Lecture prepared by Carlos Fiorentino using multiple sources, for the purpose of display in the Biomimicry Alberta Workshops setting only.

Biomimicry*Alberta*

welcome!

Saturday

12:00	Arrival, site orientation and room assignment / Park in visitor parking & meet in office
12:45	Introductions to your table and lunch
2:00	Guest: *Dr. Johnson* *(Biogeoscience institute UofC)*
2:30	Introduction to BAW02, Biomimicry and GoP *Kira Hunt | Carlos Fiorentino | Marjan Eggermont*
3:15	(break)
3:30	**Stream 1: Nature** [Outdoor adventure for active folk w/BA mentors] Intro to GoP strategies template Hike / Observerving nature's solutions. **Stream 2: Design** [Gentle idea generation w/BA mentors] Intro to GoP strategies template Short outdoor sit / walk Brainstorm problems in AB
5:00	Brief group presentations
5:45	(break)
6:00	Dinner and free time
7:00	GoP match-up activity: Breakout groups by interest
8:30	Social (bring you own drinks)

Sunday

8:00 am	Breakfast
8:45	Biomimicry Wakeup Outdoor Activities
9:30	Update on biomimicry projects in AB *Dan Sameoto | John Nychka | Godo Stoyke* Update on ABMI–Alberta Biodiversity Monitoring institute *Kira Hunt* Biomimicry Global Design Challenge 2017 *Carlos Fiorentino | John Nychka*
11:00	(break)
11:15	Next Steps [GoP Agenda] and Deliverables
12:00	Lunch
12:45	Thanks and Goodbyes

BiomimicryAlberta

Living things have done everything humans want to do, without guzzling fossil fuels, polluting the planet, or mortgaging their future.

After 3.8 billion years of R&D, failures became fossils and what surround us is the secret to survival

~ Janine Benyus

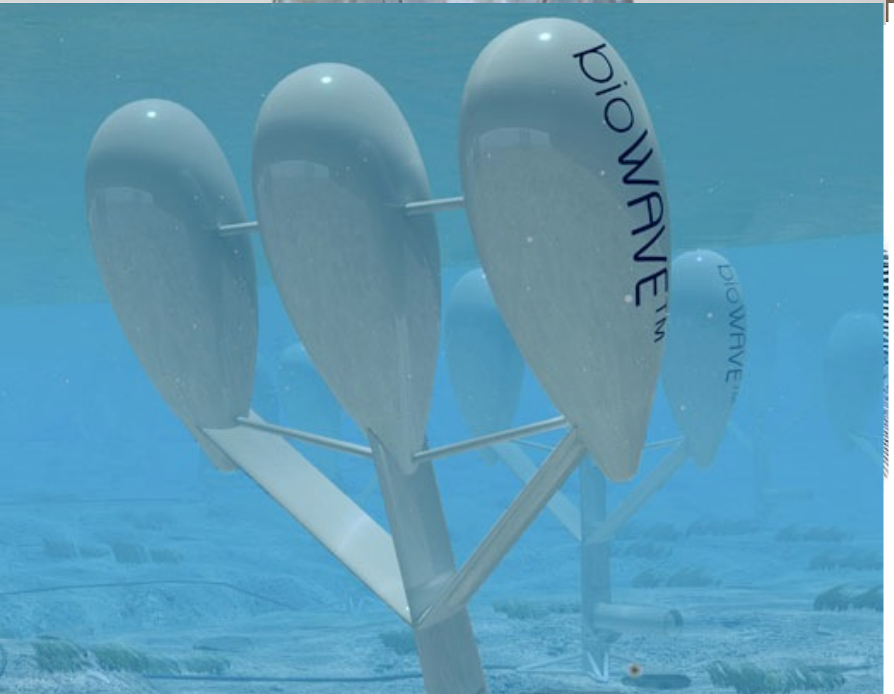
Sustainable Design Has Been Solved
- Why Are We Ignoring It?

