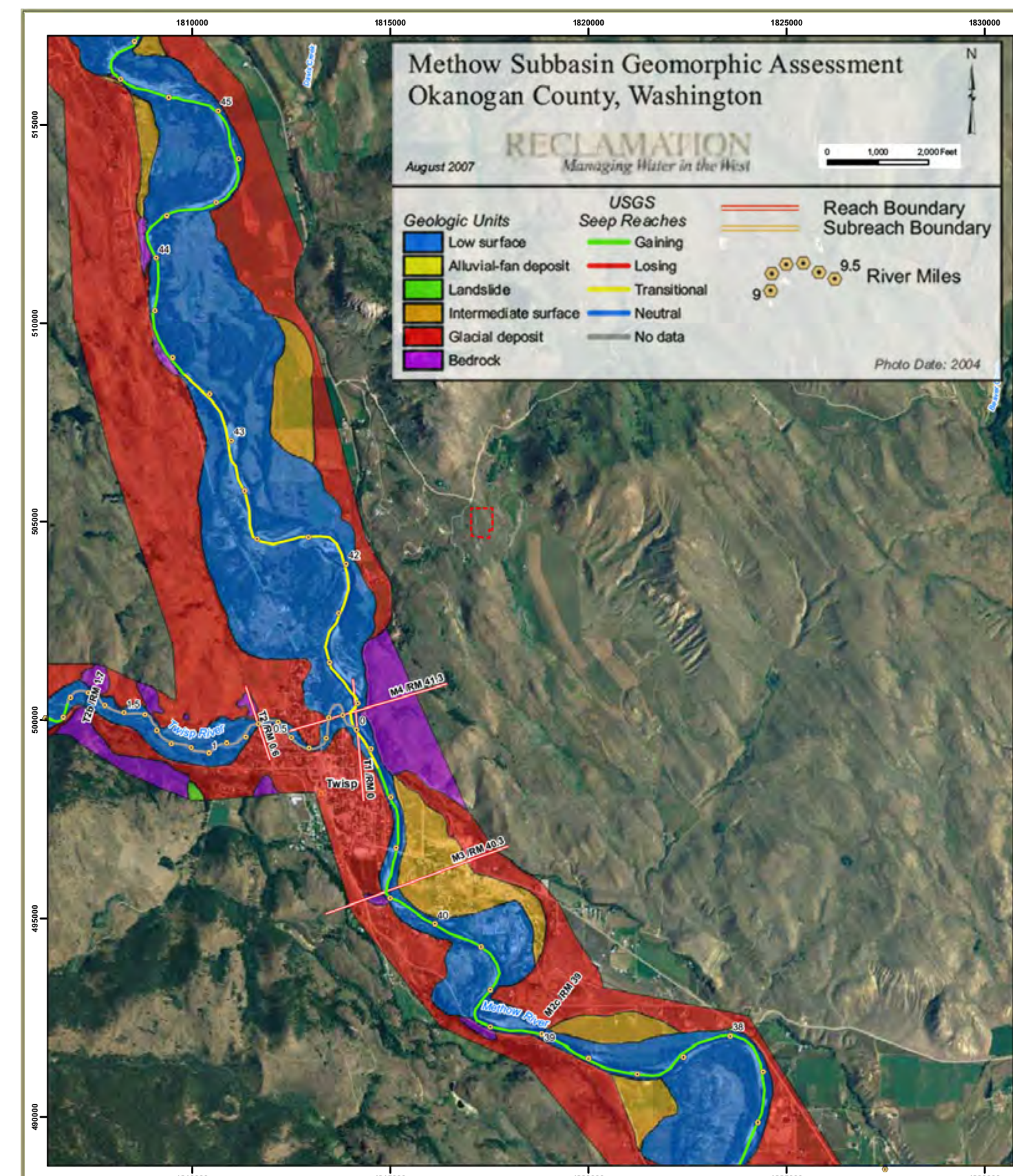

Fig. 129, 130 - Soil types in the area are the result of glacial activity. Images: Baesecke, et al.

5.2.2 WATER: Hydrology & Precipitation

The Methow River is a tributary of the Columbia River, the largest river in the State of Washington, eventually forming the border between Washington and Oregon. The river is fed directly from the project site on the western side of the site, where groundwater flows into small streams which must cross the East Twisp-Winthrop Road. On the eastern side of the site, water flows from the hill into a wetlands area which continues south, connecting to Jim Johnson Lake and other streams and creeks before arriving at the floodplain around the Twisp Municipal Airport. The water never quite reaches the river as it is intercepted by pasture and grain fields or soaks into the ground, charging the aquifer. The wetlands next to the site provide valuable habitat for wildlife.

While certain areas in the vicinity are under groundwater restrictions, no such limitations exist on the site. There is an active well on the northeast corner of the site which currently pumps 63 gal/min. The well now pumps to a cistern located along the eastern edge of the crown of the hill.

As no development to date has taken place on the project site and its position at the top of the hill implies runoff in all directions, multiple challenges arise. One challenge is simply keeping water on the site. Another is avoiding runoff from the site during and after construction, with the potential for erosion of the hillside and pollution from vehicles and any agricultural activities.

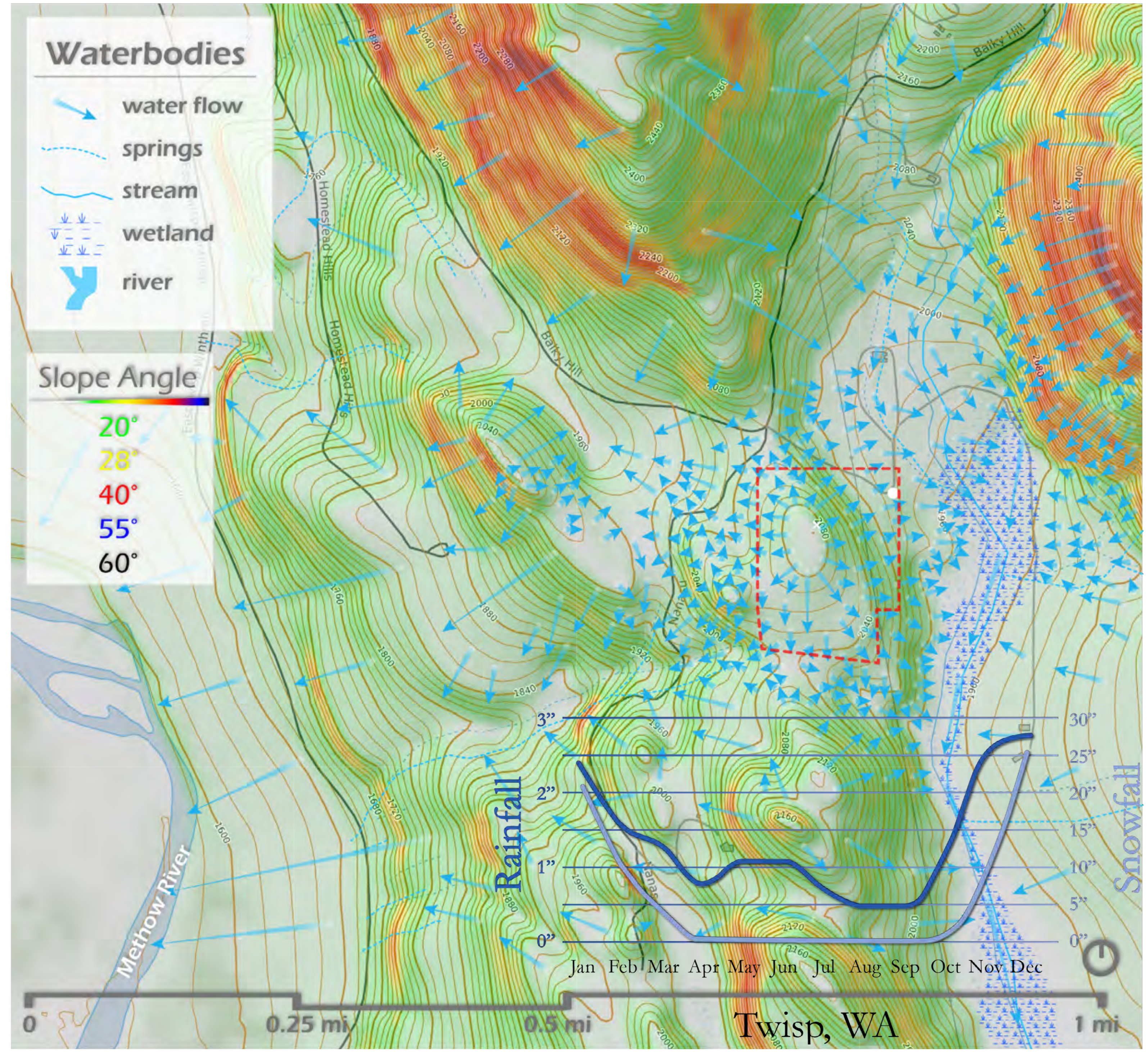

Fig. 131 - A study of the site's hydrology shows a wetland area immediately adjacent on the eastern slope, while the western side of the hill flows towards the Methow River, a tributary of the Columbia River. Inset graph: Annual rain and snowfall averages for the town of Twisp, WA. Dry summers and cold winters lead to little rain during the summer. Capture of winter precipitation is essential to reducing or eliminating the need to draw from the well system. Diagram adapted from data and maps courtesy Okanogan County GIS Overview, CalTOPO.com, & BestPlaces.net.

Endnotes

Okanogan County GIS Overview. Accessed March 11, 20. https://www.okanogancounty.org/planning/map.htm.

5.2.3 AIR: Wind

Data was gathered from the Western Regional Climate Center's website, WRCC.com. The North Cascades Smokejumpers Base (NCSB), located between Twisp and Winthrop, is the closest WRCC recording location to the site. Monthly data was collected for the twelve months of 2019. For the purposes of this site analysis, every other month has been included from left to right, top to bottom, beginning with January and ending with November.

According to the windroses, winds move through the area primarily from the north northwest and northwest and less often from the southwesterly directions. Movement from other directions is negligible. Windspeeds generally do not climb over 19 miles per hour. These speeds may be higher given the hilltop position of the site. ("Planning a Small Wind Electric System.")

The directionality of the wind and the incorporation of buffers should be considered in order to facilitate the creation of microclimates and plant growth. Placement of any wind turbines may be facilitated by aiming them in a northwesterly direction to maximize existing flows. If earth moving is conducted or trees planted, an opportunity may exist to direct wind flows towards said turbines. As wind power is not a part of the Organs system, it will not be addressed in the design.

Endnotes

"Planning a Small Wind Electric System." Energy.gov. Accessed April 13, 20. https://www.energy.gov/energysaver/planning-small-wind-electric-system.

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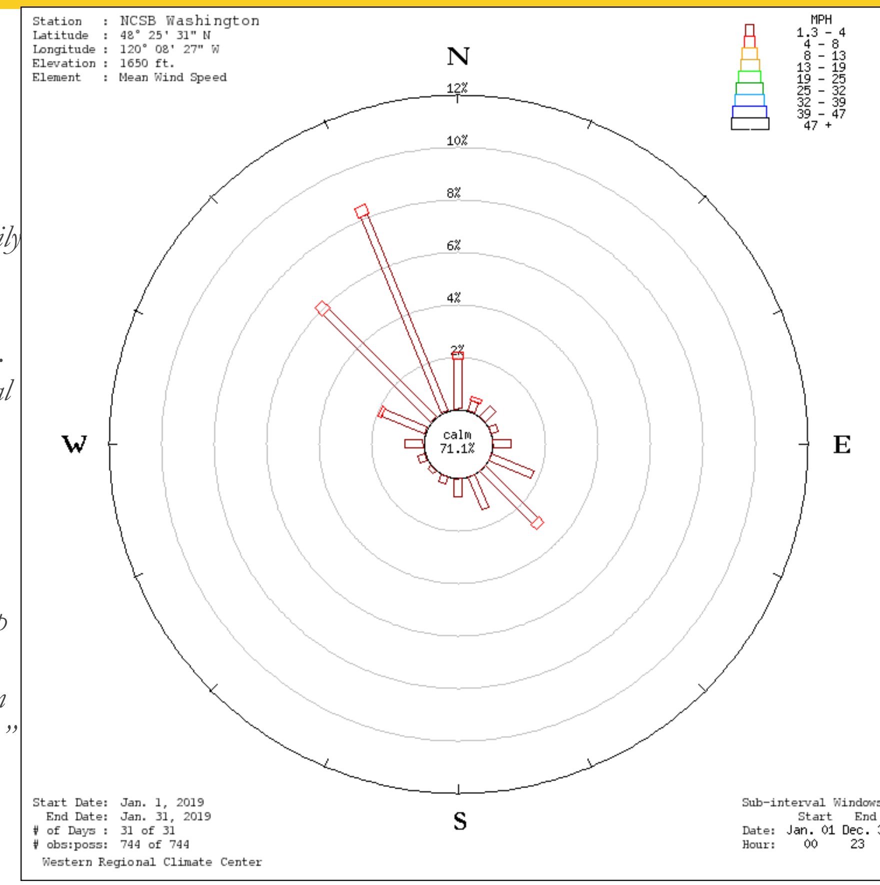


Fig. 132 (left) - January wind conditions at the nearby NCSB remained below 9 mph and primarily came from the northwest direction. The wind was calm 71.1 % of the time. Image: "Western Regional Climate Center."

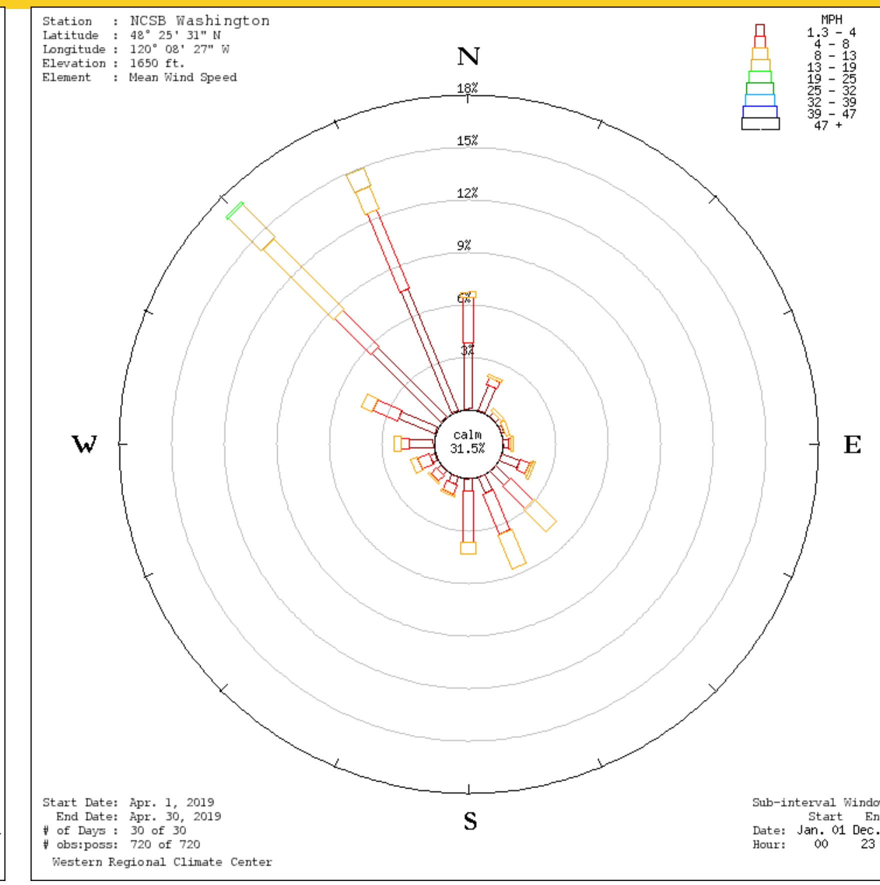


Fig. 133 (right) - April wind conditions show increased speeds, peaking just over 19 mph. A drop of nearly 60% in calm weather. Image: "Western Regional Climate Center."