~ Corman Farrell /Huffington Post

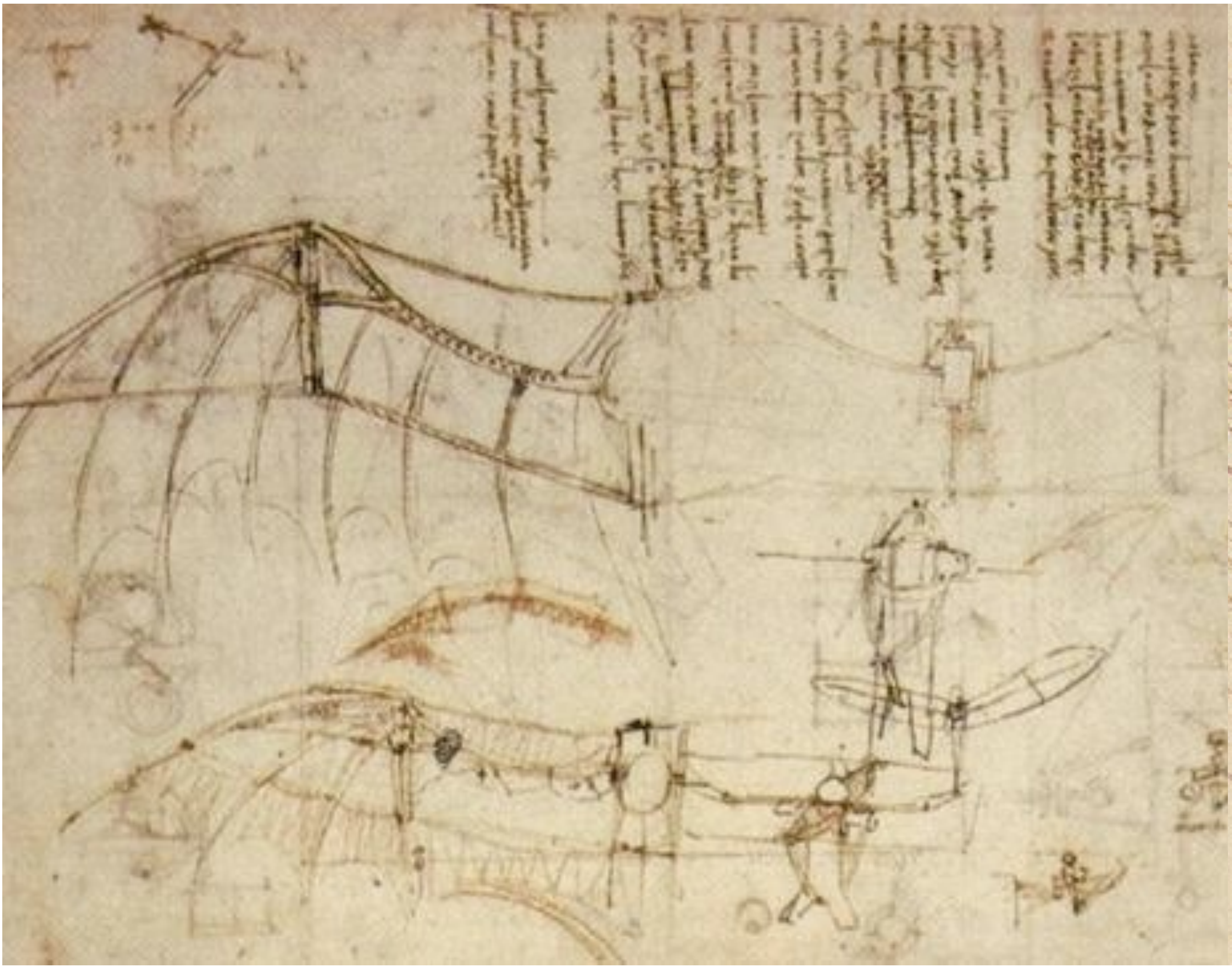


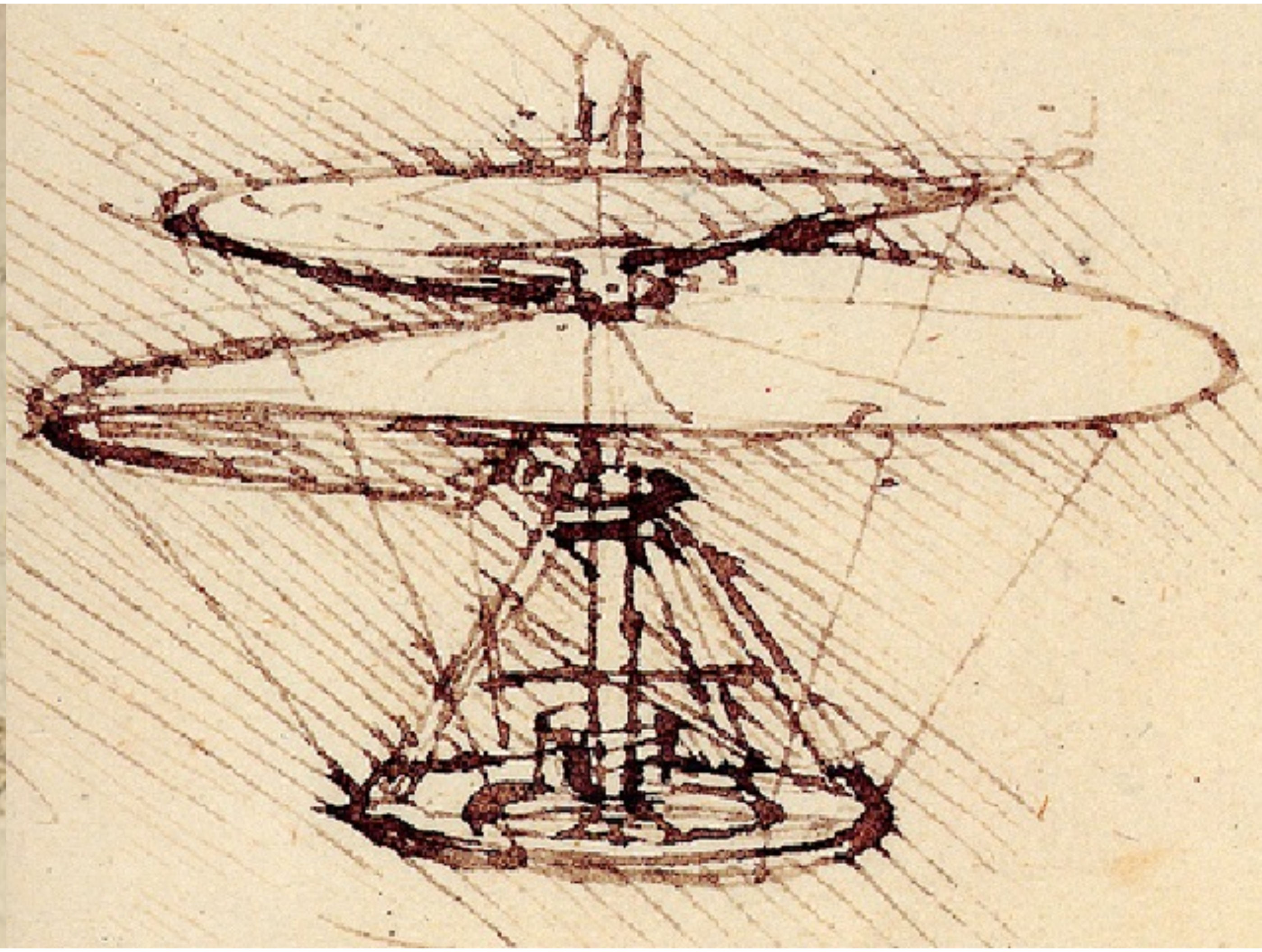


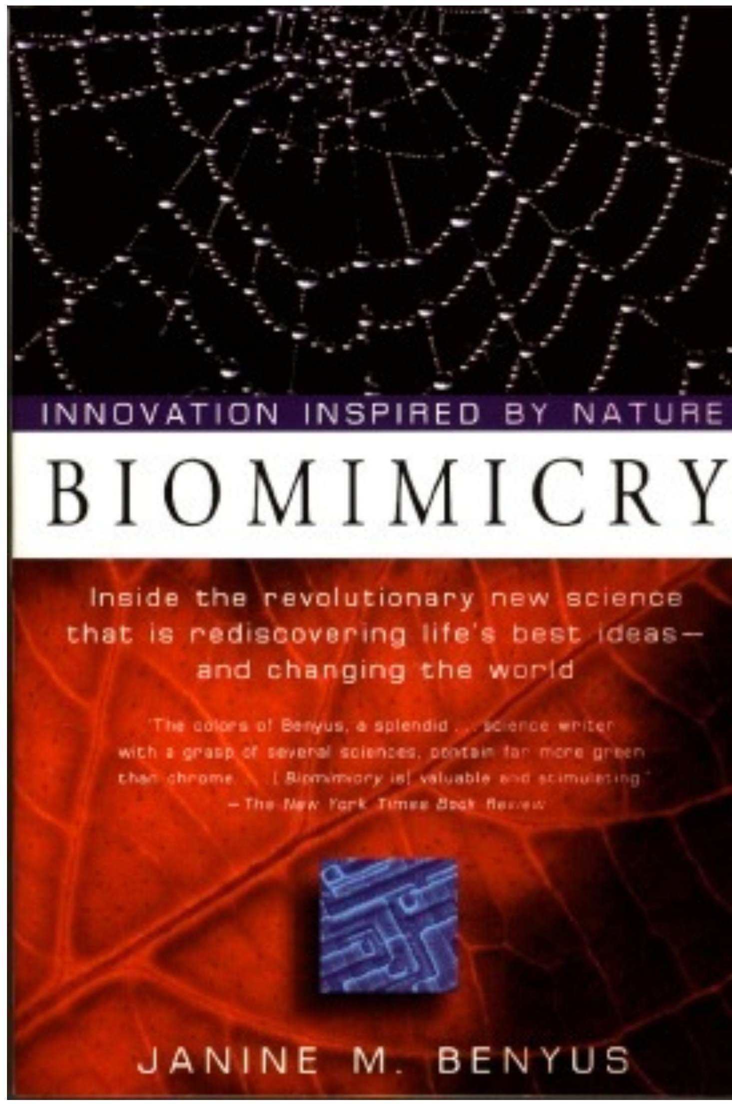


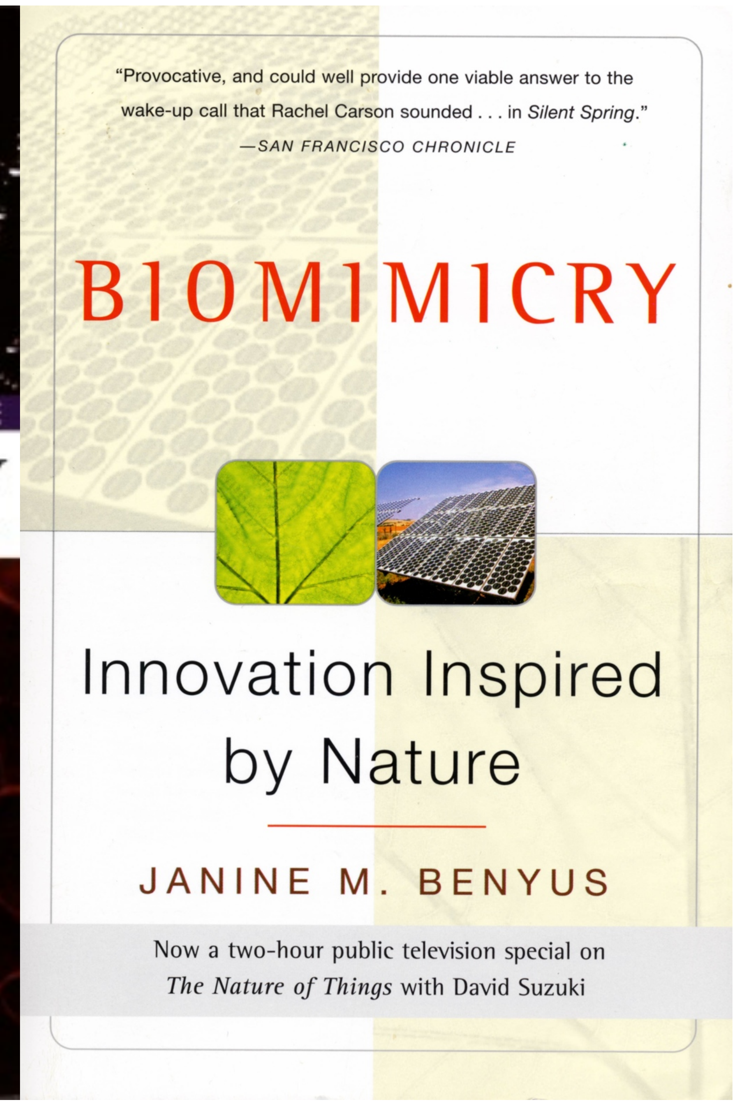

bioWAVE™

Bio-inspired design : biomimetics : biomechanics : bionics : biomimicry






INNOVATION INSPIRED BY NATURE
BIOMIMICRY
Inside the revolutionary new science
that is rediscovering life's best ideas—
and changing the world
"The colors of Benyus, a splendid . . . science writer
with a grasp of several sciences, contain far more green
than chrome. . . [Biomimicry is] valuable and stimulating."
—The New York Times Book Review
JANINE M. BENYUS


"Provocative, and could well provide one viable answer to the
wake-up call that Rachel Carson sounded . . . in Silent Spring."
—SAN FRANCISCO CHRONICLE
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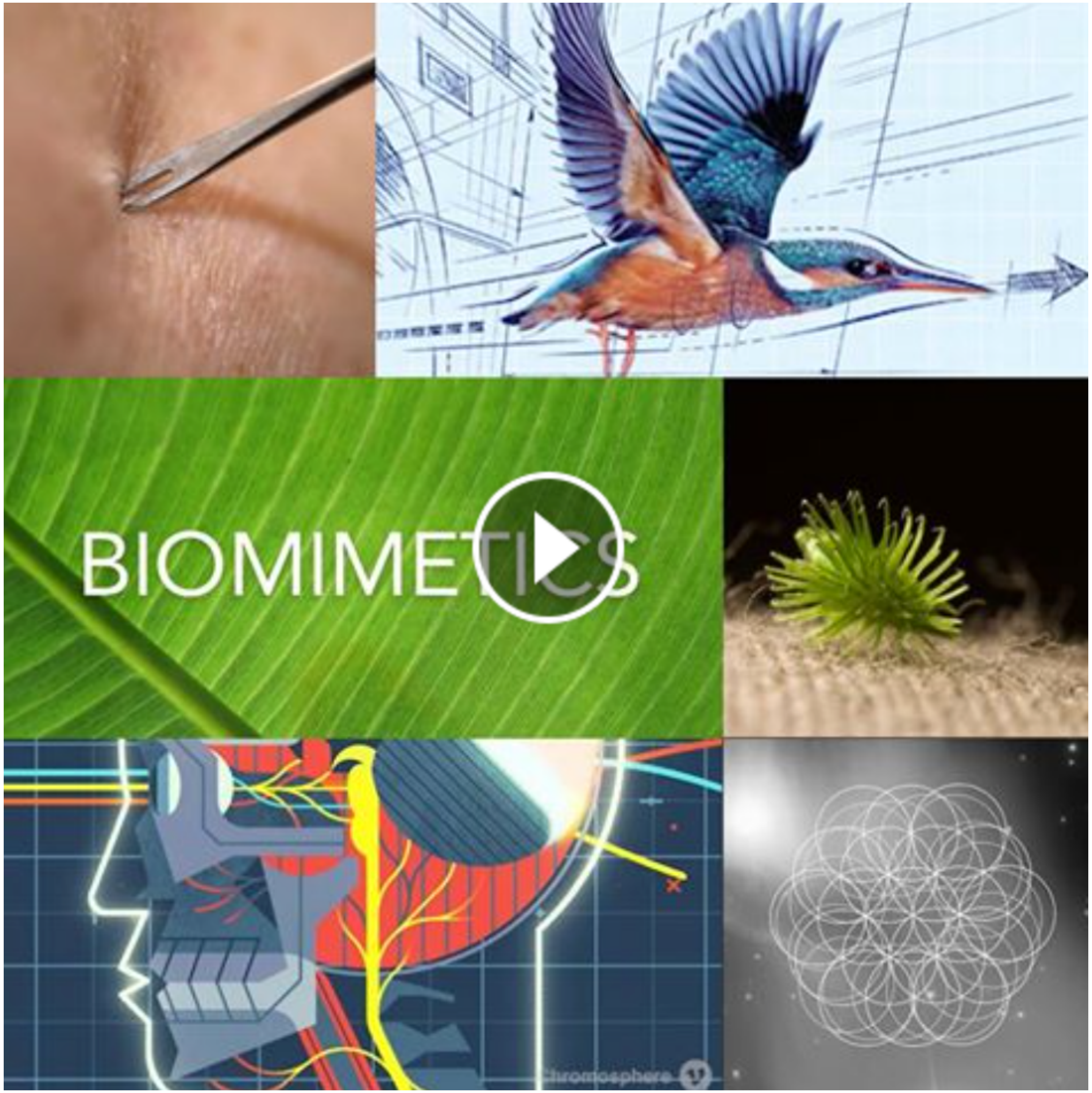
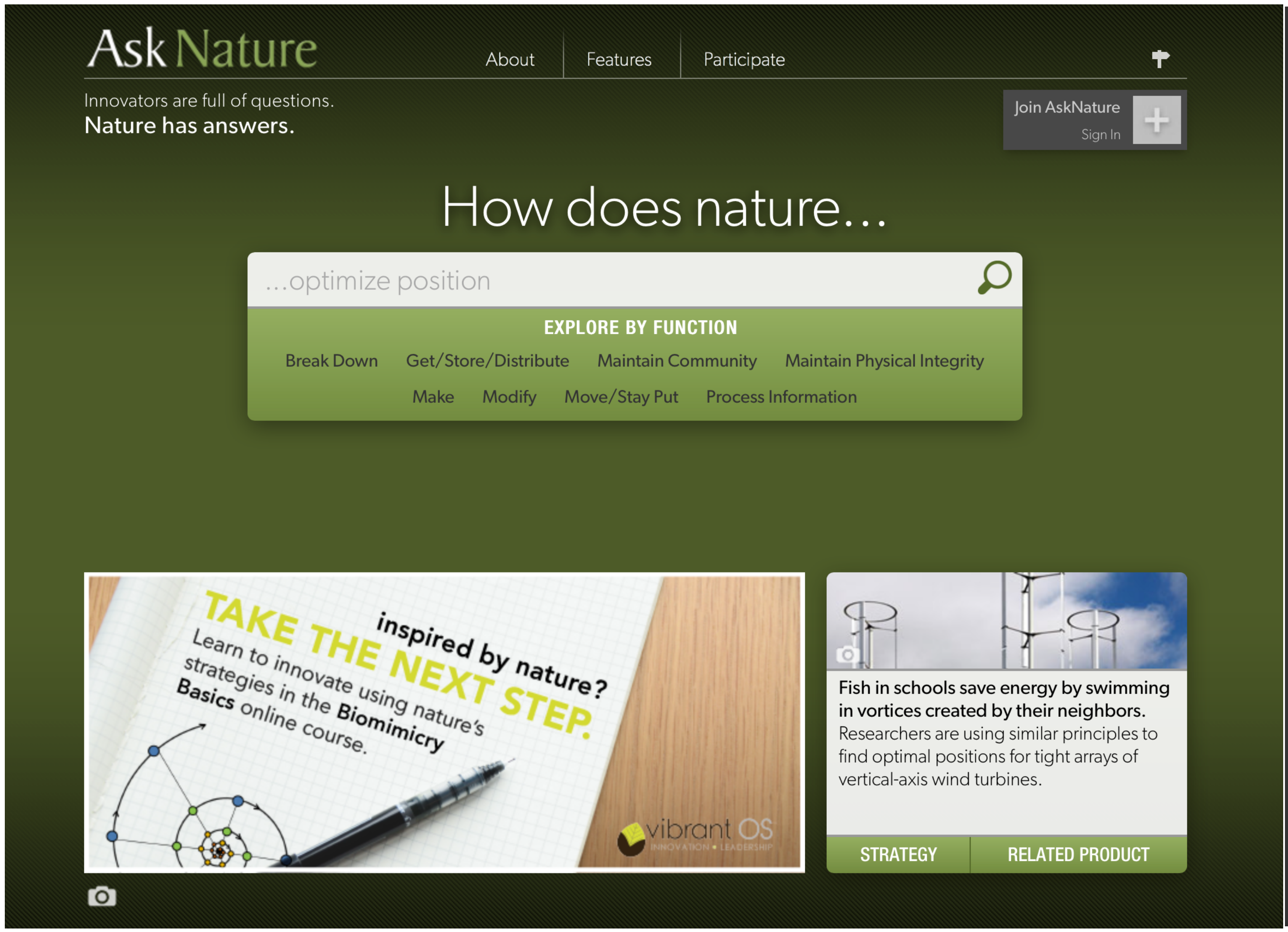
Innovation Inspired
by Nature
JANINE M. BENYUS
Now a two-hour public television special on
The Nature of Things with David Suzuki


BIOMIMETICS
chromosphere



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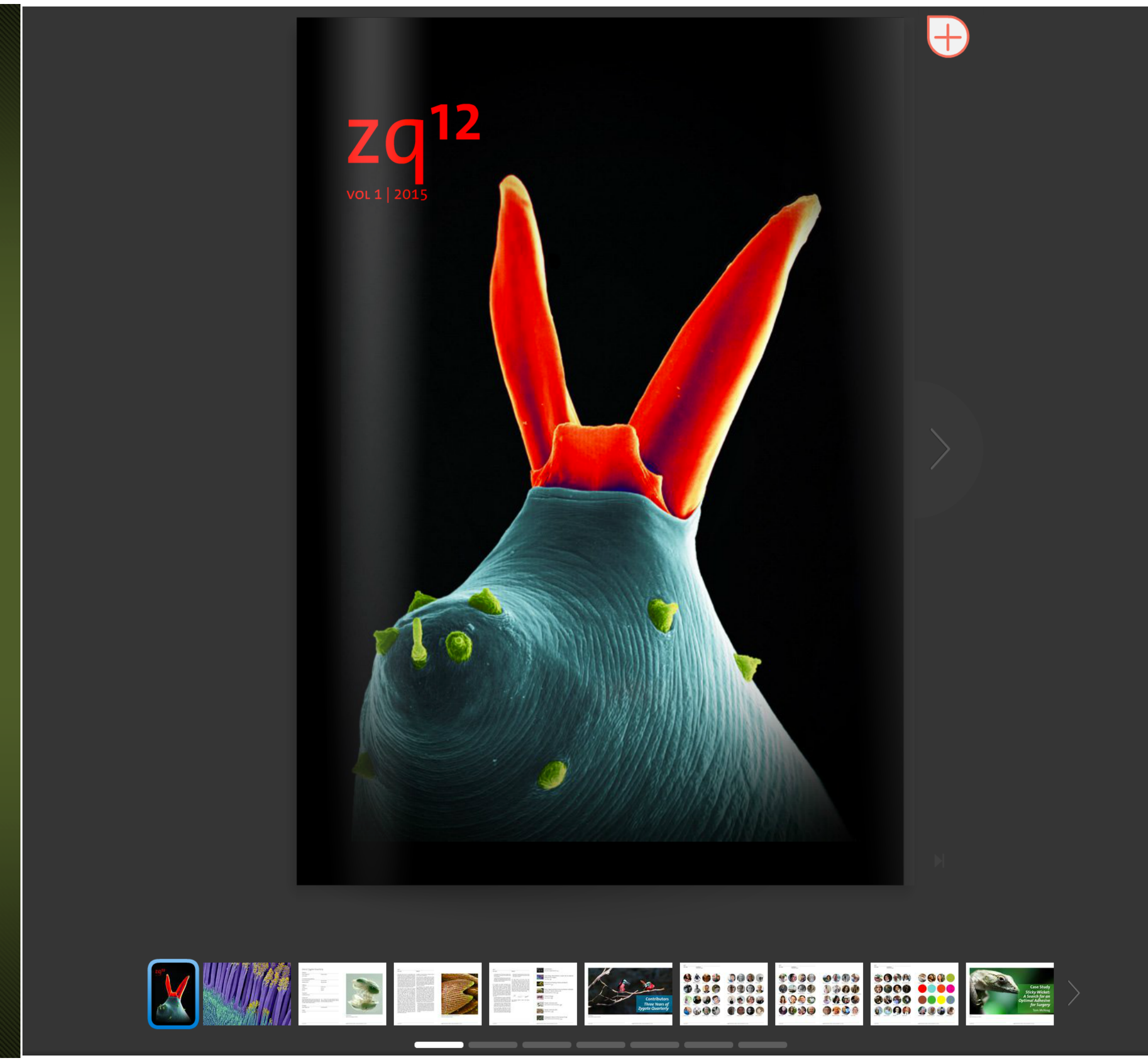


zqjournal.org


MH14EY7014

theguardian

Guardian sustainable business Technology and Innovation

The greenhouse that acts like a beetle and other inventions inspired by nature

For a new generation of innovators, biomimicry - the imitation of nature's ecosystems - may help solve some of humanity's toughest resource problems

Sundrop Farms, a Seawater Greenhouse project in Port Augusta, Australia - a greenhouse inspired by the desert beetle. Photograph: Seawater Greenhouse

Bruce Watson

Sunday 10 April 2016 16.00 BST

Biomimicry

(from *bios*, meaning life, and *mimesis*, meaning to imitate)

Organisms and environments integrate and optimize strategies to create conditions conducive to life. ***How can design create conditions conducive to life?***

Biomimicry sees nature

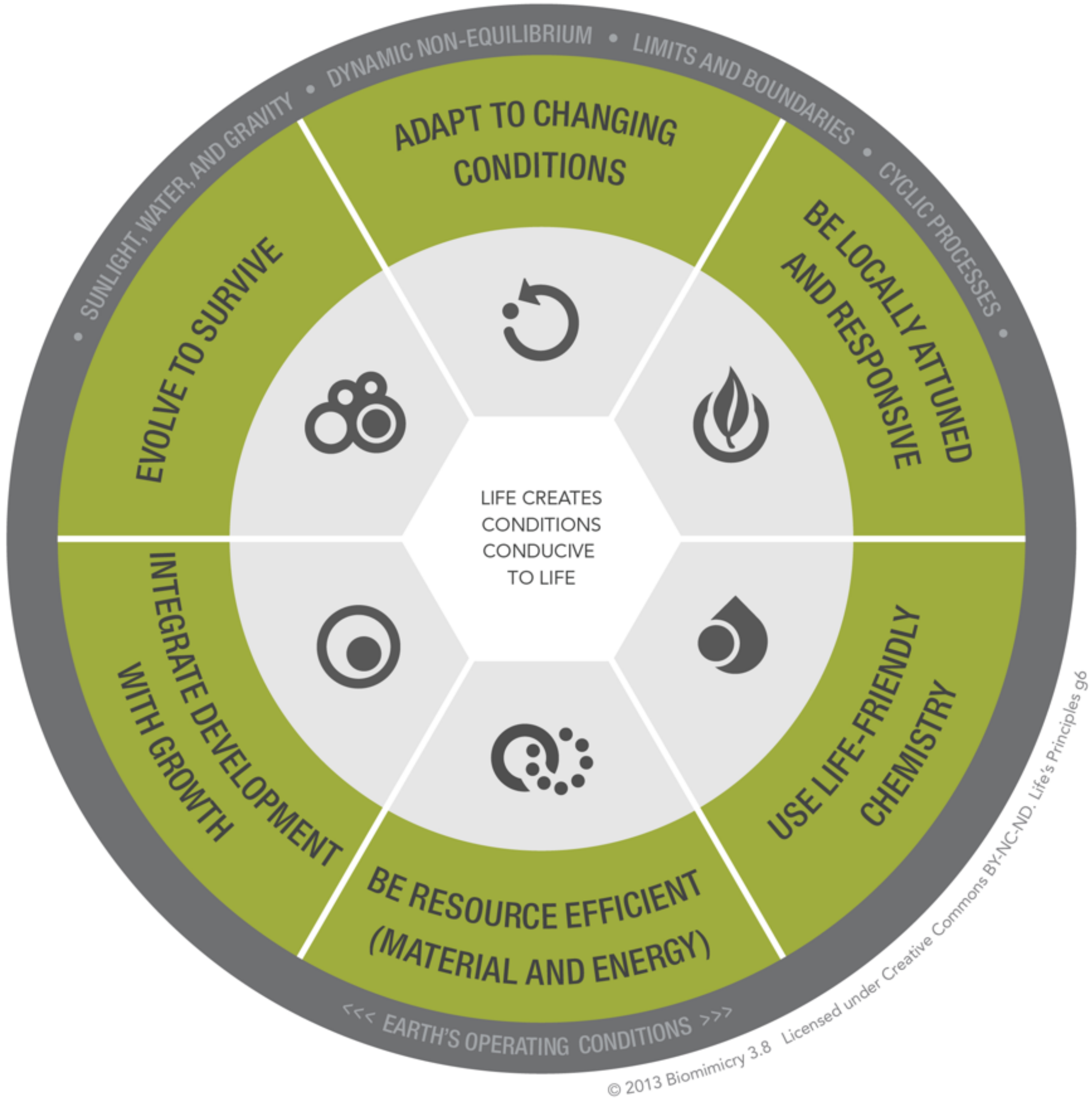
as a model
photosynthesis,
self-assembly,
natural selection,
self-sustaining ecosystems

as a measure
uses an ecological standard to judge the rightness of our innovations, what works, what is appropriate and what lasts

as a mentor
introduces an era based not on what we can extract from the natural world but on what we can learn from it