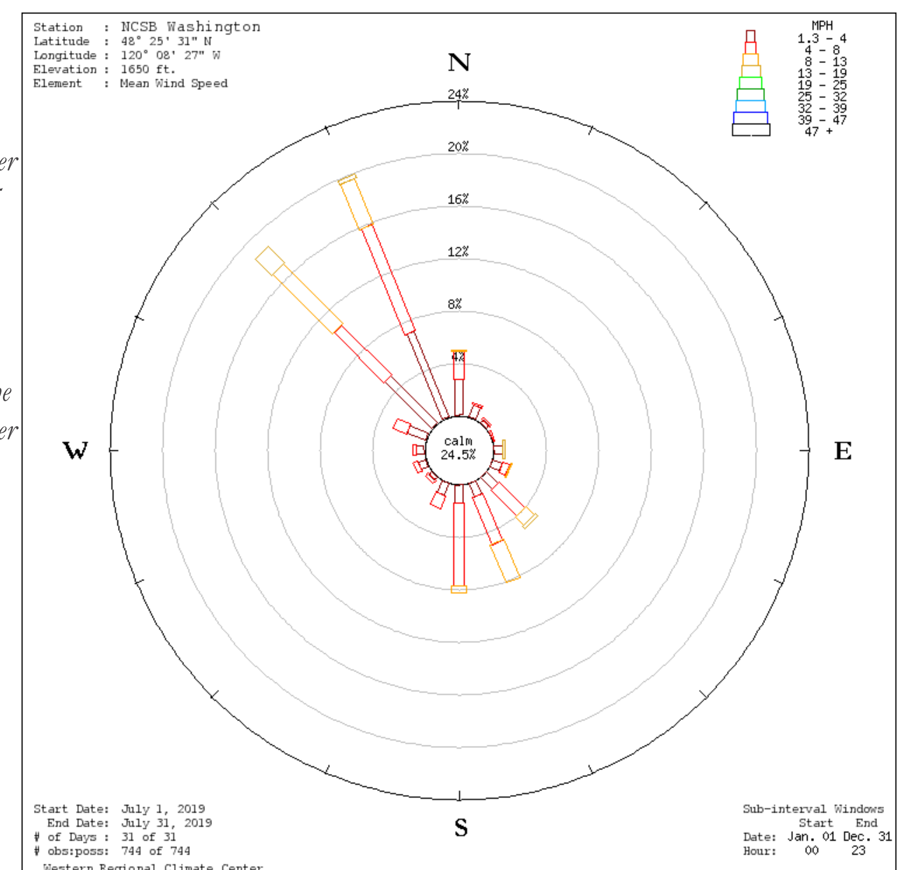


Fig. 134 - In July the percentage of calm weather continued to drop to 24.5 % of the month. Image: "Western Regional Climate Center."

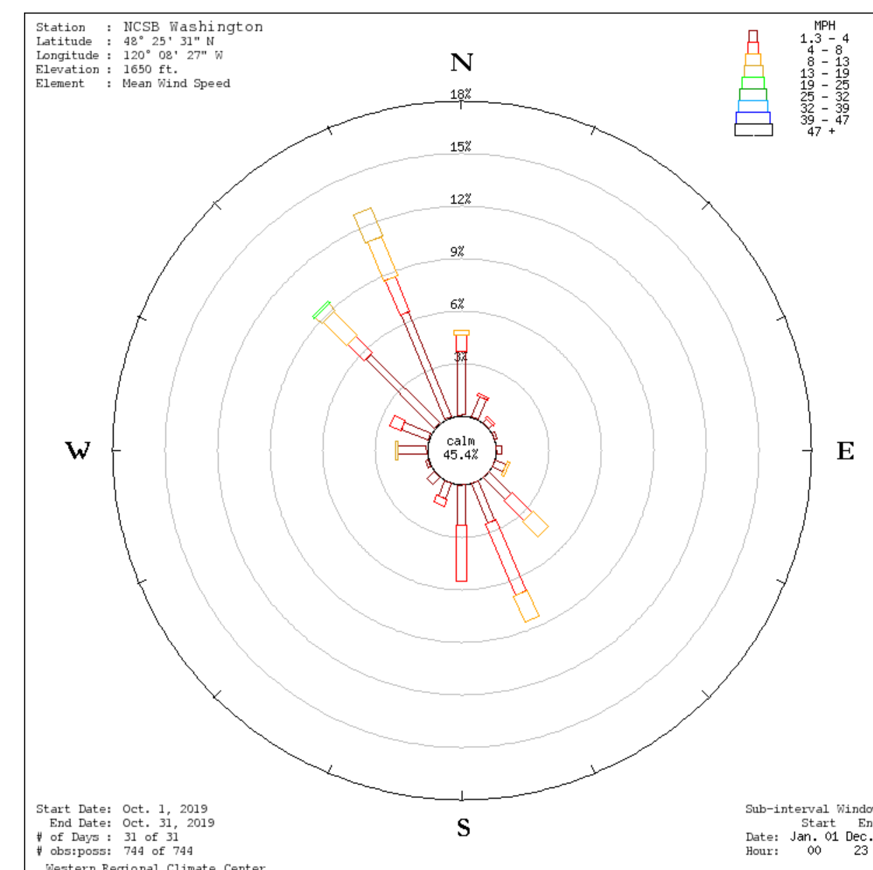


Fig. 135 - By October the percentage of calm weather is increased to 45.4%, though bouts of windy weather reached higher speads. Image: "Western Regional Climate Center.

5.2.4 LIGHT: Sun & Shade

Sun and shade diagrams were taken from the Okanogan County GIS website, powered by CalTopo.com, for the months of March, June, and December for the hours of 0600, 0900, 1200, 1500, 1800, and 2100. This provided daylight information for the solstices and equinoxes, as March is representative of August in relation to the angle and direction of the sun.

According to the diagrams, the sun does not hit the site before 6:30am and only does so between the equinoxes during the warmest part of the year. This is due to blockage by the peak of Balky Hill to the east. The site receives full sun at noon, year round, providing ample daylight for gardens and photovoltaic arrays.

Endnotes

Okanogan County GIS Overview. Accessed March 11, 20. https://www.okanogancounty.org/planning/map.htm.

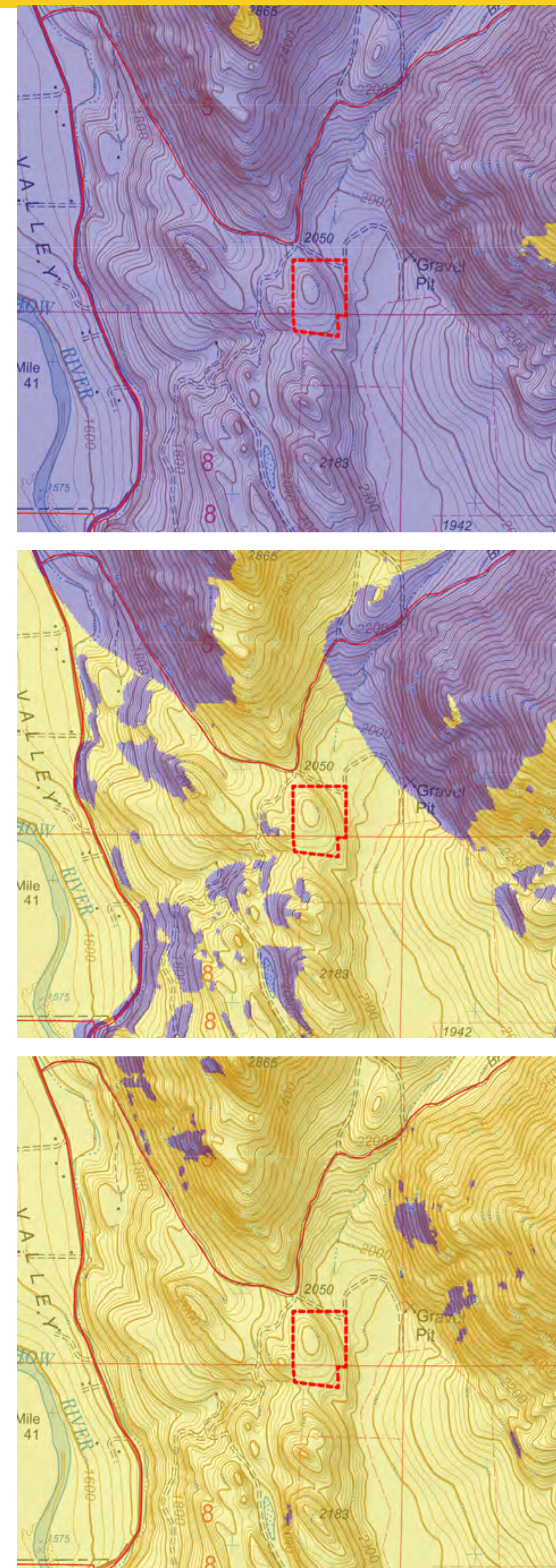


Fig. 136, 137, 138 (left) - Sun diagrams for 9am during December (top), March and August (middle), and June (bottom). Site boundaries are in red. Images adapted from Okanogan County GIS Overview and CalTOPO.com.

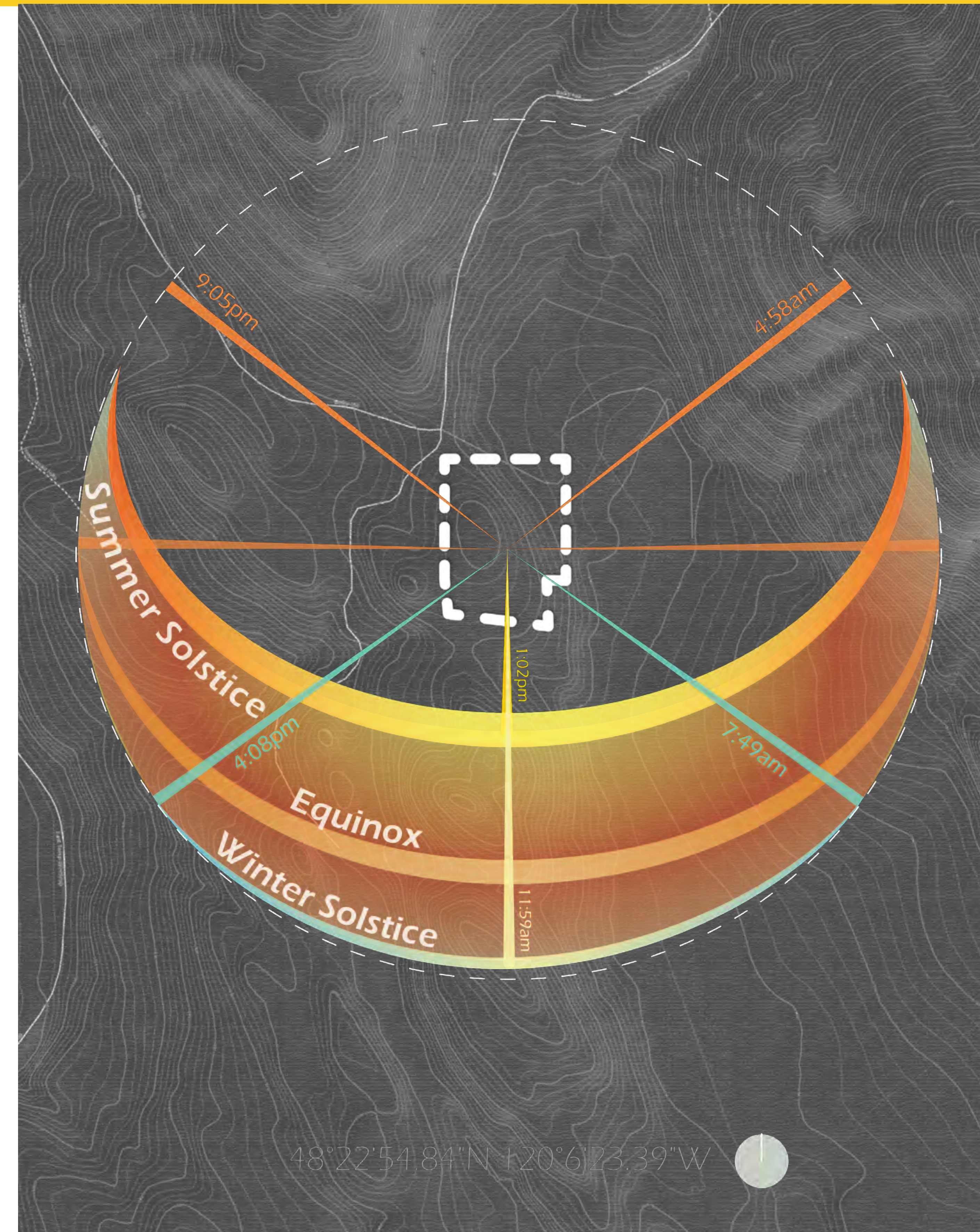


Fig. 139 (right) - A solar diagram overlaid on a shaded topo map indicates the limitations of winter daylight and the extents of summer exposure in the morning and evening hours. Image adapted from Okanogan County GIS Overview and CalTOPO.com.

5.2.5 FIRE: Controlling the Burn

A wildfire diagram on the left was taken from the Okanogan County GIS website, powered by CalTopo.com. The diagram was then altered and keyed in Adobe Illustrator for clarity.

As the diagrams show, the only wildfire damage caused to the site over the last 10 years was between 2011-2014. This occurred during the Carlton Complex Fire which was "the largest single wildfire in Washington history, burned 256,108 acres, destroyed 353 homes, and caused an estimated $98 million in damage." (Kershner, 2014) The fires were sparked by lightning striking several locations in the area. Despite the massive extent of the fires and damage caused to the region, the project site was relatively untouched.

Wildfires are a reality in the Methow Valley. Fire resistant design calls for adequate spacing of trees and flammable materials from buildings (defensible space) by a minimum of 30', limbing up of trees, clearing of underbrush, planting of fire-resistant species, and avoiding flammable materials in building design - among other suggestions. (Home Builders Guide to Construction in Wildfire Zones, 2008) Periodic controlled fires may be recommended, preferably at night when the heat of day is reduced.