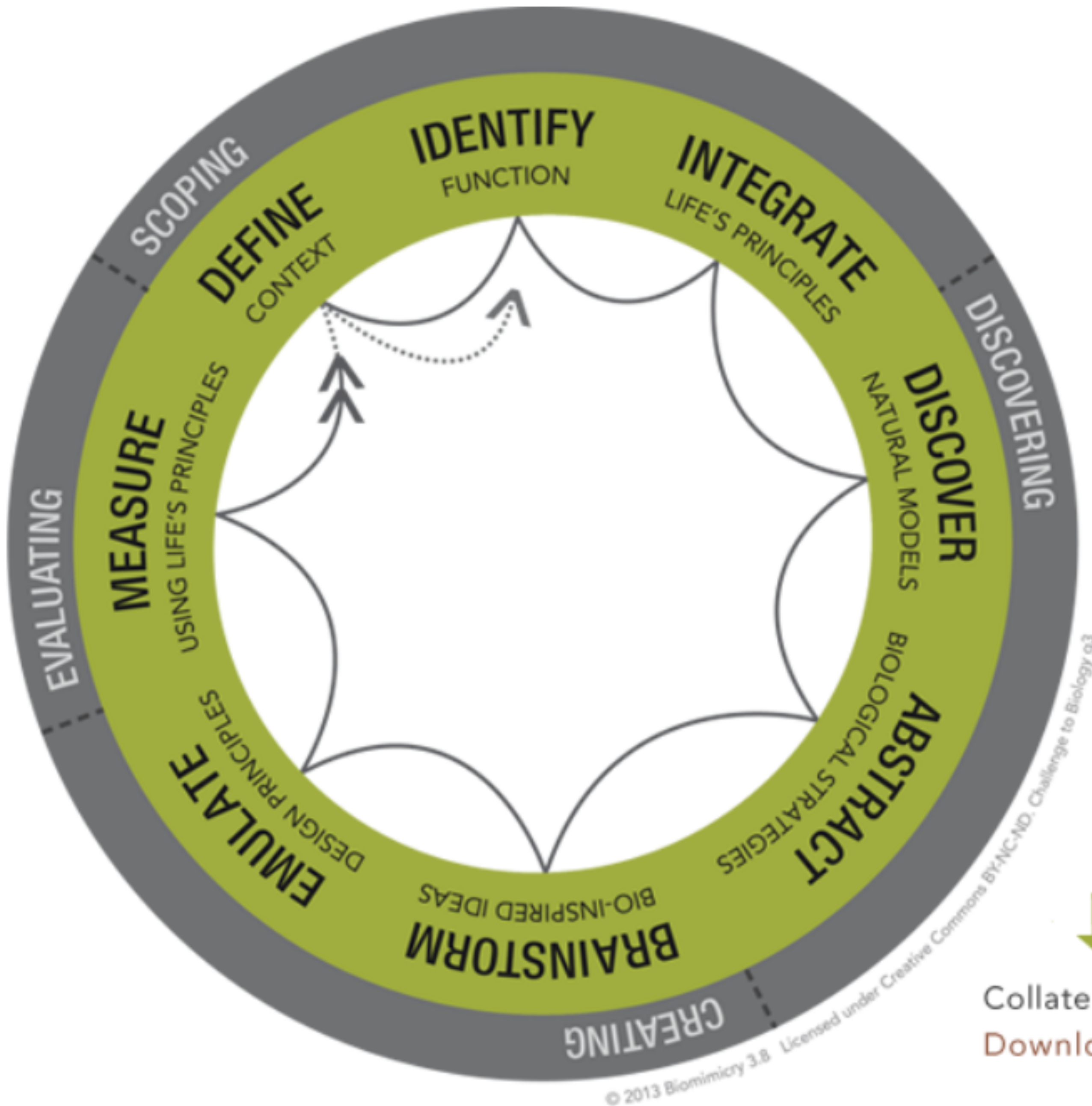
Cannon of nature’s laws, strategies, and principles:

- Nature runs on sunlight
- Nature uses only the energy it needs
- Nature fits form to function
- Nature recycles everything
- Nature rewards cooperation
- Nature banks on diversity
- Nature demands local expertise
- Nature curbs excesses from within
- Nature taps the power of limits



LIFE'S PRINCIPLES

Biomimicry DesignLens



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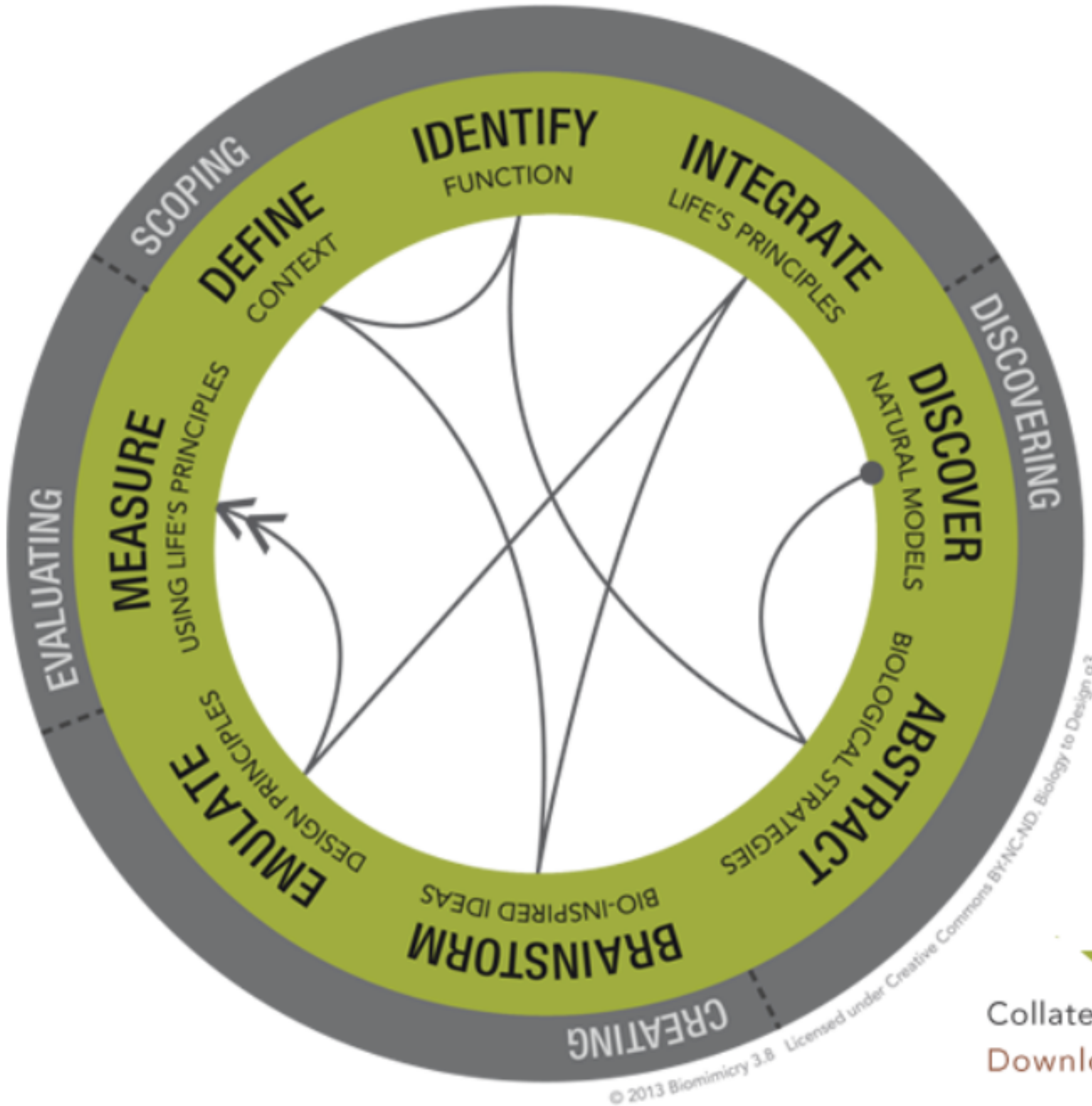
Challenge to Biology

Challenge to Biology is a specific path through Biomimicry Thinking. This is useful for scenarios when a specific problem is at hand and you are seeking biological insights for the solution. It is particularly useful for a "controlled" setting, such as a classroom, or for creating an iterative design process. Not surprisingly, the best outcomes occur when you navigate the path multiple times.



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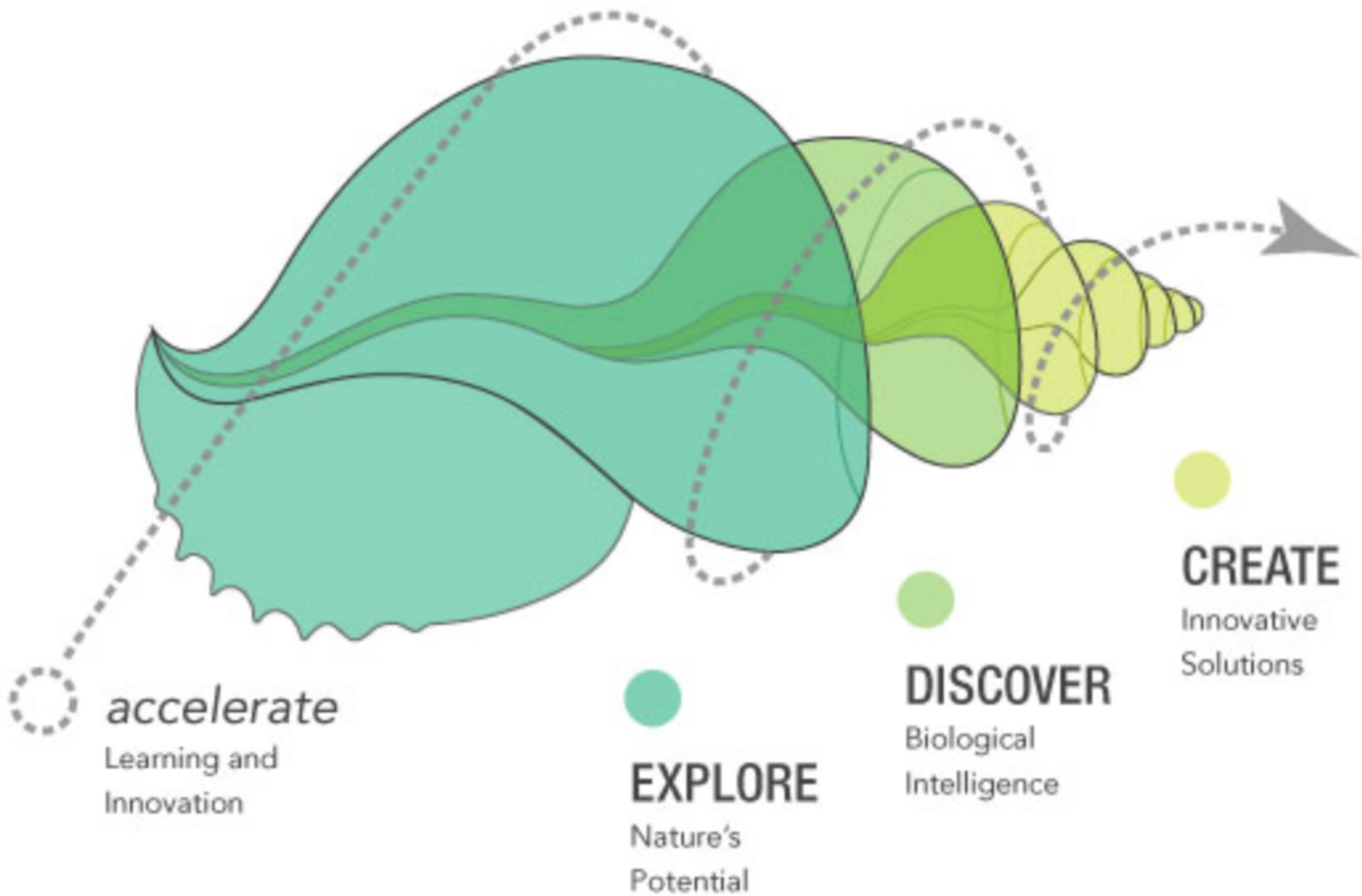
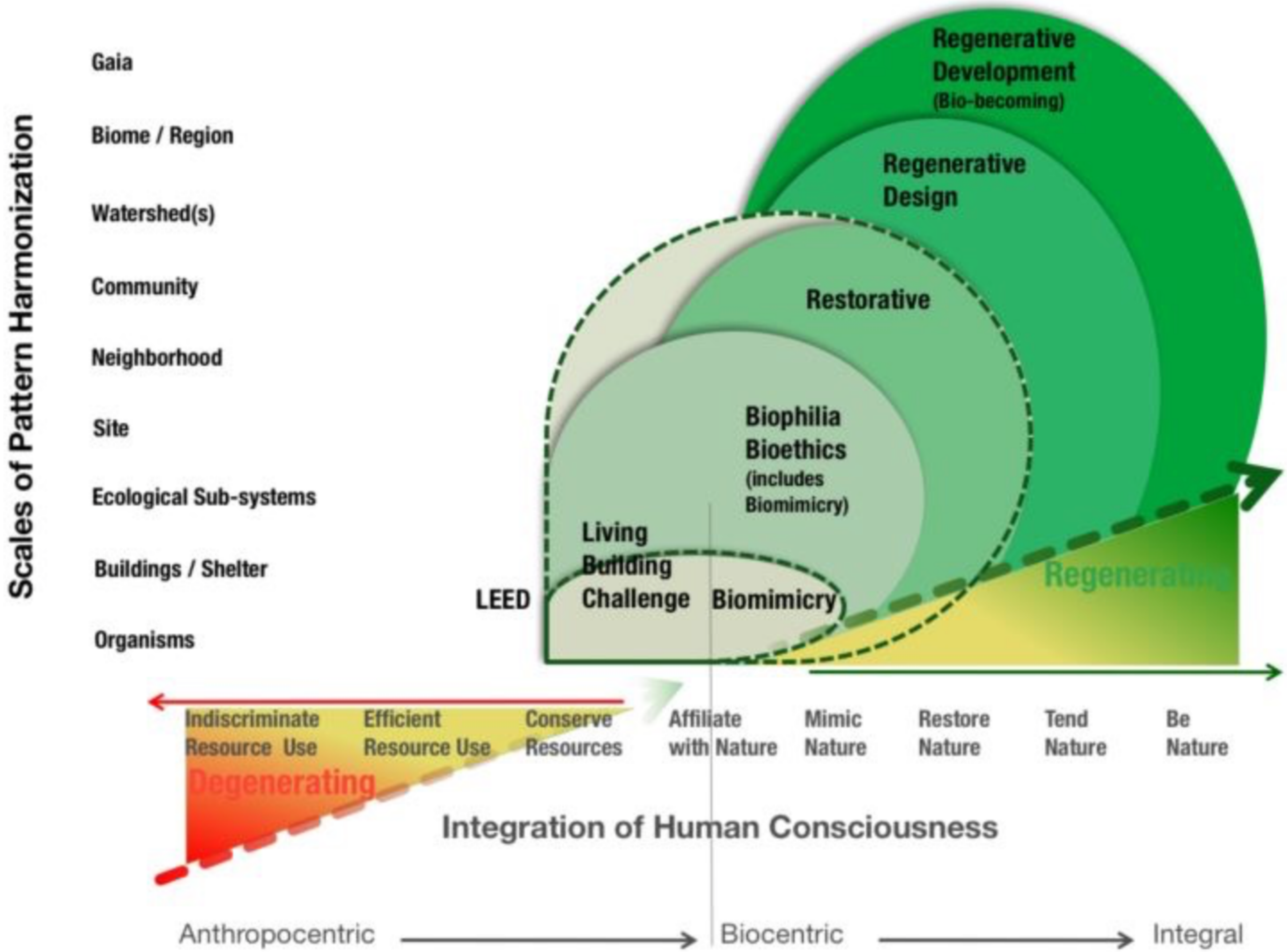
Biology to Design

Biology to Design is a specific path through Biomimicry Thinking. This path is most appropriate when your process initiates with an inspirational biological insight (including a Life's Principle) that you want to manifest as a design. Those who might follow this path include inventors and entrepreneurs, students who don't yet have their own design process, those interested in discovering strategies that might inform new innovations, and educators interested in sharing biology in ways that generate interest with non-biologists.



Explore	Discover	Create
We broaden the solution space by translating your challenge into a function found in nature.	We find nature's best practices relevant to your challenge.	We emulate nature's strategies—leading to novel and sustainable design and product concepts.


Scales of Pattern Harmonization
Gaia
Biome / Region
Watershed(s)
Community
Neighborhood
Site
Ecological Sub-systems
Buildings / Shelter
Organisms
Regenerative Development
(Bio-becoming)
Regenerative Design
Restorative
Biophilia Bioethics
(includes Biomimicry)
Living Building Challenge
LEED
Biomimicry
Regenerating
Degenerating
Indiscriminate Resource Use
Efficient Resource Use
Conserve Resources
Affiliate with Nature
Mimic Nature
Restore Nature
Tend Nature
Be Nature
Integration of Human Consciousness
Anthropocentric
Biocentric
Integral

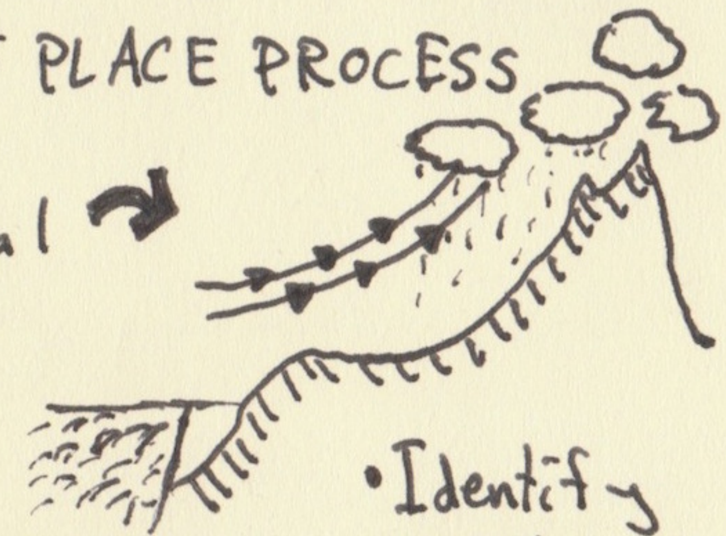
BAWØ2
Biomimicry Alberta Workshop

BARRIER LAKE FIELD STATION,
KANANASKIS, AB.