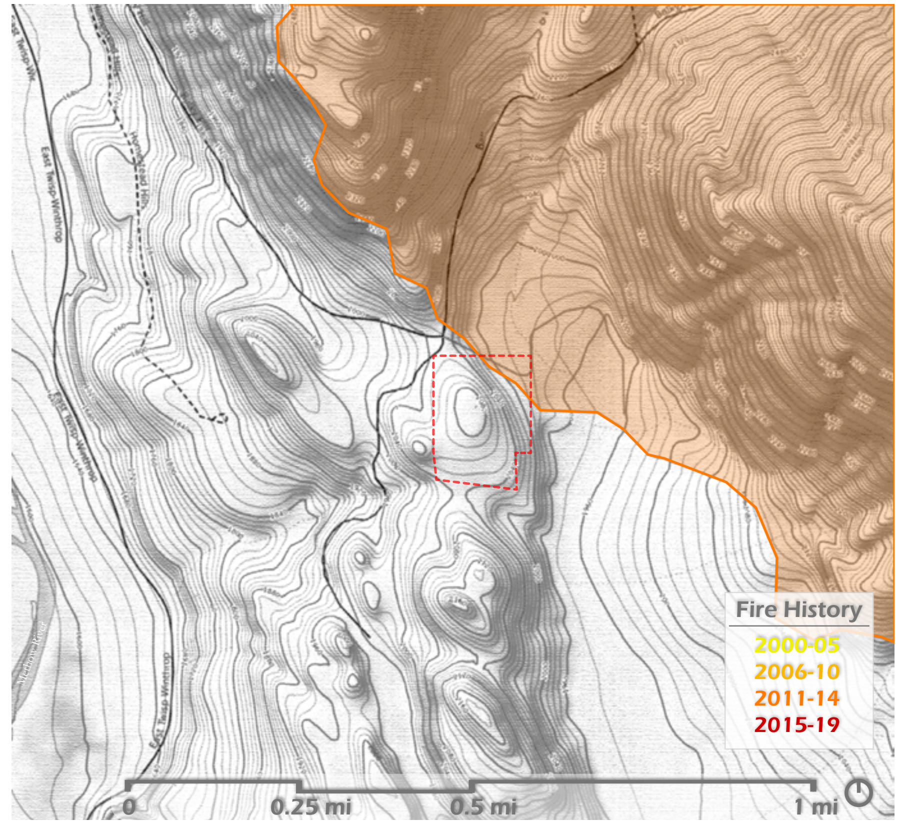
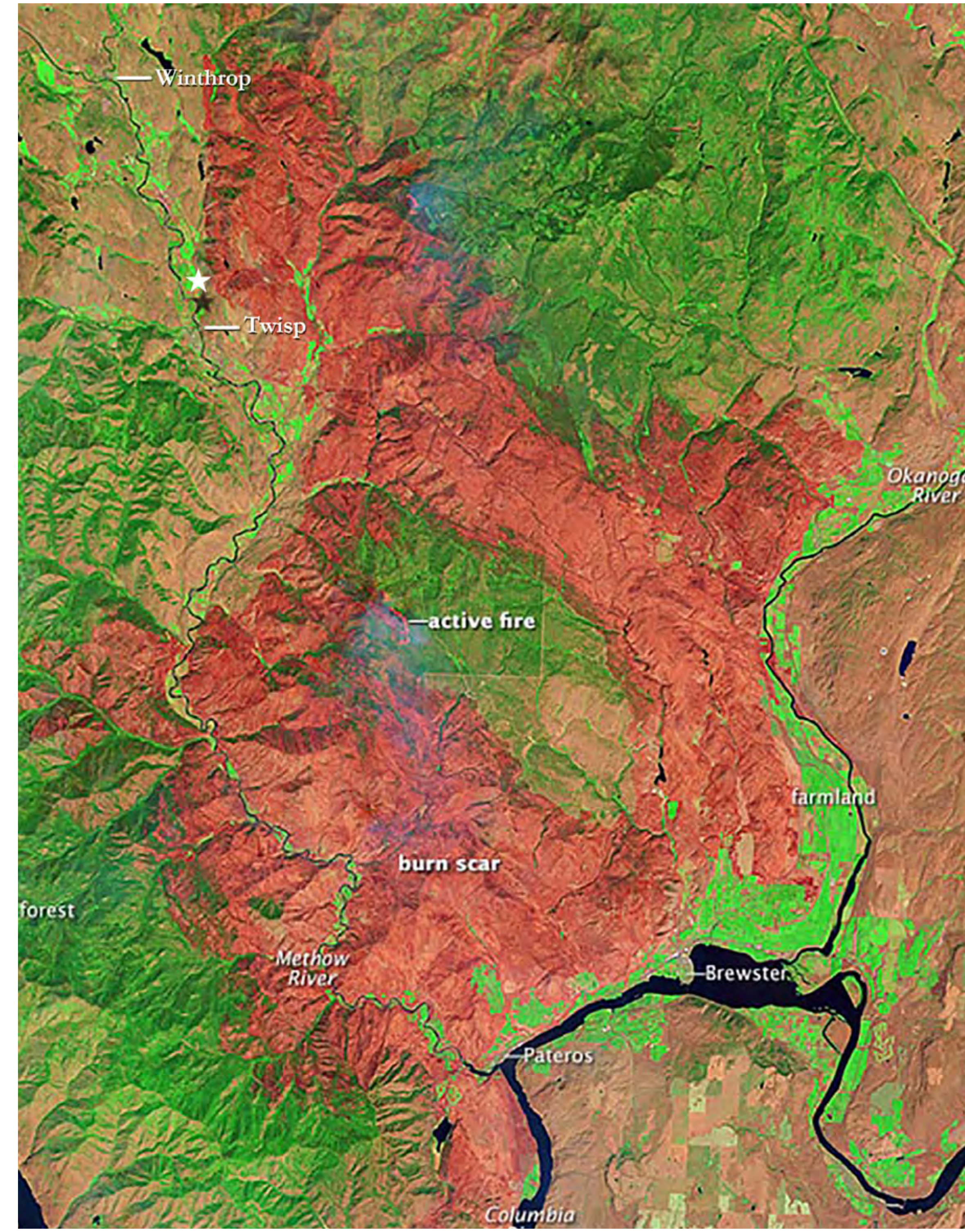


Fig. 140 (above) - Overlay of the extent of the Carlton Complex Fire around the site. The damage to the property was insignificant. Diagram adapted from Okanogan County GIS Overview & CalTOPO.com.

Fig. 141 (right) - False color infrared of the Carlton Complex Fire burn scar, courtesy NASA Earth Observatory. Image: Kershner, 2014. Notation added for Winthrop, Twisp, and the project site indicated by the shadow of the white star.



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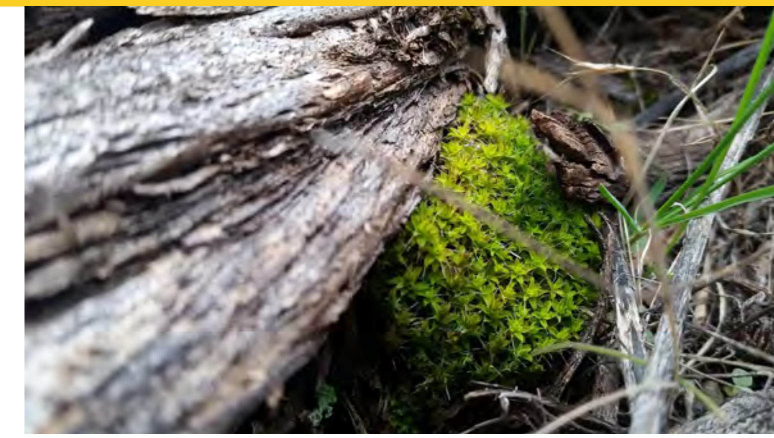
Kershner, Jim. "Carlton Complex Fire." Carlton Complex Fire, December 10, 2014. https://www.historylink.org/File/10989.

Okanogan County GIS Overview. Accessed March 11, 20. https://www.okanogancounty.org/planning/map.html.

5.2.6 LIFE: Flora & Fauna

A site visit on 6/22/2019 produced the following images. Plants at all scales except trees were visible (figs. 148 & 154). Much of the landscape is coverved in sage and bitterbrush (fig. 146). A few fungi were spotted popping up from the earth (figs. 151 & 154). Pollinators and insect eggs were seen on and around flowering plants (figs.149 & 152). We nearly stumbled into a massive anthill that had subsumed the skeletal remains of sagebrush (fig 147). Holes told the tale of gophers or small reptiles (fig. 150). Bones gave evidence of mid-sized animals and their predators (fig. 153). Deer scat (feces) was prevalent at the very top of the hill, along with depressions in the grasses where they often rest (fig. 156). As we look to increase bio-diversity on the site, we should work to preserve what exists.







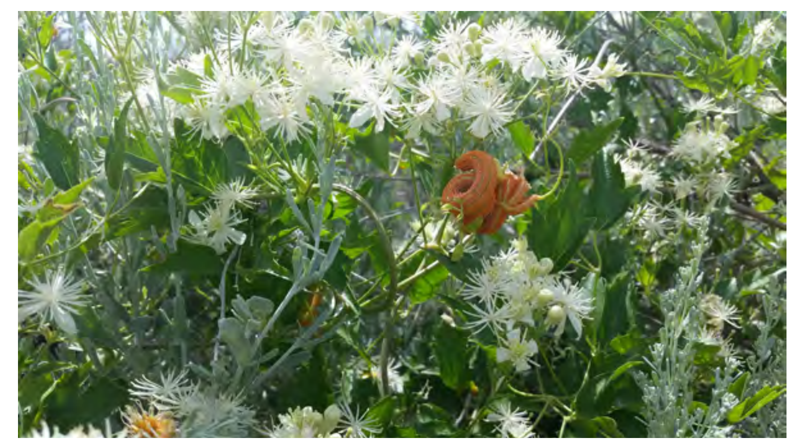




Fig. 142 through 152 (top to bottom, left to right) - Photos taken at the site reveal evidence of a number of species common to scrub-steppe biomes.

5.2.7 LIFE: History

First People

After the recession of the glaciers some 10,000 years ago, the tribes and bands of people speaking Interior Salishan flowed into the valleys and coulees which the ice had carved out of the great mountains between the plains and the Salish Sea. From present day British Columbia into my home state of Washington, the language became more exclusive and today we know it as Okanogan. (Ruby, 2010, pp184) In the valley where this site analysis focuses, the Methow dialect nsilxcín was distinct from others outside the valley, but close enough to allow trade between the plains and the coastal peoples. There are different interpretations of the placenames of the area, and Methow is no exception. According to Robert Ruby, Methow or /mətx-ʷú/ translates to "place of the sunflower seeds" while the arcGIS Story Map Journal of describes it as "blunt hills around a low valley." (Ruby, 2010; Story Map Journal, 2020). Twisp or /txʷəc'p/ translates to "yellow jacket," "wasp" or the sound they make. ("Twisp, Washington," 2020) During the warmer months, their presence remains evident to this day.

The Methow "initially lived year-round in pit houses -- excavated, permanent shelters with woven mats of grass or reeds for roofing. Depressions believed to be pit house foundations have been found at 18 sites in the Methow Valley." (West, 2011) Evidence has been found of canoes carved "from giant cedars that grew in the upper valley, leaving stumps of trees believed to have been about 500 years old at the time they were cut."

Fig. 153 - A reconstruction of a traditional pit house and teepee at the Methow Valley Interpretive Center. The pithouse is built around a central firepit with raised seating all around and is covered by a timber frame and bark.
Photo: Methow Valley Interpretive Center, 2017.

Fig. 154 - Local artists produce a range of work in various media at TwispWorks, seen beyond the gates of the Methow Valley Interpretive Garden.
Photo: Methow Valley Interpretive Center, 2017.

A visit to the Methow Valley Interpretive Center in Twisp provides an opportunity to explore the geological and cultural history of the area through a small museum space. Outside, an "interpretive garden" is filled with the various plants which sustained and had been cultivated by the Methow people prior to the arrival and intrusion of Europeans and their descendants. Within the garden, a recreation of one of the original pit houses offers visitors the opportunity to step inside a surprisingly cozy living space surrounding a fire pit with an open oculus to allow the smoke from the fire to exit while maintaining communal comfort within.

First Contact

Earliest account of European and European-American movement through the valley dates to 1780 and later in 1811 when a fur trader named David Thompson was welcomed by the Methow people. When Alexander Ross visited 3 years later, he wrote that his hosts were "In all respects, exceedingly kind," echoing the opinion of Thompson before him. (Ruby, 2010, pp 184) While the Methow were forced to relocate and join the Confederated Tribes of the Colville Reservation on July 7th, 1883, in my experience, the tradition of hospitality is evident in the community that has grown in behind them.

Early dreams of a gold rush led to mining in the area, which initiated the encroachment of roads and homesteads onto the soon to be vacated lands of the Methow. The move to the Colville Reservation with the signing of the Moses Provision was not the end of the line for the descendents of the first people of the valley, but it was the end of their culture as distinct from the other tribes of the region. Their population had been ravaged by smallpox in the mid 1800s, leaving approximately 300 Methow by 1883. (Hart, 2010). There are effectively no living members of the Methow people, as intermarriage and language loss have ceased to form a functional group identity. (Story Map Journal, 2020)

Today

The town of Twisp was incorporated on August 6th, 1909. By 1904, "the town had several general stores, a doctor who also owned a drug store, butcher shops, livery barns, a hotel, a boarding house with a billiard room, a blacksmith shop, two restaurants, a bank, a real estate office, a barber shop, two saloons, a state fish hatchery, an opera house, a weekly newspaper, and a Methodist church." There were 227 residents of Twisp at the time of the 1910 census. Electricity and motion pictures arrived a year later. (West, 2011)

In 1927, Curtis King opened up an automotive repair shop which would be called King's Tire Service and later Cascade Kings. Today the original shop has long since been sold and is home to a new distillery. The new shop, too, has been sold as the eldest son, Clayton King, looks to retirement. The fueling side of the business, however, remains and is set to fund construction on the 10.25 acres on Balky Hill, the site selected for this thesis. The site itself is not known to have had any prior human occupants.

Today Twisp remains the largest town in the Methow Valley. The area has drawn increasing numbers of artists due to its natural beauty and laid back way of life. Confluence Gallery, the Merc Playhouse, (West, 2011), and other arts oriented businesses thrive in Twisp, especially at TwispWorks. The Barn and the Barn Cinema draw crowds to Winthrop. The annual Blues Festival attract audiences from around the region and beyond every summer - 2020 being a notable exclusion. Wineries, cideries, and breweries host art and musicians, creating a vibrant tapestry of arts and culture woven into the fabric of the Methow Valley.

Fig. 156 - Piles of tires tell the tale of past work at Cascade Kings.

Fig. 157 - The fuel pumps poised above the icy ground. They await new owners as Clayton King moves on to an entirely different kind of energy work with his reiki practice.