Alberta Genius of Place Project

HOW TO BEGIN

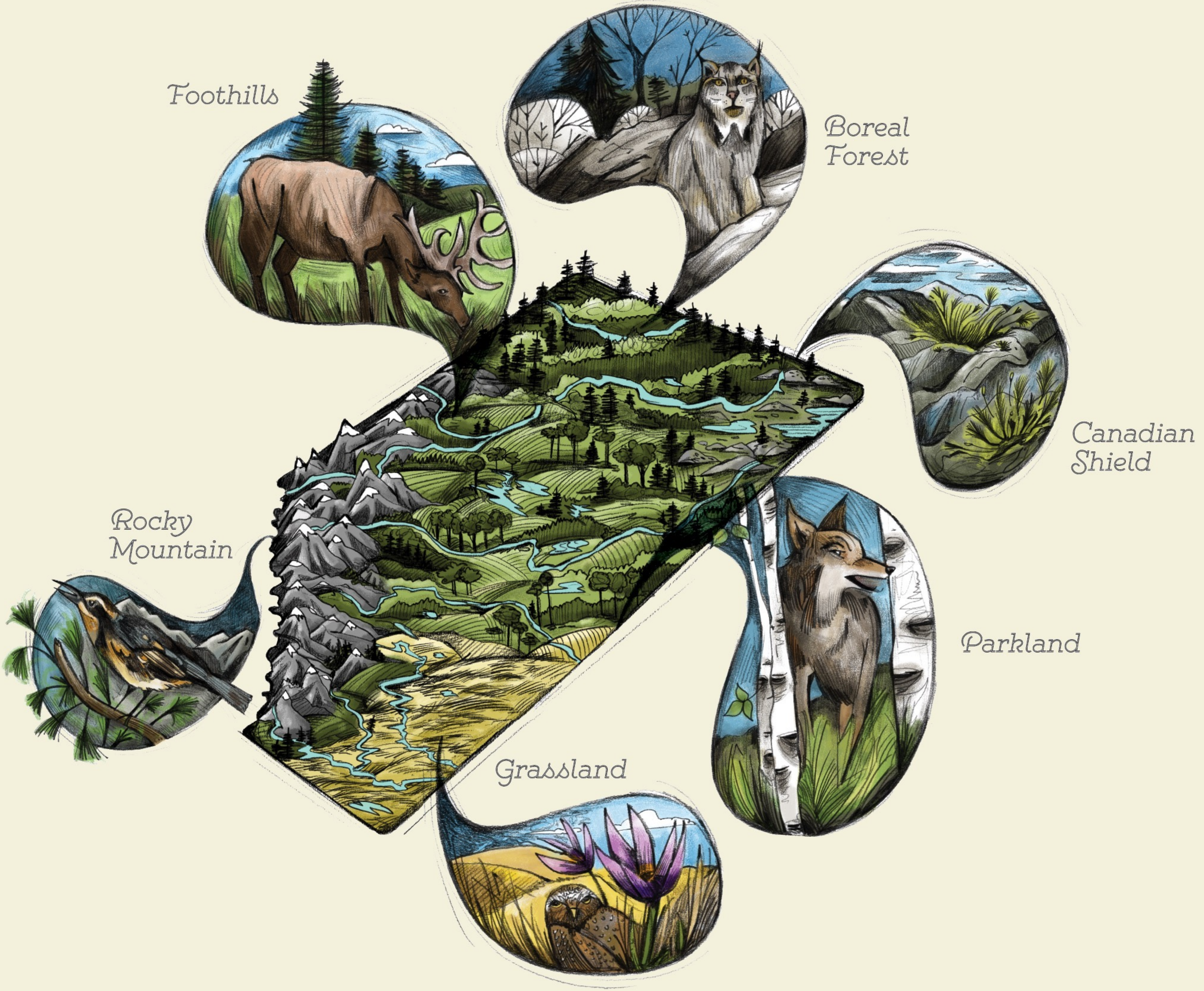
THE GENIUS OF PLACE PROCESS

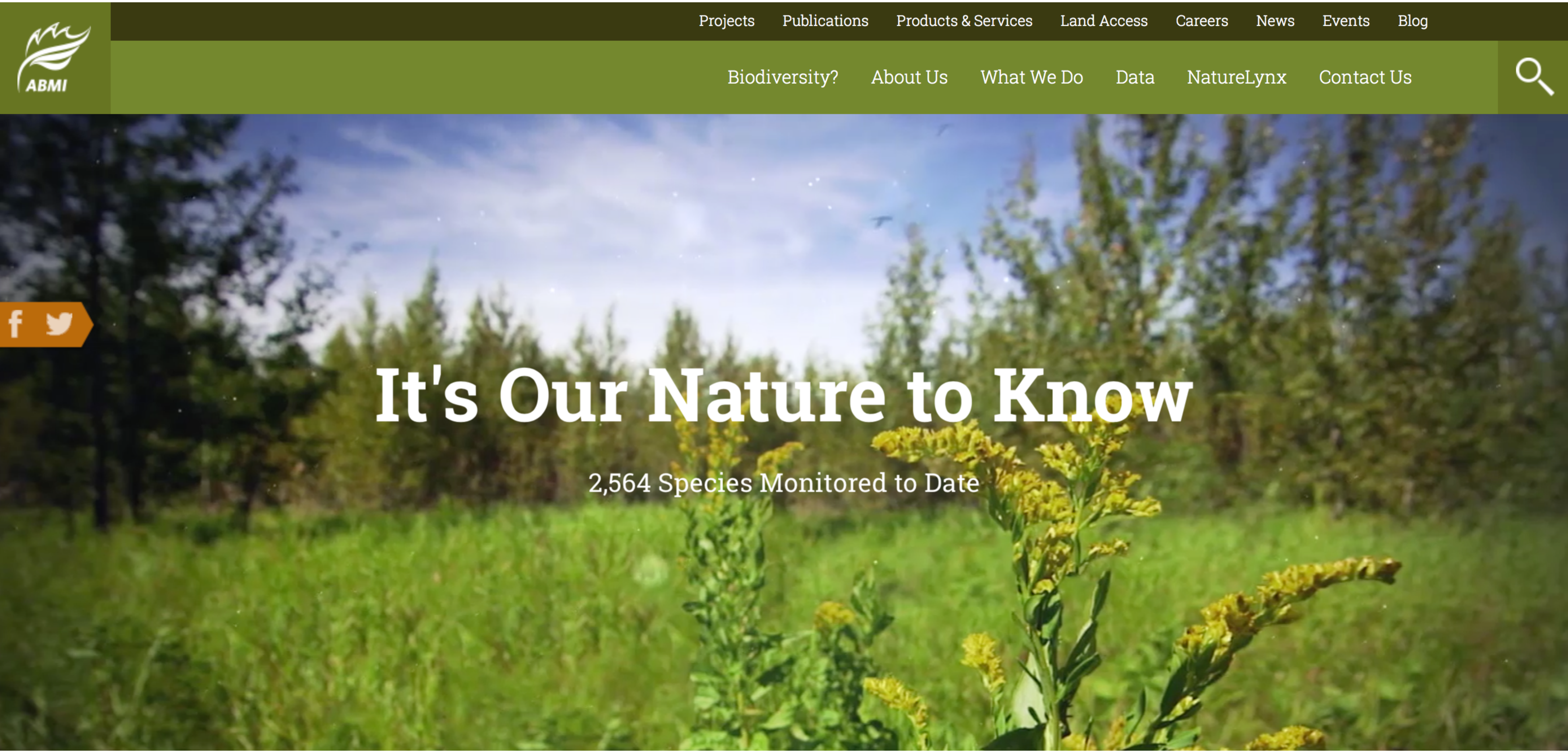


- Understand local conditions
  - The effect of climate change
  - Identify local ecoregions

Q: HOW DOES NATURE MANAGE WATER?

- Identify patterns that emerge in nature related to your challenge
- Identify the plants, animals, and ecosystems that handle your challenge well
- Pull out design principles from those organisms


Foothills
Boreal Forest
Canadian Shield
Rocky Mountain
Parkland
Grassland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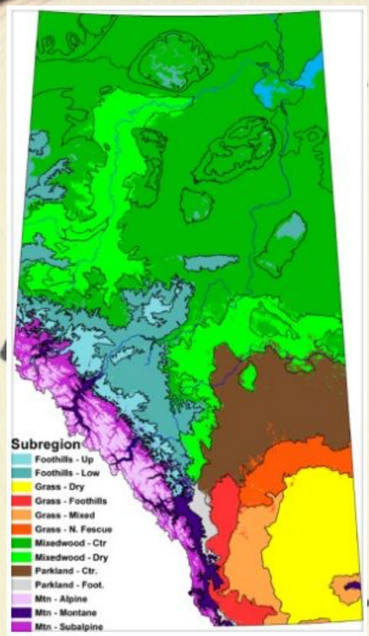
It's Our Nature to Know
2,564 Species Monitored to Date



LOCAL GENIUS

DRAWING ON
3.8 BILLION YEARS
OF EVOLVING LIFE

GENIUS of PLACE

HOW DOES NATURE DEAL WITH THIS CHALLENGE

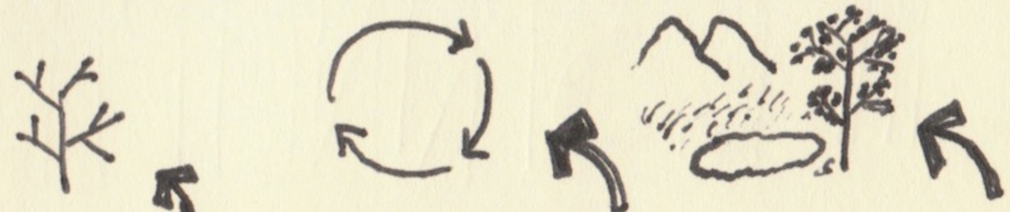
HERE?

WHAT DESIGN PRINCIPLES CAN WE LEARN?

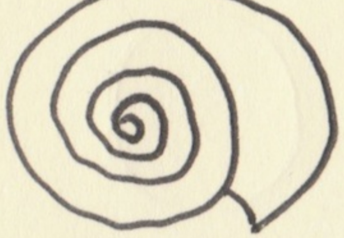
LIFE'S PRINCIPLES

- EVOLVE TO SURVIVE
- BE RESOURCE (MATERIAL AND ENERGY) EFFICIENT
- ADAPT TO CHANGING CONDITIONS
- INTEGRATE DEVELOPMENT WITH GROWTH
- BE LOCALLY ATTUNED AND RESPONSIVE
- USE LIFE-FRIENDLY CHEMISTRY

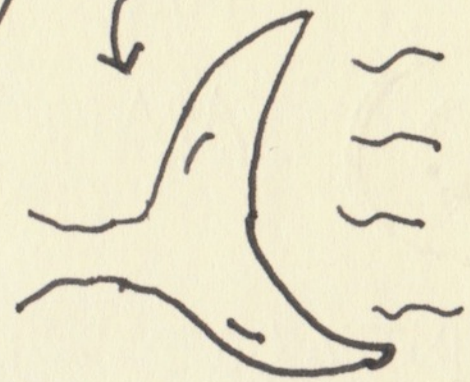
WHAT WE MIMIC



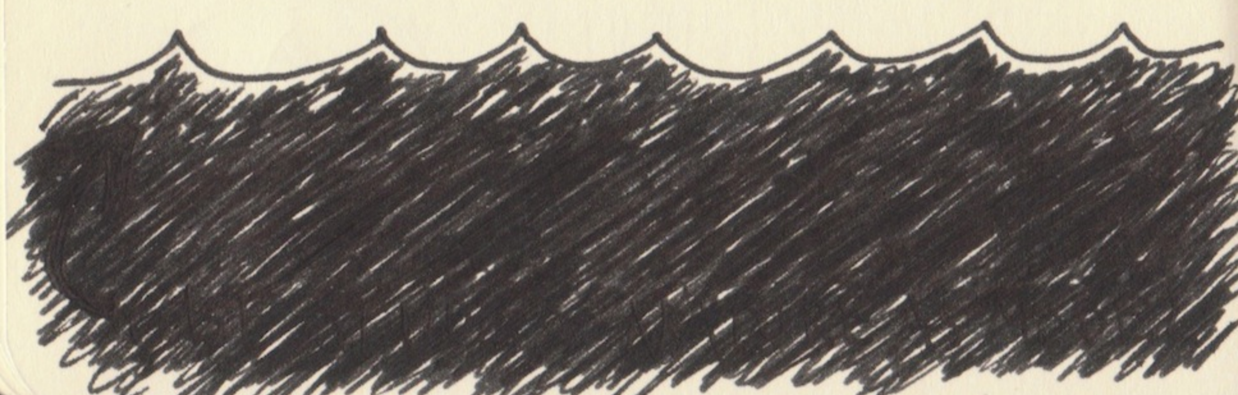
FORM PROCESS ECOSYSTEM



FITTING FORM TO FUNCTION



CASE STUDIES: NATURE AS MODEL

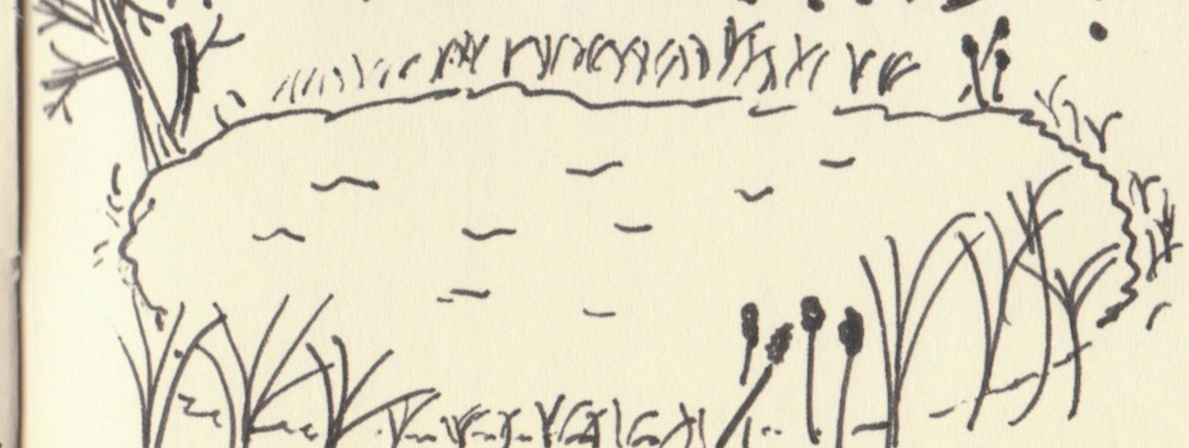


SUSTAINABLE STORMWATER PRACTICES

- Bioswale
- Ecoroof
- Living wall
- Rain garden
- Building wastewater

AND MANY MORE...