End notes

Baesecke, Heike, Jennifer A. Bountry, James S. Hadfield, David Hopkins, Edward S. Lyon, Todd Maguire, Robert McAffee, et al. RECLAMATION - Managing Waters In The West: Methow Subbasin
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5.3 Final Forms and Functions

A place that is exposed, windswept and barren will remain windswept and barren unless four key things happen there, regardless of order. First, there must be water. In rain, in fog, from glaciers or aquifers, in mists that are exhaled by plants, in the waste products of animals, or transported through the diversion or the construction of hydrotechnical and transportation systems - to include the ones that humans continue to build. The second key is that there must be plantlife. The hydrological cycle depends upon plantlife to find, absorb, and redistribute water through evapotranspiration and through decomposition. Thirdly, there must be something to decompose that plant matter. The other Kingdoms of Life manage that through eating and defecating. This is a huge part of the nutrient cycle and a most necessary function for pulling carbon and nitrogen from the air and into the ground. Feces and urine also move water, as mentioned, and may sustain certain plantlife in the absence of the other six aforementioned steps in the hydrological cycle. This leads us to the final key to transforming the arid to the verdant: A store or flow of essential nutrients on or to the site. Salmon make forests, the trees feeding upon them through the droppings of bears. Berry plants pop up from the poop, feeding future bears and birds while their leaves shad saplings and breath oxygen into the world. In other parts of the world, elephants and monkeys alike share knowledge through generations of where the salt lick is and where food can be found, leaving behind a periodic diet of nutrients for the insects and microorganisms that further break it down into soil.

As the site analysis shows, this is a rugged landscape dug out of an active volcanic range by the movement of water as ice and rain. The newness of the place in geological time means that it is a relatively young ecosystem, potentially lacking comparative diversity of places that have not so recently been buried beneath a glacier, let alone left sizzling by by solar energy during the summer and coated again in ice and snow every winter. The microclimates are broad and the site is widely exposed, essentially constituting an eastern slope, a hilltop with full midday exposure, a southerly slope, and slight saddle to the south west descending to the north at a leisurely pace. There is access to a well dipping beneath the wetlands to the east and into the aquifer, but there are no bodies of water on the surface.

To provide for and to mitigate the impact of humans on the local ecosystem, the following goals are set forth to be met through architectural and landscape architectural design driven through biomimetic practices:

INCREASE surface area for **WATER** capture
DEVELOP microclimates for **BIODIVERSITY**
BUILD SOIL over time
INVESTIGATE and invest in regenerative **REDUNDANCIES**
ALLOW for **ADAPTATION**

These goals are viewed through the established concepts of *Growth, Digestion,* and *Transmission* and will now be discussed. The following images were edited in Photoshop, linework was completed in Rhino 6 and Adobe Illustrator, 3D modeling was done in Rhinocerous 6, models were modeled there and with Lumion. Not all phases discussed are necessarily rendered below.

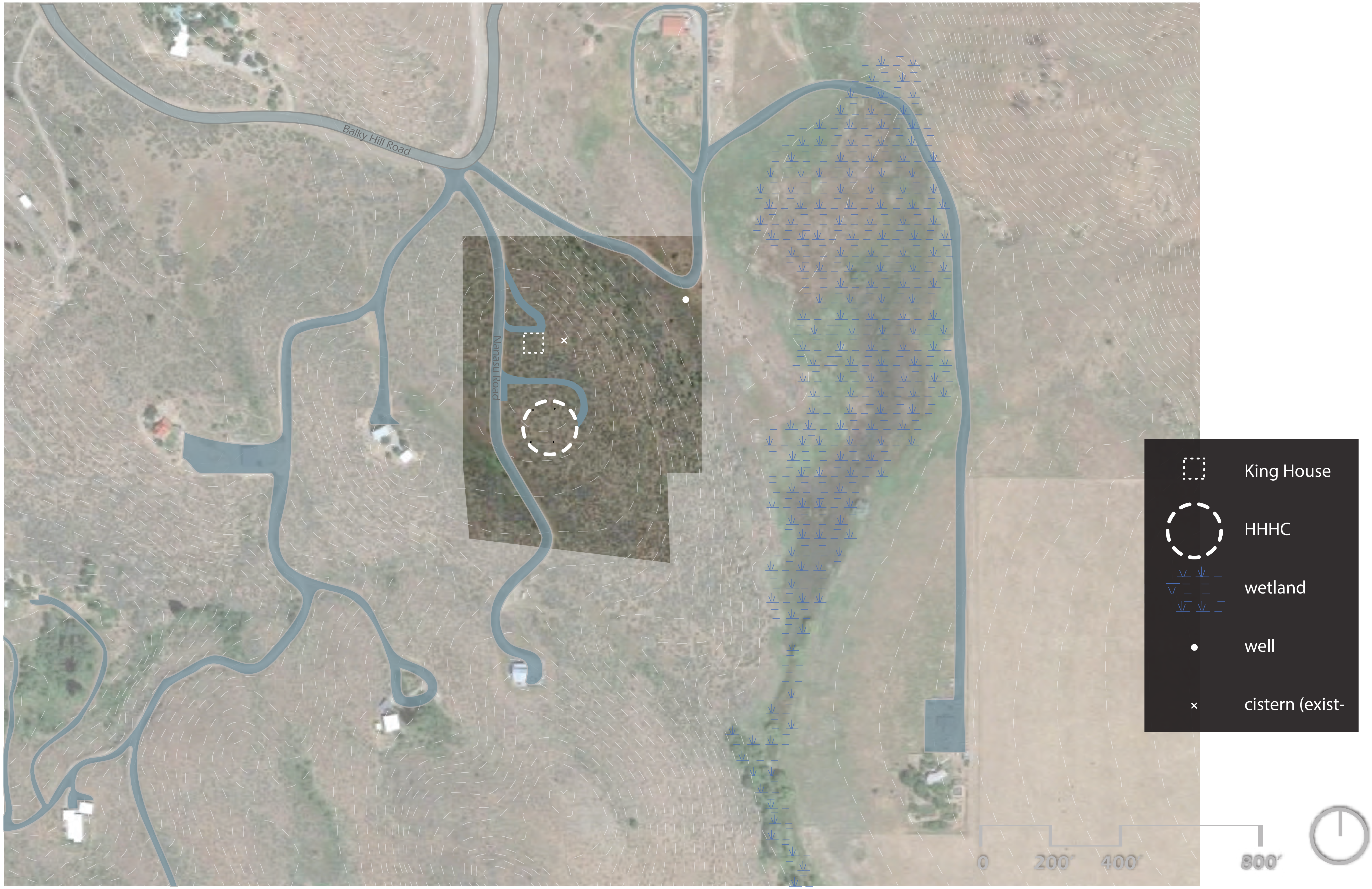


Fig 158 - An aerial view of the King property, showing the variable terrain surrounding the hilltop on which the site sits and highlighting its ajacent position to wetlands. To the west and outside of frame are the Methow River and the Town of Twisp, WA. Base image courtesy Google Maps.

Fig 159 - An early site plan only shows the development of the holistic health and healing center. Its form and several features have been directly inspired by the native Pacific rattlesnake, a local we have yet to meet on site. Base image courtesy Googke Maps

5.3.1 Growth

A small clutch of eggs, ovular and leathery to the touch, begin to shift and twitch in the dark and damp. An egg tooth and small mouth push out from a ruptured shell, tasting the air as the young snake emerges. Within its body, an elegant skeleton of arched ribs provide a parenthetical embrace of the snake's organs. The hinges of spine create a chain of support for the muscles and tendons woven around the body of the snake. Nerves, blood, and lymphatic fluid course through conduits running between the organs, through the muscle, and under the skin. The skin is fresh, hardening in the air and, soon, under the radiation of the Sun. It is staggered as shingles, grown with the purpose of movement, of adaptability, of durability.

Shell and bone are built, grown, extruded. Skin - hardened, treated, cured, and cared for. If we look at the most resilient and regenerative species for lessons, a glance at the starfish-like pattern enmeshed in the hillside is a starting place. Beyond the initial concerns for construction of the initial building, the snake analogy holds. How can the organism grow over time? What is the form that would follow expansion? Can the analogy of a shedding of skin be applied here, for instance? And if the snake's growth proves finite, how can other organisms be approached to drive the evolution of this member of the Archinae forward?

I have taken some inspiration from the radiant and symmetrical growth patterns of some lichen and certain corals. These species are mutually co-dependent with those that live within them. Lichen are fungi and algae living as a regenerative community. The former house the latter, and the algae pay rent in the form of sunlight converted into fungus food. The algae don't get eaten by the fungus, rather they enjoy comfortable digs and a means of spreading across the planet.

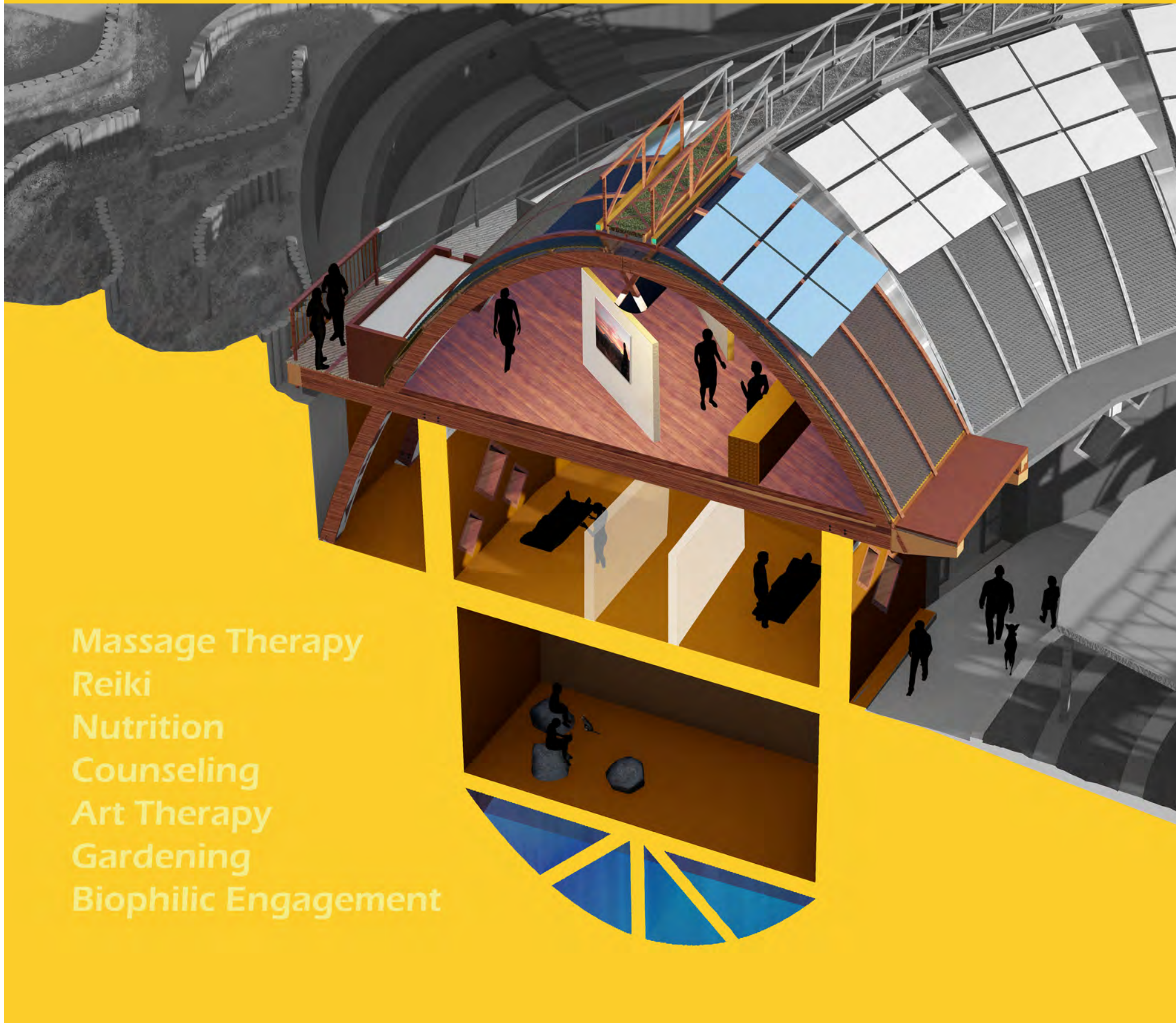
Like a Reef

Coral benefit from the flow of nutrients being captured and cycled by their occupants and visitors. Some species offer protection of the coral in as an unacknowledged exchange for the protection and abundance provided by these living structures. So too does the site which provides forage and habitat for a variety of beneficial species, space being made for those who keep the numbers of others in check or those who provide other special benefit. Boxes for owls and other birds, snags installed or left standing, trees and bushes, houses for hens and sheds for larger animals. Fungi are sown into the ground and are built into the walls as insulation. A ribbon of insulated glass or plexiglas housing stretches around the rooftop "Spine" as a bioreactor for energy and CO_2 capturing algae. Their fate is revealed in the section on Digestion. If genetic modification is an option, these same algae can have their genomes tweaked to promote bioluminescence or increase oil production. Otherwise, selective breeding and labwork are a slower means of achieving some of the same results. The algae benefit from their relationship with the other organisms in the Archinum, or Arch (Ark), and the arch draws energy from the relationship in return while it's resident inhabitants benefit in their own ways.

Landing, Sowing, Planting, Growing

Phases of construction are discussed in Chapter 6, but in brief the idea is to use shipping containers loaded offsite over the course of several months or more with materials, tools, and equipment and ship them to the site. When they arrive at the site with the gasifier and biodigester system, they are set up as a workshop protected from the elements; a mycolab for the immediate production of mycelium based insulation and Reishi mushroom based "cartilege" built into the bracing system in the catenary arches; and as a sauna which integrates a set of steam boxes which are heated by the gasifier and biodigester from the GUTS system, allowing for the steam bending of the wood. Small diameter wood from sustainable forestery, wildfire prevention programs, and trees killed by invasive species like the pine beetle are prepared, CNC milled, and joined in glulam members. The first sets of the arches have an inital job as part of the formwork for pouring and compacting a rammed earth foundation and cistern system, with the arch supporting the roof being mirrored in the ground below. Above water is held outside and snow kept above the structure, while the same shape will collect and contain the water that is filtered and remediated in the belly of the beast, as it were. This is the beginning of the BONES and SHELL systems.

The SHELL system requires a period of sorting and sifting soils from the excavated area of the site; staging the other admixtures; building the rest of the reusable formwork for the rammed earth walls; and then installing them. PEX tubing and conduit run through the floors and walls which will eventually connect the water system with heating in order to create the HEART system. The LEAF system goes up as photovoltaics are temporarily mounted to the shipping containers with solar water heaters mounted beneath them, allowing the energy of the sun to assist electric pumps in pulling the water up and through the PEX tubing and into a water heater. This also helps in drawing heat out of the PV cells which increases their efficiency. As the water drops down into the system, whether to hot water taps or to a heat exchanger, it flows through small pipe turbines which generate a small amount of energy which goes back into powering the pumps. Ultimately, the goal is for each step of the growing process to be powered by the sun exclusively, either through PV, thermal energy, or as plants through the GUTS.