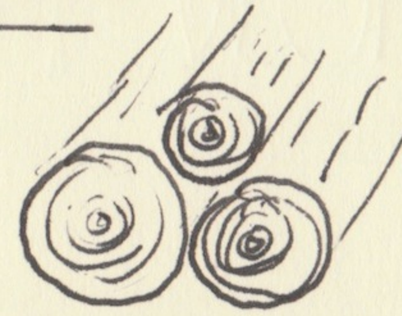
→ HOW CAN WE TREAT OUR WASTEWATER TREATMENT PLANT AS A WETLAND?



USING BIOMIMICRY TO BUILD LIFE-FRIENDLY STRUCTURES

EXAMPLES

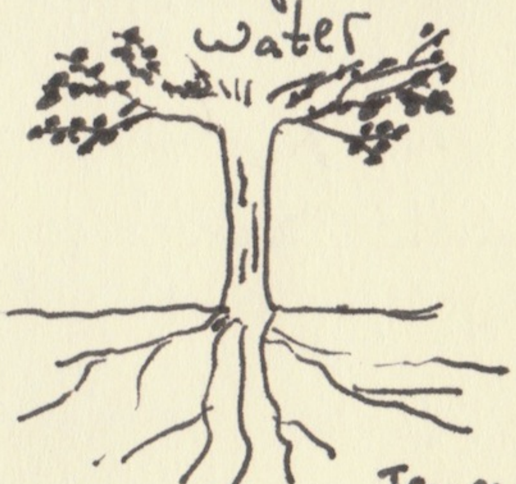
BEAVER DAM
↳ Controlling/redirecting flow



DOWNED WOOD
↳ Absorption, divert water

OLD GROWTH FOREST CANOPY
↳ Intercept & slow water

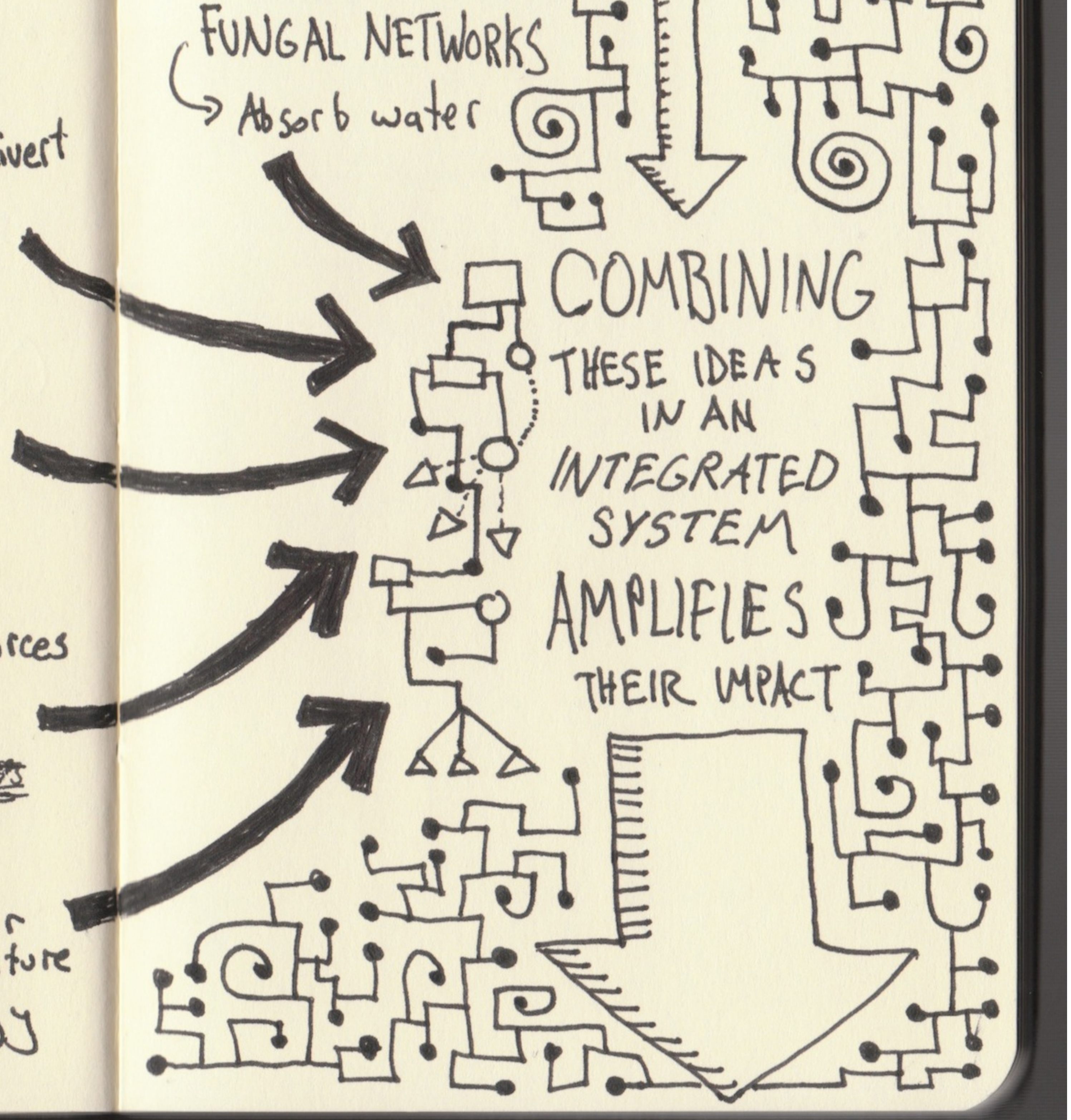
MISTLETOE
↳ Share resources



HYDRAULIC REDISTRIBUTION
↳ Transport water

MOSS
↳ Absorb water and capture energy

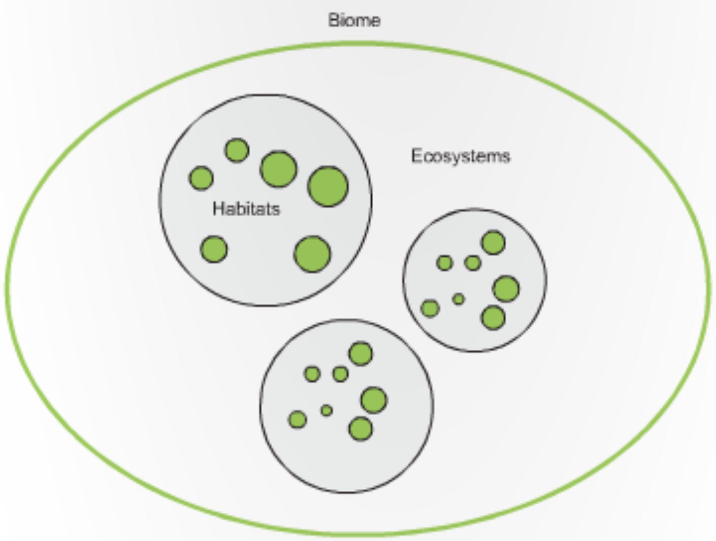
FUNGAL NETWORKS
↳ Absorb water



COMBINING THESE IDEAS IN AN INTEGRATED SYSTEM AMPLIFIES THEIR IMPACT

Sample process

Source https://issuu.com/hoknetwork/docs/geniusofbiome?e=3095950/2547879

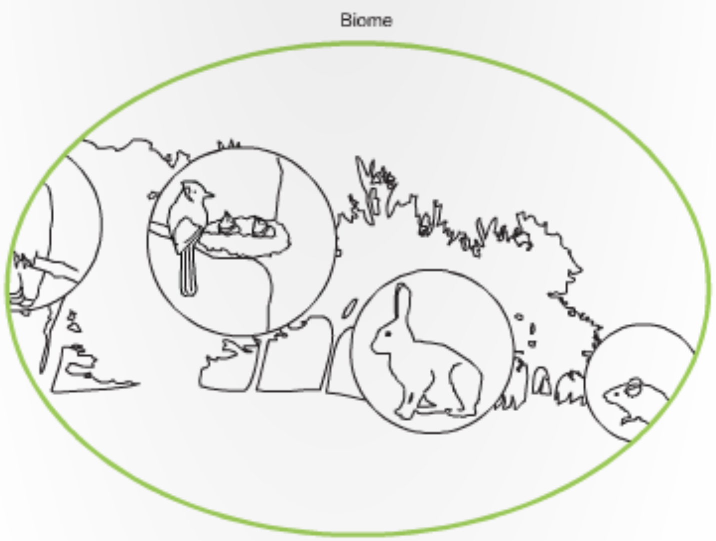


what is a biome?

A biome describes a type of climate and vegetation that exists in specific regions throughout the world. The climate in eastern North America, for example, is similar to the climate in eastern China. The trees that thrive in those conditions are broadleaf trees such as maples and oaks, along with conifers such as pines and firs.

The habitats and ecosystems found in a biome function in similar ways. The patterns in how they function create relevance for human design. If the living organisms in these biomes are challenged by similar climates and conditions, what design ideas can we learn from their examples of adaptations and survival mechanisms?

There are many biome classification systems. All are similar yet different in how they divide climactic and ecological conditions. Biomimicry 3.8 has selected the best classification system that provides a commonly used biome map that fits its needs. The classification system is a derivative of the World Wildlife Fund classification of terrestrial ecosystems that describes 18 biomes (Hassan et al. 2005; Olson et al. 2011).



what is the genius of biome?

Drawing inspiration from natural systems provides a fresh opportunity to rethink and reimagine how to solve human design challenges. The *Genius of Biome* report offers designers, architects, and planners examples of how organisms and ecosystems have adapted to biome challenges of climate, energy, materials, nutrients, and communication. A biome report can be applied to a wide geographic range of projects with the same or similar climate and vegetation.