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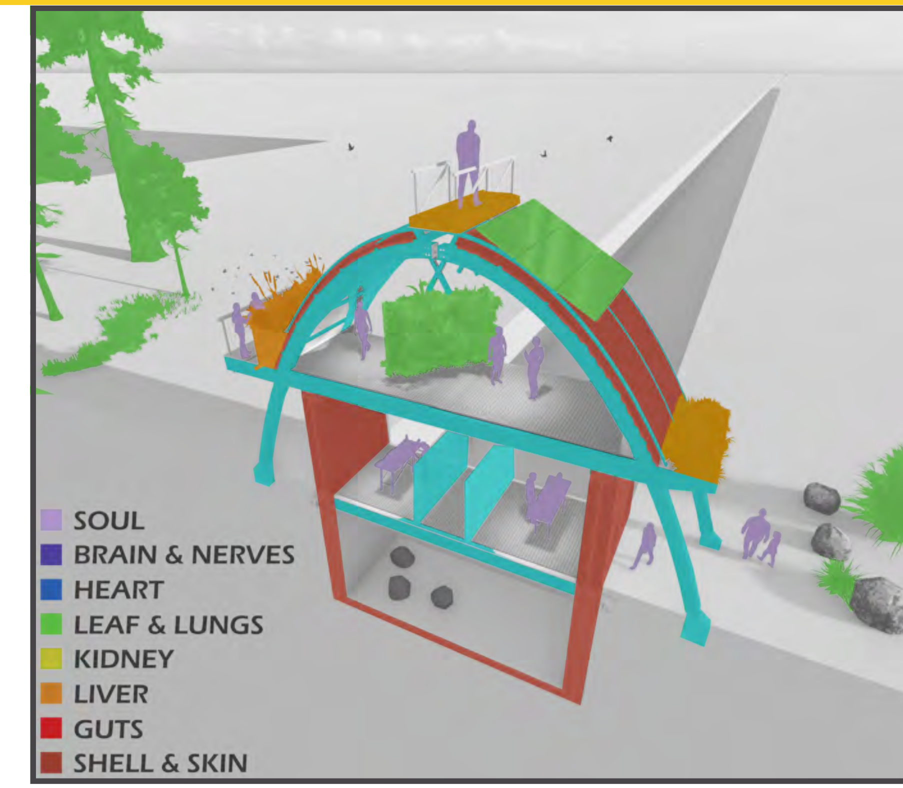


Fig 160 - The Organs are diagrammed in color over the basic module. LUNG & LEAF is visible in green, LIVER is visible in orange, and SHELL & SKIN appears in rusty red.

Fig 161 - The basic module for the design is constructed of rammed earth walls and glulam or CLT beams. Joined with a combination of mechanical joints and Japanese styled joinery, curves in the catenary arch and cross bracing are achieved through a combination of CNC milling and steam bending utilizing surplus thermal energy produced in the GUTS and KIDNEY systems. Imagnie the scene with plants.

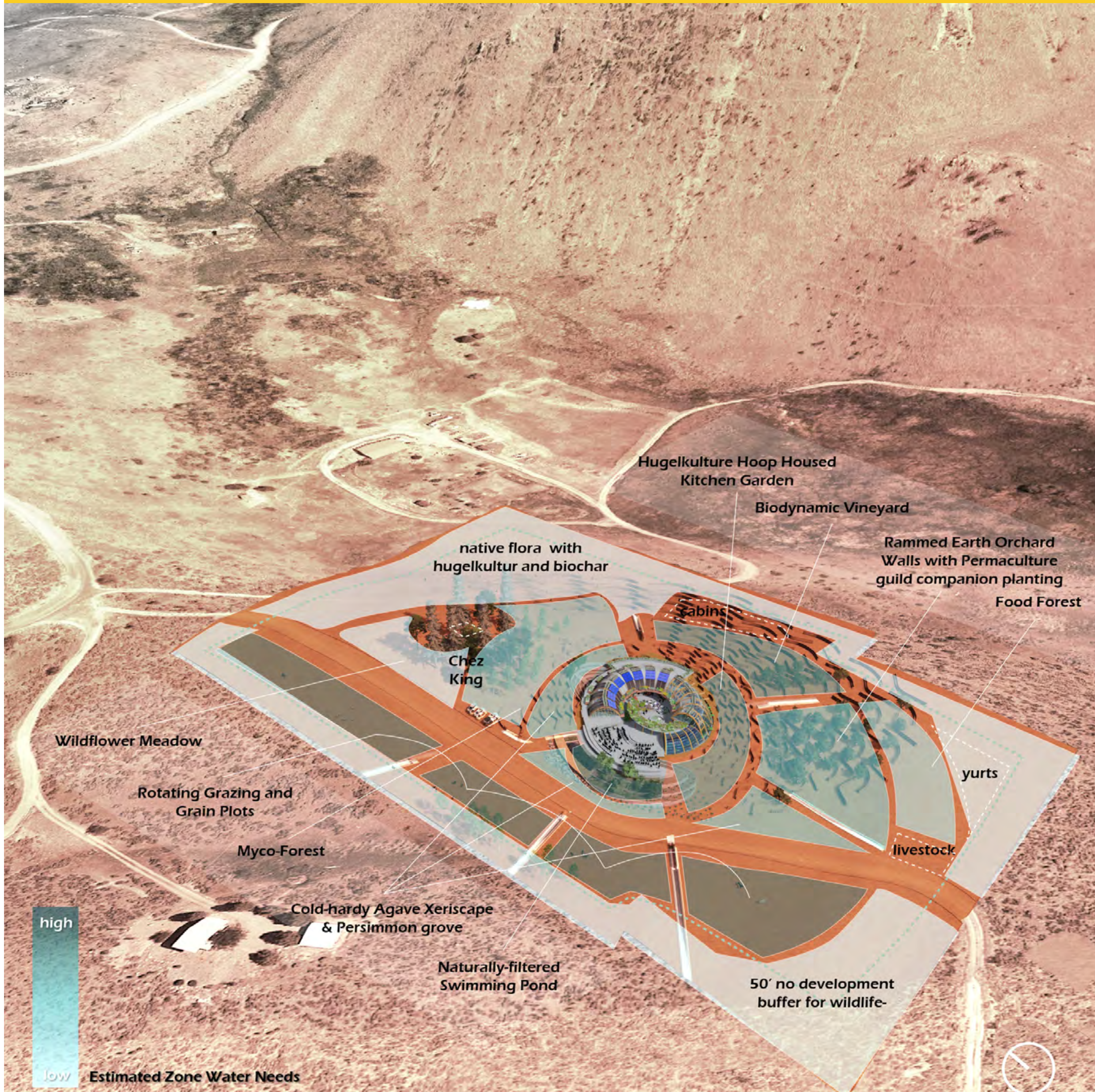


Fig 163 - A clay model representing the building up of stone and rammed earth walls in the terrain for the formation of microclimate creating Hugelkultur beds and mycelium inocculated woodchip paths. Over the course of decades and centuries, the original walls would be subsumed under an ever deepening blanket of biodiverse soils with diverse microclimates providing intraspecific variation and development of crops as data and genetic material are developed over generations.

Fig 162 - A generalized master plan for development of the site. Base image courtesy Google Maps.

5.3.2 Digestion

The rattlesnake stalks its prey, slipping between brush and stone over the loose soil. The mouse slips between the stalks of grass, pulling the seeds down and into rapidly filling cheeks. As it eats, it excretes, hops away. Food on the tongue, it doesn't hear the sound of the snake's approach. There is little struggle and one meal leads to another, the waste of each creature going on to feed the fungi and bacteria feeding the plants which, in turn, feed the next generation of rodents and reptiles. Generations pass, soil builds, generations grow and the cycle continues like the steady accretion of nacre onto a pearl.. What falls to the Earth becomes earth, each living thing a part of the digestive process that is the skin of our planet.a

So too is the role of fire. Rather than viewing fire as a threat, I suggest looking at it as a digestive activity. As the spider and snake inject venom as a means of killing their prey and commencing their digestion, indigenous practices globally use small, controlled quantities of fire in order to break down biomass and cycle it back through the food chain. In this way, fire is like venom in that it is digestion that takes place outside of the body. It simultaneously paralyzes that which would harm and that which must be consumed.

For land left to native vegetation, controlled night burns return as a ritual. Where grains are growing, livestock and wildlife can cut it back with their teeth and burn the vegetation within their bellies. The seeds of the grains are fed to the KIDNEY system where they make malt, are brewed into beer, or receive further distillation into spirits. Everything growing and every scrap of waste has a place in the foodchain.

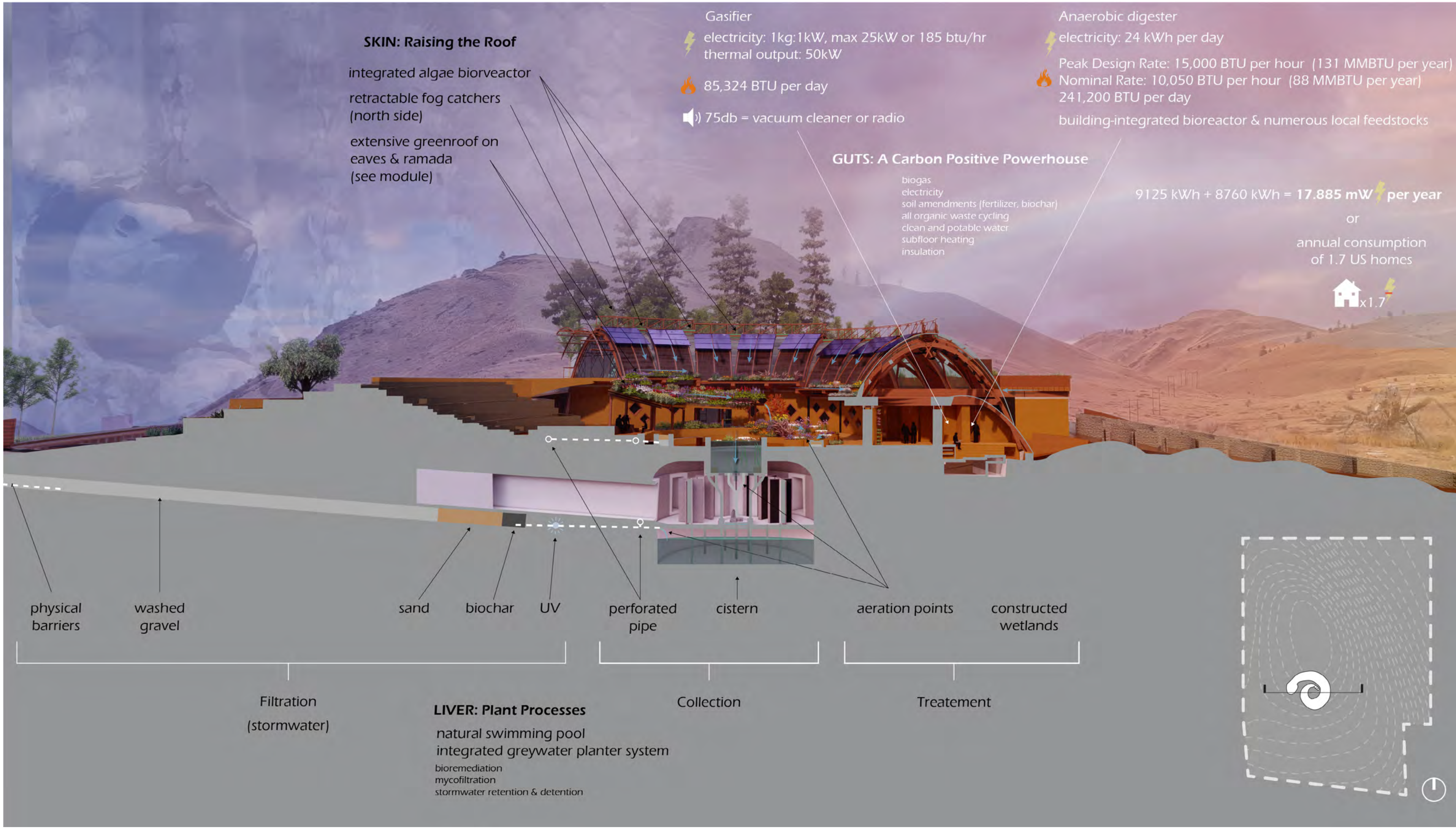
What doesn't go to an animal (to include present and future species *Homo*) is fed to beneficial microorganisms before it attracts non-beneficial species of any size. Scraps then proceed to the biodigester where they are converted to soil amendments, fertilizers, and fuel by cousins of the microorganisms turning the seeds into alcohol. The process of eating breaks down and refines. The smaller something is, the more refined its output. The goal in the digestive systems of the GUTS, KIDNEY, and LIVER is to take all of the waste streams that we can identify and to tie them into the foodchain in order to remove that which is harmful or otherwise undesireable and to convert it into something that is beneficial and desireable.. It's the circle, the circle of life.

The systems that are being developed in these drawings are meant to tie together throughout the building and landscape in a system that shifts from orderly and controlled towards the center to loosely managed towards the perimeter. Integrating the LIVER system, for instance, into the structure of the building itself, and then feeding it into the cistern system which constitutes a large part of the HEART is being designed so as to use solar energy and the heat produced through the GUTS to move matter and transmit energy from where it is undesirable to where it is functionally useful. At each stage, the building and site are using acts of digestion to power growth through the conversion and transmission of energy, matter, and materials through the overall system.

Management

Where there is food, there will be mouths looking for a meal. Management is essential and good management will reduce how much time anyone has to spend hauling woodchips or foodwaste. Permaculture and food forest design paired with training for selective pruning and organized harvests will count for much where these systems are applied. Part of the digestive process, then, is the gathering of and processing of data in order to reduce the amount of guesswork involved in any activities and maximize automation of any processes. Breeding, for instance, stands to benefit from the legacy of Norman Borlaug's "Green Revolution" while the system itself helps avoid the issues of hybridizing for reliance upon petrochemicals. These systems hold the potential of completely removing the need for that industry entirely while creating good, healthy, clean jobs in renewable energy, local food and healthcare systems.

Fig 164 (opposite) - A section cut looking north emphasizes the development of water treatment and storage systems through the SKIN and LIVER systems. While the GUTS retain and reduce water needs through Hugelkultur beds, the also produce potable water through gasification and biodigestion processes. These processes also produce electricity and thermal energy - the latter of which can be used for steaming the wood for the BONES system before being tapped as one of the redundant subfloor heating systems of the HEART.


SKIN: Raising the Roof
integrated algae biorveactor
retractable fog catchers
(north side)
extensive greenroof on
eaves & ramada
(see module)
Gasifier
electricity: 1kg:1kW, max 25kW or 185 btu/hr
thermal output: 50kW
85,324 BTU per day
75db = vacuum cleaner or radio
Anaerobic digester
electricity: 24 kWh per day
Peak Design Rate: 15,000 BTU per hour (131 MMBTU per year)
Nominal Rate: 10,050 BTU per hour (88 MMBTU per year)
241,200 BTU per day
building-integrated bioreactor & numerous local feedstocks
GUTS: A Carbon Positive Powerhouse
biogas
electricity
soil amendments (fertilizer, biochar)
all organic waste cycling
clean and potable water
subfloor heating
insulation
9125 kWh + 8760 kWh = 17.885 mW per year
or
annual consumption
of 1.7 US homes
x1.7
physical
barriers
washed
gravel
sand
biochar
UV
perforated
pipe
cistern
aeration points
constructed
wetlands
Filtration
(stormwater)
Collection
Treatement
LIVER: Plant Processes
natural swimming pool
integrated greywater planter system
bioremediation
mycofiltration
stormwater retention & detention

5.3.3 Transmission

The snake slips into the daylight, reaches a rock, and absorbs the Sun's energy from the sky above and from the baking earth below. It takes in the scent of the air, like a extending its senses into the world like the telescopic vision of the eagle soaring over the river to the west. Nerve impulses send messages to the snake's brain alerting it to the rising level of its internal temperature even as it registers exterior temperatures with the precision of an infrared camera.

Transmission of information, of heat, of energy, and ideas are explored in this iteration of this project in the following ways. Transmission of ideas: using the power of story to convey the notion of what we are as a species and as a planet are well served through aesthetically biophilic design, as a look at deep time and evolution prove without even looking at recent successes. Transmission of heat: from the LEAF & LUNG and GUTS systems to bend the wood for the BONES; to power the movement of water through the HEART and to regulate temperatures to maximize comfort in all spaces throught the year and gain energy efficiencies in the process. Transmission of information gathered through sensors and turned into data for analysis and immediately responded to through automation powered through microcontrollers such as Arduino, small single board computers like Rasperry Pi or old smartphones, and a mesh network running across the site and connecting to the wider community. Classes and training in various healing modalities, permaculture, nutrition, mycology, and fermentation will spread skills and draw in money. With the completion of the site, transmission of arts, culture, and civic engagement are amplified through the ampitheater. Finally, as movement between spaces with a design that emphasizes ADA compliant accessbility at all levels, as evidenced by the "ramphitheater" design.

Nomenclature

Kingdom: Archinae

Phylum: Chordatum

Class: Sacrissanus

Order: Heliostructura

Family: Thuja

Genus: Serpentes

Species: Unknown

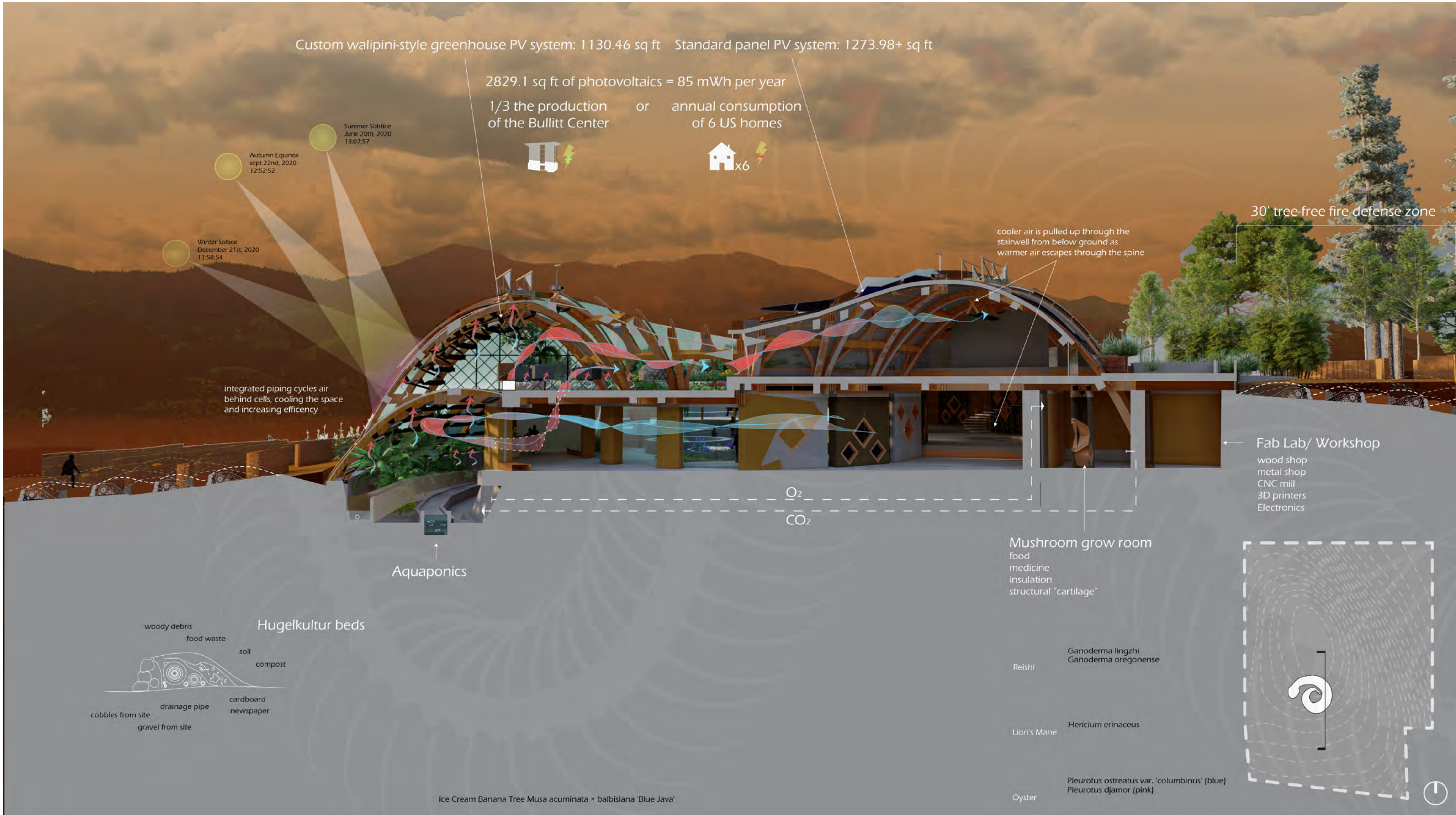
I'll briefly cover the taxonomic ranking I've assigned this project. The Kingdom of our newly discovered form of Life receives its name for obvious reasons. Architecture of buildings or of landscape is best done holistically and the Archinae embody that vision. Professional titles are well and good, but the planet needs more designers who know and care enough about each to allow one to inform the other, rather than always sacrificing the living for the appearance of a clean line.

I've chosen to assign the phylum based upon a major structural feature, as we have in Animalia. The phylum is a play on Chordata, the phylum to which the vertabrates belong. This building has a spine. It is made of wood and does not ambulate, but it has a spine and is designed to live independently of a host organism - read the grid - though it can certainly feed into it. It is also a place where music is made and radiates outwards towards the surrounding mountains and hills. So the phylum Chordata may ring true.

As for the class, I've considered the anthropocentric purpose of the structure and site. *Sacris* is Latin for the word "sacred" and "sanus" means "healthy." I chose to design a holistic health and healing center which produces its own energy, food, and medicine because I believe that good health should be considered a sacred right. We have the technology and the biology to manage it.

Along with the notion of sacred health, this type of project aims to create space and opportunities for community to connect with one another, with themselves, and with the living world around them. Here there is an invitation to experience and celebrate the seasons as plantings turn to harvests and the sun penetrates the earth to shine on a stone in a sacred space below the courtyard. Sunrise and sunset, solstice and equinox the doors are swung open and the light is shown the way into the sacred heart buried in the earth. Above the rocks and small garden in the chamber is a glass bottomed pool, the sky looking down upon them. At the surface, water slips over the lip of a transparent pipe which penetrates the bottom of the pool, dripping upon the rock below. The space is, in its own way, a temple to Time, guarded by the Rainbow Serpent at the watering hole. The passage of the year is marked in different times from inside to out. In the innermost sanctum, the wearing away of the stone occurs on geological time, which is deep. When the sun steps in the doors every year, as it does at Newgrange in Ireland, it touches the space as a secondhand ticking a clock. Beyond this space, time moves faster, as people and seasons shift. There is a slight dialation of time, however, which occurs for people when they receive treatment and for plants in the greenhouse where their growing seasons are prolonged and artificially augmented. At the edges, where a bioreactor system hosts algae and the tanks where the yeast ferment their brew, time moves quickly.

The order refers to the fact that the building is responsive to and was designed in consideration of the movement of the Sun. The Family refers to the Western red cedar, the tree of life, which was used as a starting point for the yakisugi treatment and glulam structure, though other woods will work.



Custom walipini-style greenhouse PV system: 1130.46 sq ft
Standard panel PV system: 1273.98+ sq ft
2829.1 sq ft of photovoltaics = 85 mWh per year
1/3 the production of the Bullitt Center
or
annual consumption of 6 US homes
x6
Summer Solstice June 20th, 2020 13:07:57
Autumn Equinox sept 22nd, 2020 12:52:52
Winter Soltice December 21st, 2020 11:58:54
30' tree-free fire defense zone
cooler air is pulled up through the stairwell from below ground as warmer air escapes through the spine
integrated piping cycles air behind cells, cooling the space and increasing efficency
Fab Lab/ Workshop
wood shop
metal shop
CNC mill
3D printers
Electronics
O_2
CO_2
Aquaponics
Mushroom grow room
food
medicine
insulation
structural "cartilage"
Hugelkultur beds
woody debris
food waste
soil
compost
cardboard
newspaper
drainage pipe
cobbles from site
gravel from site
Reishi
Ganoderma lingzhi
Ganoderma oregonense
Lion's Mane
Hericium erinaceus
Oyster
Pleurotus ostreatus var. 'columbinus' (blue)
Pleurotus djamor (pink)
Ice Cream Banana Tree Musa acuminata × balbisiana 'Blue Java'

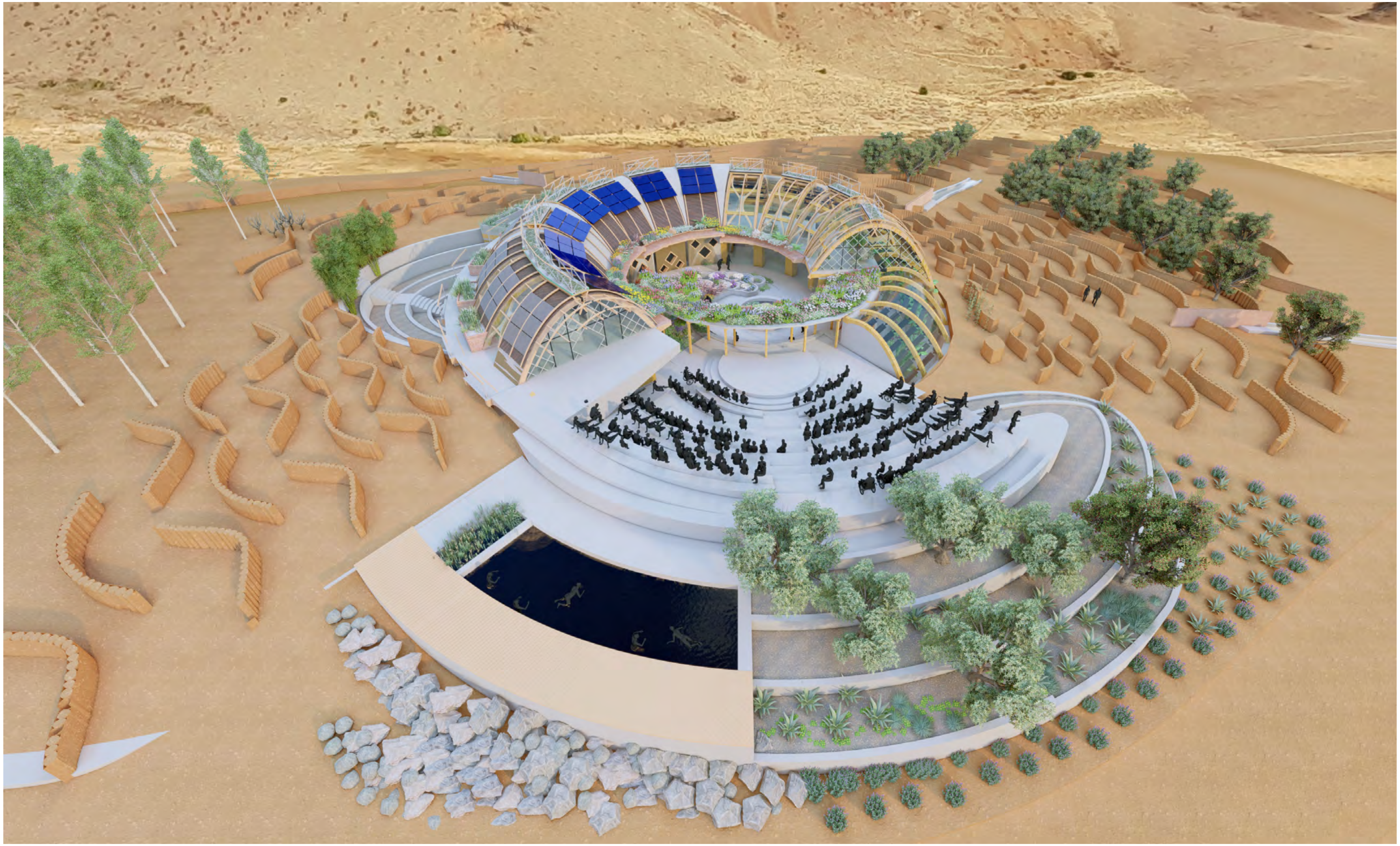


Fig 165 (previous page) - A section cut looking north emphasizes the development of water treatment and storage systems through the SKIN and LIVER systems. While the GUTS retain and reduce water needs through Hugelkultur beds, the also produce potable water through gasification and biodigestion processes. These processes also produce electricity and thermal energy - the latter of which can be used for steaming the wood for the BONES system before being tapped as one of the redundant subfloor heating systems of the HEART.

Fig 166 - An aerial perspective of the design concept, still largely in clay model form. The site is entirely ADA accessible, with the amphitheater doubling as a ramp to the upper level of the structure. A separate set of ramps rises from the sub-basement level of the sanctuary to the top level of the main structure and greenhouse.

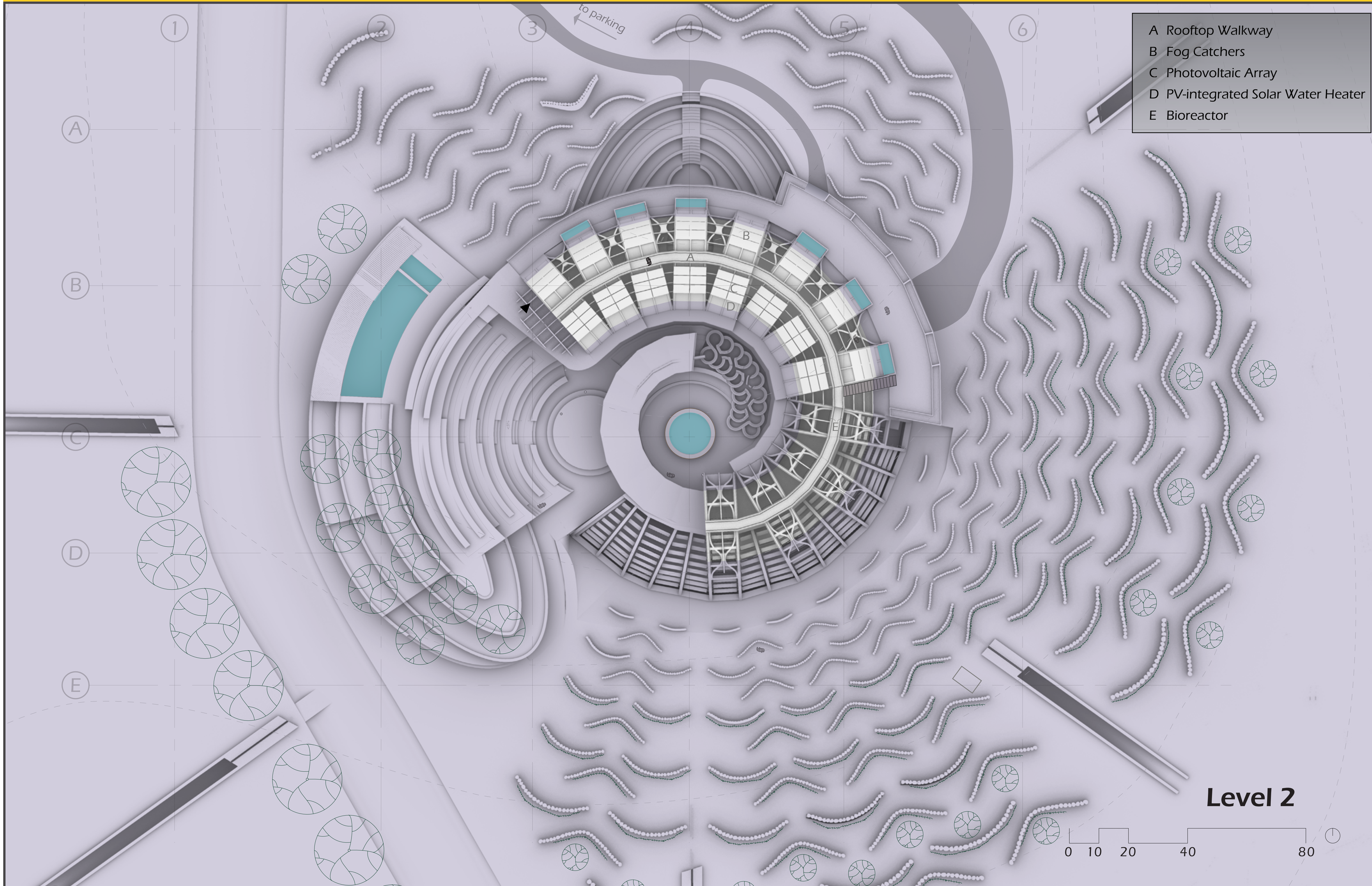


Fig 167 - The basic module for the design is constructed of rammed earth walls and glulam or CLT beams. Joined with a combination of mechanical joints and Japanese styled joinery, curves in the catenary arch and cross bracing are achieved through a combination of CNC milling and steam bending utilizing surplus thermal energy produced in the GUTS and KIDNEY systems.

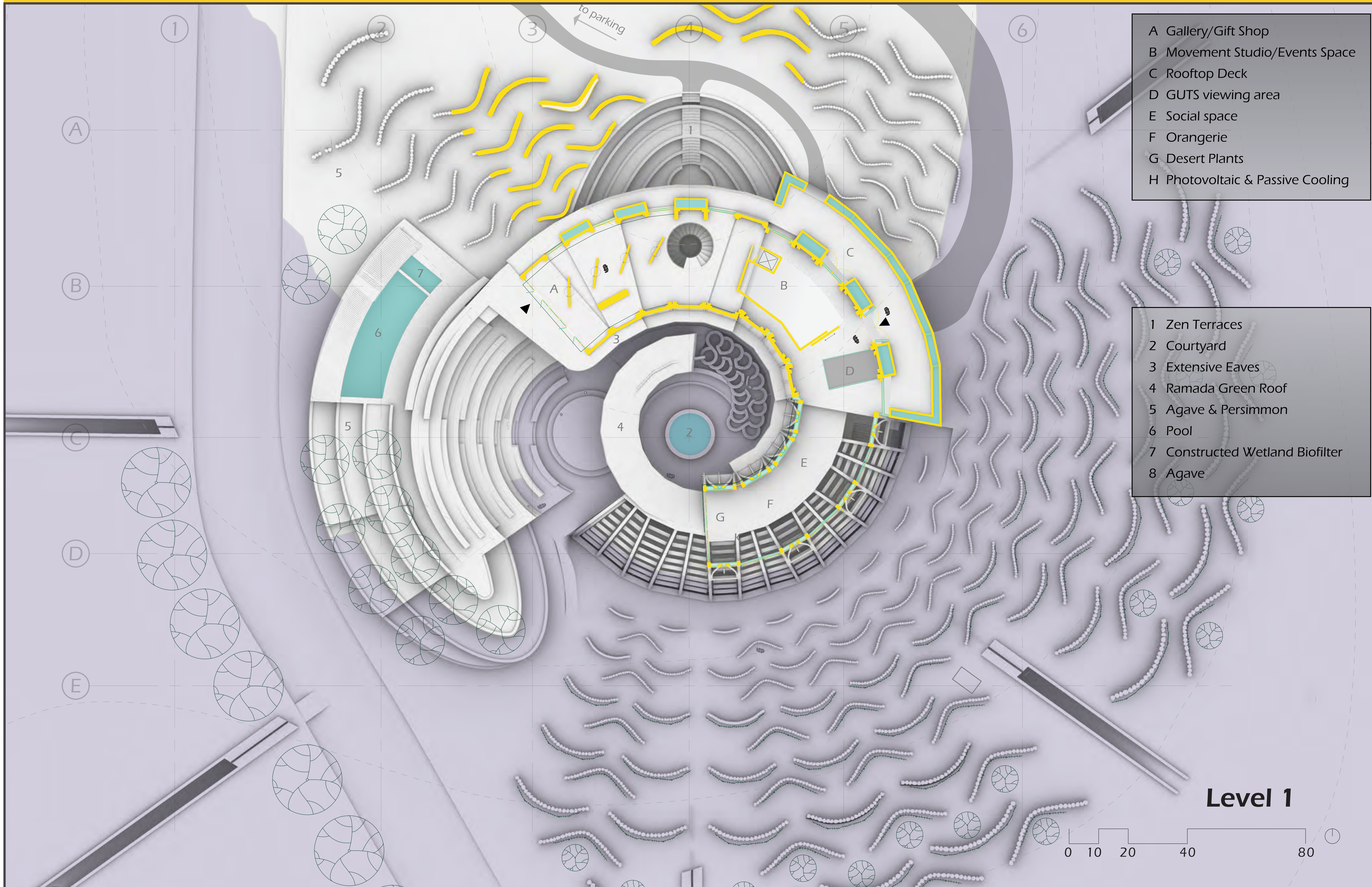


Fig 168 - Level one hosts a gallery, movement studio, and access to the second level of the greenhouse.

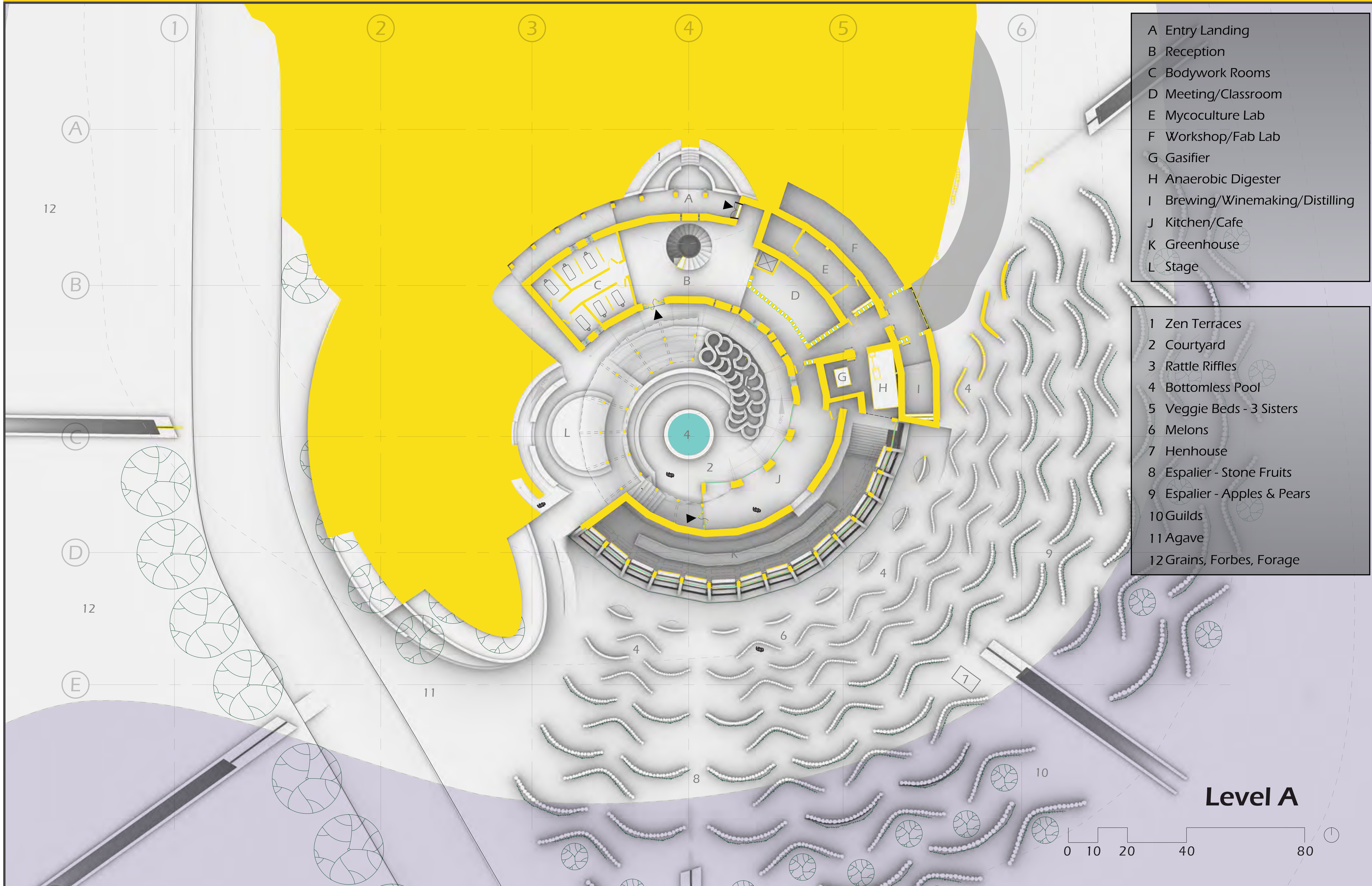


Fig 169 - Plan view of Level A. The transition between the greenhouse and the exterior beds would ideally feature hoophouses that, if the building were to grow, could become a greenhouse expansion using the same catenary module. Inside,

6 *PHASES*

6. PHASES

The phases detailed below utilize a metaphorical agricultural framework, preparing the land for the "planting" of the building and "growing" the systems. As agriculture itself follows a biomimetic tradition, the metaphor is apt. If this project were to move forward immediately, phases One and Two are meant to take place over the course of a summer, if weather (wildfires) and pandemics permit. Phase Three and Four would take place during the following winter and into the new year. Phase Five would take place during the subsequent two to five years and is primarily focused on growth, maintenance, and fine tuning of the systems from earlier phases. These phases are considered optimistic at best, though by no means represent a limitation to the motivated and well-funded.

The sketched diagrams that follow look at using shipping containers may be used as temporary storage and later delivery of collected materials and tools to a site, if not also for longer term structural needs on site. If allowed to refill with other materials and tools at a given site, the containers could be delivered to the next project like a burr on an animal or seed caught by the wind.

Phase One (Deconstruct/Gather/Transport) occurs off site and includes:

- selecting seeds - Purchasing and locating shipping containers for transport, storage, and initial building structure.
- tooling - Gathering and purchasing materials, tools, power systems, appliances, etc.
- harvesting - Deconstruction/dismantling of buildings for materials that would otherwise be slated for demolition.

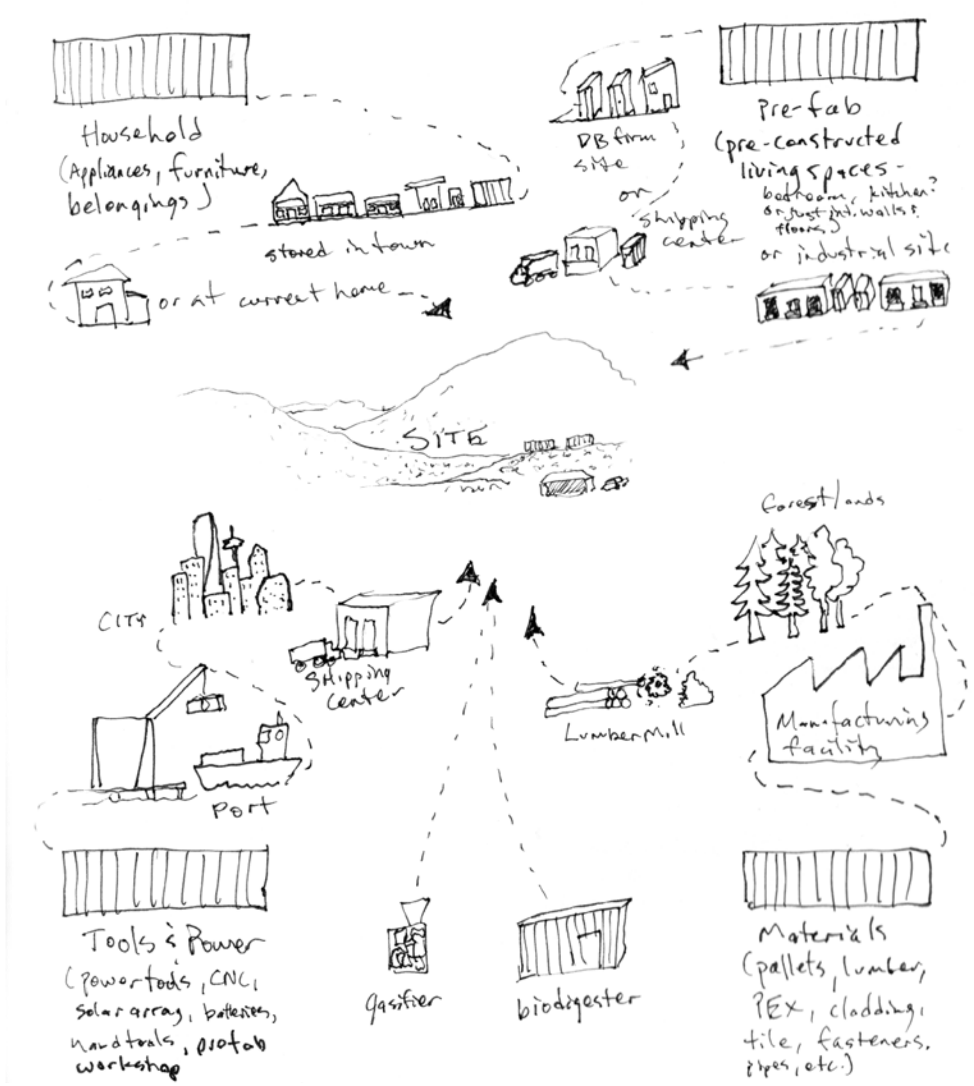


Fig. 170 - Like salmon feasting in the sea to return through rivers to lay their burdens in the forest, shipping containers fill with tools, equipment, materials (new and repurposed), and system components before transport to the site.

Phase Two (Attach/Embed/Plant) occurs onsite and includes:

- clearing - plant removal and relocation, runoff mitigation, earth moving, installation of a temporary driveway and staging area;
- importing/sowing - materials, tools, and a photovoltaic system onto the site with shipping containers for storage and principal living areas, earthwork (digging out house footprint, constructed wetlands & ponds, sorting soils for later use, berming and swales on property), seeding wildflowers, laying out gardens;
- constructing/growing - laying of pipe and subfloor heating, pouring of slab and footings, installation of shipping containers, rough framing of living spaces inside and between containers, building indoor greywater systems, building hugelkultur beds, planting winter garden beds;
- finishing - outfitting of mushroom grow room, rough plumbing and electrical, insulation installation, cladding, drywall or plywood interiors, beginning inoculation process of woody biomass for incorporation into gardens.

Phase Three (Cocoon/Convert/Grow) includes:

- importing/sowing - organic materials/compostables from off site sources (restaurants, etc) brought in for biodigestion. Woody biomass is brought in for gasification. Materials for mushroom cultivation brought in and inoculated.
- construction/growing - interiors rooms finished, milling/lasercutting and gluing of glulam structural members, preparation of rammed earth formwork, mushroom growing to capacity.

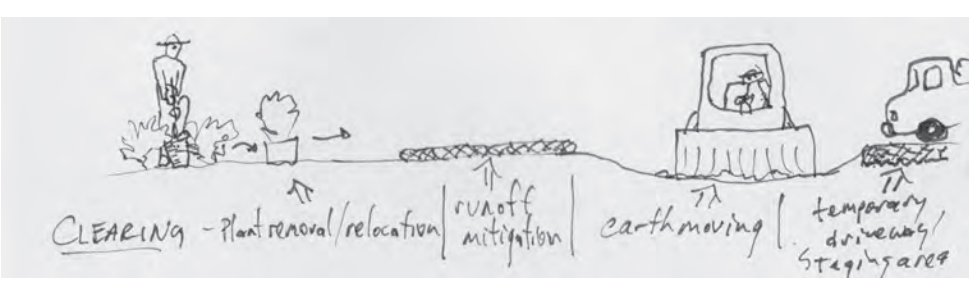
Phase Four (Expand/Metamorphose/Unfold) includes:

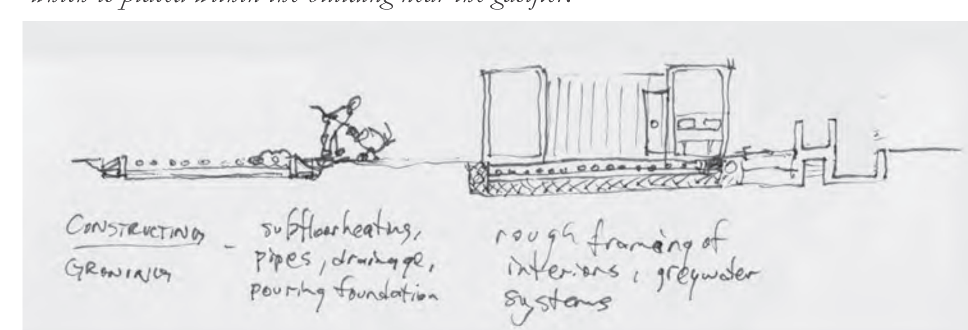
- clearing - expanding the berm/swale system, clearing a field for rotational planting of grains with the aid of a small number of livestock;
- importing/sowing - building and raw materials, tools, seeds, new varieties of fungi for propagation, setting up sales networks for products (mushrooms, wildflowers, etc), adding materials to new hugelkultur beds'
- construction/growing - construction of rammed earth walls and roof structure, construction of greenhouse, raised beds, earth berm terracing around house, installation of vineyard, construction of fruit walls with espaliered fruit trees;
- finishing - installing yakisugi cladding, windows;
- harvesting - gathering seasonal crops and wildflowers, harvesting mushrooms, marketing surplus at the farmers market in Twisp;
- evolving - installation of sensor systems, Internet-of-Things, mesh network, data collection.

Phase Five (Regenerate/Release/Repeat) includes:

- clearing - rotational planting through grid system (one out of 10 fields active at a time), allowing fallow fields to be taken over by native plants;
- sowing/importing - raw materials, seeds, new varieties of fungi for propagation, scheduling events and installations;
- construction/growing construction of amphitheater, constructing a farmstand on Balky Hill Road;
- harvesting - crops, wildflowers, mushrooms, conducting assessments, gathering data;
- evolving - data analysis, strategizing future growth (expansion or contraction), evaluating partnerships.

Fig. 171-173 - Sketches looking at early phases. In this early iteration, shipping containers would not only provide transport and storage, but they would become the workshop and mycolab before being integrated into the structure of the new building. This notion carries to the design described in Chapter 5, where the biodigester arrives in a shipping container which is placed within the building near the gasifier.





7 CONCLUSIONS & REFLECTIONS

This thesis began with the questions:

- What is the role of biomimicry in the built environment?
- What is it and how does it both define and redefine our understanding of human cultural and social development?
- Finally, in what ways can a biomimetic approach to design of architecture, landscape architecture, and engineering be applied to a site specific applications?"

Through the lenses of Story, we share information about the world and that information affects our daily and long term actions. The story we've been telling ourselves about the built environment is that it can be abstracted outside of Nature, outside of the biological, and does not need to play by the same rules. Biomimicry places us back inside of the living environment, our biosphere and biomes at all scales. Reconsidering the things we Homo sapiens give life to, through a biomimetic framework, arguably provides our best hope at sustainable and regenerative development. And here we see that even the story we've been sharing about sustainability has been too narrow, too simplistic, too abstract. There is no "away" to throw things to. Complexity is a necessity and we each need to better understand the embodied energy, carbon, and backstory of every single item, element, and resource that flows through our lives. That is doubly true for designers and decision makers, the people who tell and retell the stories that shape our world.

By applying the design spiral of biomimicry to the concept of building as living organism, an essential set of systems was developed and described as organs. These were based upon relationships between organisms at various scales, mechanical processes, and resource flows. An iterative design process then emulated these organs into and through a site specific design, responding to established design constraints, program, and site analysis. A phased approach was considered for the design and construction, also following the biomimicry process.

The results of the design process provide one more example of integrative systems design within the built environment, following the real case studies featured earlier in the document. Herein, the 8th Kingdom of Life, the Archinae, is pushed towards an evolutionary step of ecological integration through the closing of resource loops, providing intentional redundancies, and applying the regenerative power of biodiversity to waste streams. These steps reveal a wealth of opportunities to reduce costs, produce energy, sequester carbon, harvest rainwater and snow melt, and to feed ourselves and the species that rely upon our own.

Under the rubric of biomimicry and the Living Building Challenge, this project may be judged an initial success. If I were to start this all from scratch, I would likely pursue a combination of extruded SHELL and fabric formwork of rammed earth for a structural system. This would have taken its geometry from actual shells in order to explore radial patterns of growth. I would have also liked to have looked at the potential for creating a scaffolding on which to grow a SKIN of chitin, as with Aquahoja - the MIT project under Neri Oxman (The Mediated Matter Group) - or used the bioMASON brick technology (bioMASON) to create a plating or rainscreen with a hexagonal gridwork to reduce materials and allow for a more organic geometry.

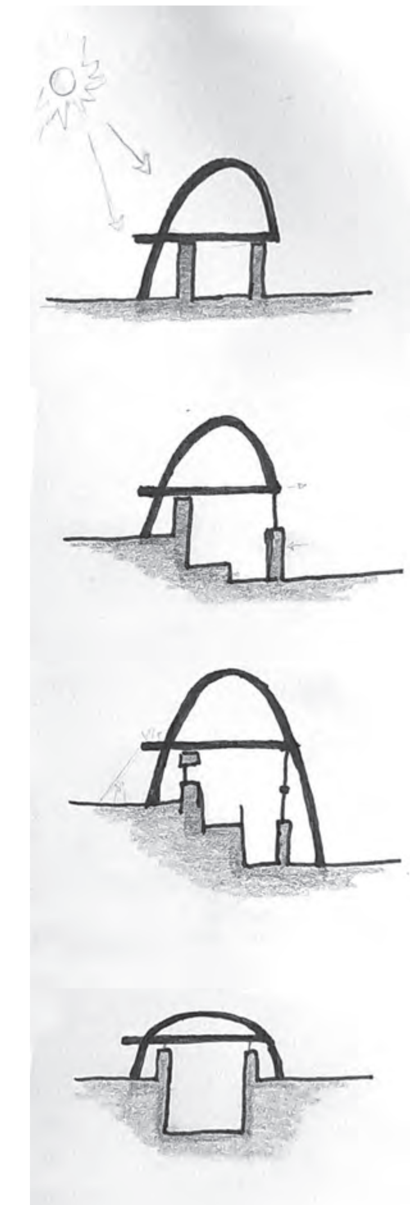


Fig. 174 - An early section diagram exploring the relationships between catenary arches and rammed earth walls. I remember where I started with this project. I am looking forward to seeing where it may be taken in the future.

Still, I am left with these larger questions:

- *How should our buildings behave?*
- *How do these needs and their respondent and respective Organs determine what should our buildings and connective landscapes look like? Are there types we must eschew completely and entirely as a matter of conscience?*
- *How can our buildings breathe life into the world?*
- *How can our buildings and landscapes consume and upcycle their wastes?*

A one of the biggest ones:

- *How can we, individually and collectively, explore and fulfill our roles as an integral member of a larger species of organism through direct action, through volunteerism, work, donations, daily habits, purchases, creative outlets, design, construction, and community building?*

To my fellow artists, designers, performers, poets, myth-makers, authors, screen writers, film-makers, and the videogame wizards:
What stories can be told of the Archinae to explore the questions and themes above? Can we transcend genres with these stories of a Living Environment? What are the human stories that arise out of a world where you could know your home as something that reacts to your presence at least as well as our latest iterations of A.I. and a smart environment? An Archinae, building and landscape, that is a pet, a friend, a family member. That give us room to grow, food to eat, cleaner water and air.

From childrens' books and science fiction to grant requests and iterative design, in what ways can we, you and I, bring the Archinae to life? Moreover, to prove that they exist and that we are raising them? I've driven past industrial agriculture and I've driven through mass produced housing. I've been in and among the homes of billionaires. We raise the Archinae like show ponies or like animals in a factory farm, veal and hogs immobilized and unsustainble with a drip in the vein and a catheter, lying in a regularly soiled bed before being consumed and never truly loved. It is bleak and these extremes don't have to be the long and short of it. Our Living Environment must be our built environment and vice versa. Otherwise the one will die at the expense of the other. To weave together our needs and technologies with the technologies and means revealed in the natural world is something we have long done and must continue to do. Seeing it all as living, an organism made of and supported by organisms - just like any other person.

Beyond applying new approaches to growing a site, it would be beneficial to apply the *Archinae* Organs systems to other climates and environments, to include the more densely populated (or urban, if we must) areas. What is an ideal size for the organs in the context of a neighborhood block? A skyscraper? Public buildings? Schools? This, however, is outside of the scope of this thesis and I look forward to seeing where this line of inquiry leads in my own future practice and that of other scholars and designers.

Fry bread and Sourdough

Personally, I've been caught between a rock and a hard place during the entirety of producing this thesis. My hopes, my ideals, my dreams, and my beliefs have crashed against the riprap of deadlines, institutional paradigms and perogatives, cultural constraints, mental health issues, and a raging pandemic within a political atmosphere that has eroded much of what we have considered to be "normalcy".

What I expected thesis to be was an opportunity to grow, form, and develop a perspective and approach to design of the built environment which would be unique to me while proving to be grounded in a deeper history of human and evolutionary development. Like a sourdough starter, this requires time to develop complexity and simultaneously become more palatable and easier on the (digestive) system. The time frame allotted by thesis constrains students and faculty from delving too deeply into these kinds of projects. The cultures of academic and professional design, simultaneously and famously, have been developed around a model of exploitation and quick returns, seeing the care of the community that makes our built environment possible as secondary to quick profits, developer demands, and the ascent of the starchitect above the masses who allow them to rise. It feels like fry bread to me. It's filling and can be very tasty, but it is made from ingredients determined solely by a history of oppression of peoples and devastation of lands. Some theses rise above, but most are forced into these narrow constraints because they are, arguably, easier and faster to produce.

As the wealthiest people have grown wealthier by billions of dollars a piece, I've jumped into starting a design build business while finishing up my thesis because we've needed the money. If I had more time to do this thesis justice, I would. If I had time to explore parametric design or integrate the bio and smart materials work coming out of Neri Oxman's lab at MIT Media Lab, I would. When I have this thesis turned in, I do know one thing I will do. I'll keep on telling the story of how our buildings are alive, if only we have the eyes and open minds to see them.

I am hopeful for the future. This study has led me to the conclusion that, despite the suggestions of some, *Homo sapiens* is not a disease. We are an evolved immune response of a planetary super organism. When the genetic code of culture, Story, is corrupted or driven by exploitative forces, our built environment manifests as cancerous growth. Vital systems shut down that were never under our control. The relationships which define those systems are based upon the sharing and interpreting of information, as is evidenced in all forms of mimicry. Humans rely upon story as a novel means of information exchange and digestion. Through myths, customs, laws, and all of the means by which we interact with one another and the wider world, Story is behind every blessing and every curse our species casts upon the Earth and the Universe beyond. Like children, the Archinae will grow according the the stories we tell.

Endnotes

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One last story.

January 16th, 2195

Bonjour Cuz,

Happy Archinae Day! I wish you were here with us. It's not entirely what I was expecting. The place feels old and new at the same time. The other Archs we've stayed at have a similar vibe, but it's different here. Walking from room to room, the lights shifting color depending on who is there and how "happy" the building is makes me feel like I'm home, for sure. But the old wood, the ancient LIVER and the smallness of the LUNGS makes me feel like I'm in a different time. You know we're the seventh generation since they built the first one? Crazy.

It has me thinking, what are we even doing? Like, I know that we do all the stuff we learned how to do when we were kids and I do love fixing things and playing with the plants and anmials. But what am I doing that will really make a difference for the next seven? Maybe this is enough. I don't know.

I talked to my folks and decided to apply for the Life Project on Mars. I'm hoping to get into the design program. They've got a heavy emphasis on bio-geo-mech-electro-engineering and art history. Old Uncle Jim's love of Art Nouveau deserves a rebirth on the Red Planet, I think. Maybe I'll grow a giant beard while I'm there.

Tons of love,
Izzy

LIST OF FIGURES

All figures, unless otherwise noted, are by the author.

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