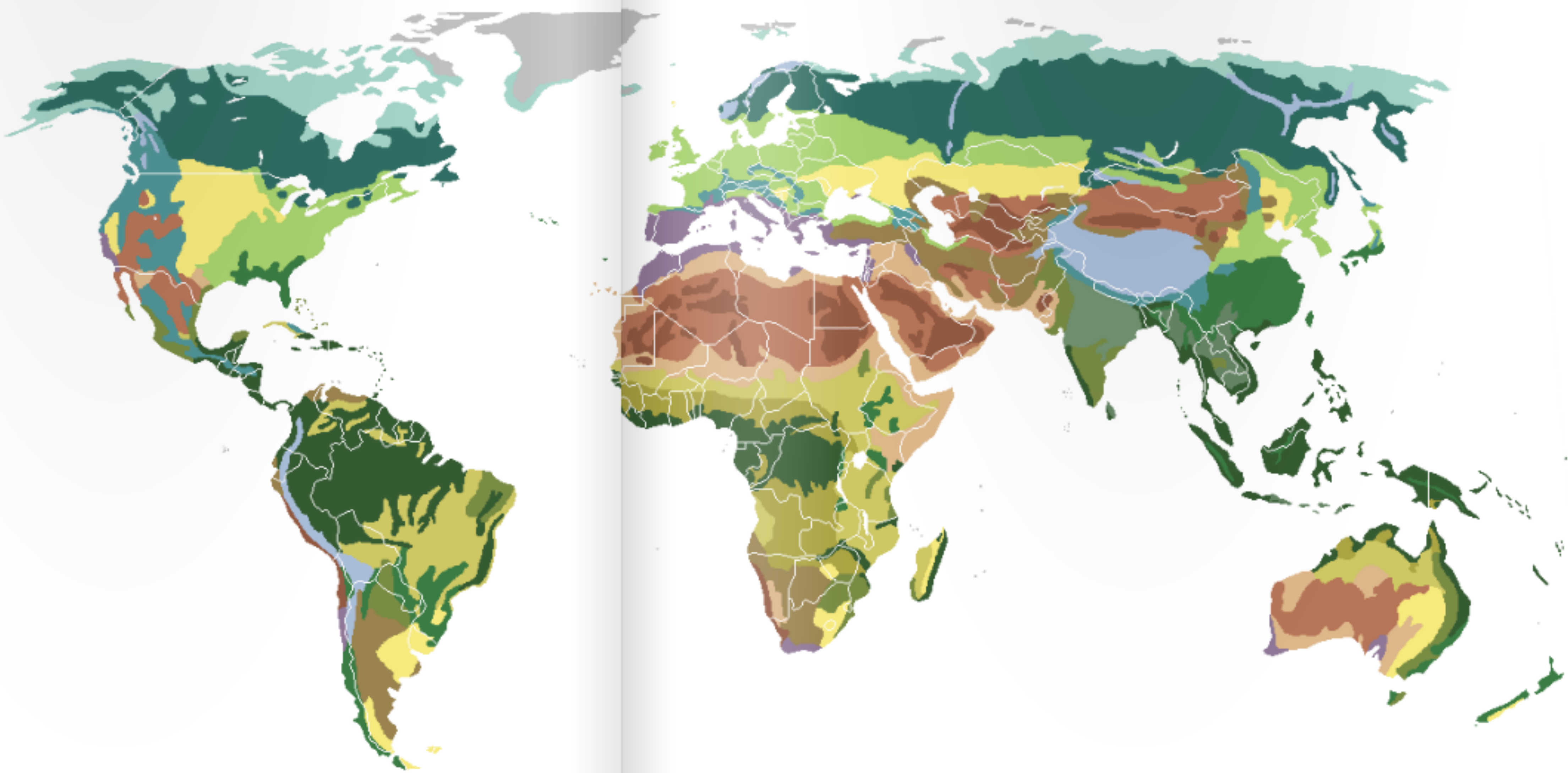
A genius of biome describes the strategies and designs adopted by living organisms found in a worldwide region of similar climate and vegetation. Further, the *Genius of Biome* also investigates and highlights strategies and designs at the ecosystem level. Ecosystems are made up of living entities along with their abiotic conditions (climate, temperature, soil types, topography). In a biome, abiotic conditions are just as important as they are to architects, designers, and planners. It is this broad view that the *Genius of Biome* appreciates and illuminates. Ecology offers an additional lens through which we can view nature's genius and learn design principles that adapt to a biome's abiotic and biotic conditions.

The *Genius of Biome* describes the biological principles and patterns common to organisms and ecosystems within a biome. This biology is then translated into design principles that can be used to inspire design innovations or identify more specific criteria for place-based design.

The goal is to inspire innovation to mimic the successful designs, processes, and patterns found in the larger scale of the natural world—ecosystems. An important part of understanding these biological and design principles and how to mimic them is to know the history of these biomes.

world biomes

- ice sheet and polar desert
- tundra
- taiga
- temperate broadleaf forest
- temperate steppe
- subtropical rainforest
- mediterranean vegetation
- monsoon forest
- arid desert
- xeric shrubland
- dry steppe
- semiarid desert
- grass savanna
- tree savanna
- subtropical dry forest
- tropical rainforest
- alpine tundra
- montane forests



biomimicry process for the genius of biome

This report represents a brief glance at some of the thousands of designs in nature. Nature has had to solve the same challenges as humans. The first step in a biomimetic process is to ask what you want your design to do. What is the function?

The next step is to biologize the question. If the problem is how to insulate against heat loss, for example, we would ask, "How does nature insulate?" We identify the functions and study how nature accomplishes that function. A team of biomimetic researchers dives into the scientific literature and asks, "Whose survival depends on solving this problem?"

For the *Genius of Biome*, we identify the operating parameters of the biome:

- Climate conditions (wet, dry, cold, hot, low/high pressure, highly variable, high/low UV)
- Nutrient conditions (poor, rich)
- Social conditions (competitive, cooperative)
- Temporal conditions (dynamic, static, aging)

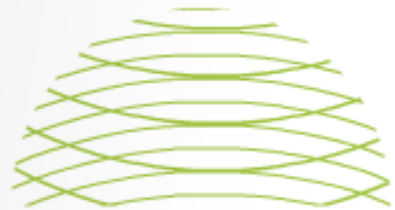
We identify the core biological principle that is used to accomplish function and describe it without using biological terms to form the design principle. The final step in this process is to emulate these principles with sketches for literal, abstracted, or conceptual applications.

The next steps can include a brainstorm session in which we develop a matrix or taxonomy of related elements or principles. We consult expert information for a deeper, broader understanding of the mechanism or process. Our repetitive process of testing the design continuously goes back to the original functions and asks, "Why?"

Nature can act as a mentor, model, and measure. Life's Principles can provide a guide to assess the potential success of an innovation or idea. Life's Principles are benchmarks of sustainability. Are our designs accomplishing the overarching pattern held in common by living organisms on Earth? Life's Principles are the deep patterns of a collection of biological principles abstracted to the broadest level.

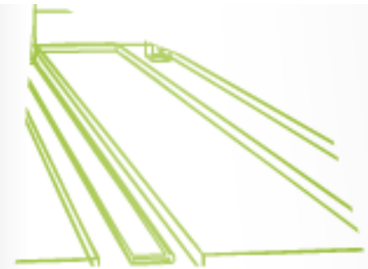
WATER
27

- minimize erosion 29
  - beavers 35
  - vegetation 29
- minimize negative impacts of rain water 41
  - lichen 41
- optimize water resources 47
  - rivers 47
- dehumidify in summer 53
  - bryophytes 53



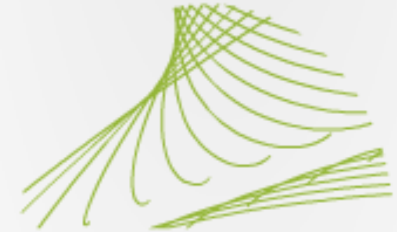
ENERGY
59

- adjust to temperature change 61
  - leaves 61
  - trees 67
- respond to seasonal change 73
  - animals 79
  - plants and animals I 73
  - plants and animals II 85
- optimize light 91
  - trees 91



MATERIALS
97

- reduce embodied energy 99
  - paper wasps 99
- regenerate materials 105
  - ephemeral herbs 105



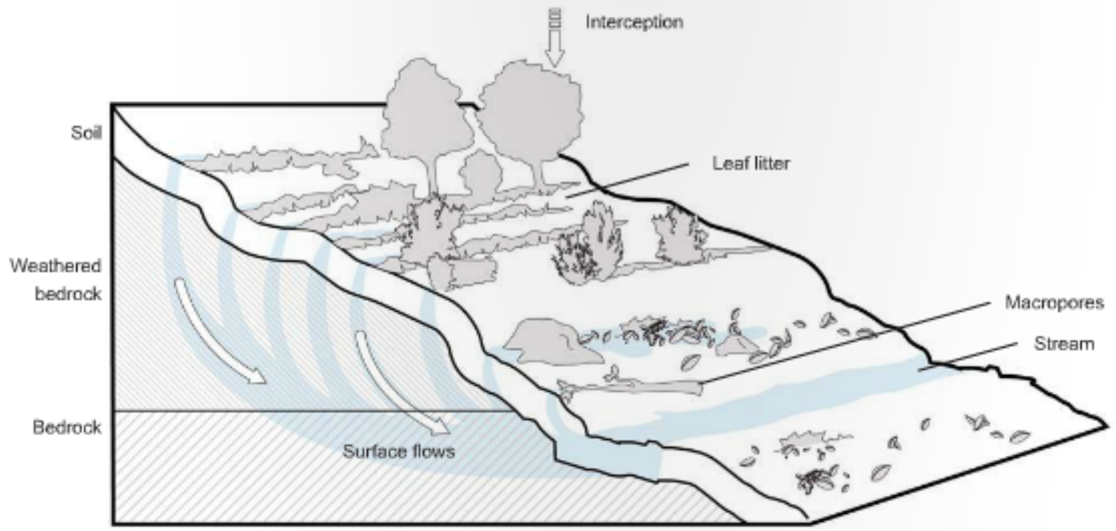
SOCIAL
111

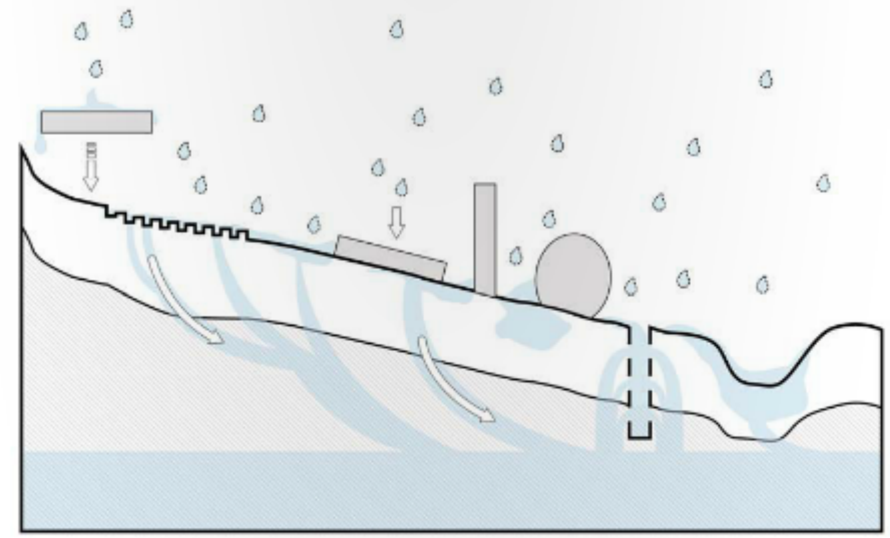
- foster social integration 113
  - fungi 113
  - pollinators 119
- design a well-functioning system 125
  - ecotones 131
  - tree community 125
- foster cooperative relationships 137
  - jay and oak 137

ECONOMIC
143

- use resources efficiently 145
  - ecosystems 145
- create system stability 151
  - forests 151
- create sustainable value 157
  - organic soil 157


vegetation
minimize erosion
Multiple modes of interception reduce the energy of falling and flowing water, encouraging infiltration rather than erosion of land.





nature's design

surface roughness increases infiltration

Surface runoff is rare in deciduous forests because of the cumulative effect of thousands of small ways that vegetation slows down water flow, especially if the runoff is first slowed in upper watersheds. During rainfall, forest leaves and branches are first to intercept and absorb the energy of raindrops, causing the water that collects to slow and pool below and partially infiltrate the soil. Plant litter, trunks, stems, and stalks add to the dissipation of raindrop energy due to friction, giving the water time to soak in.

Rainwater infiltration is enhanced by the deep, extensive root systems under forests, soil pores associated with plant roots and animal burrowing, and soil mixtures. Rich, organic matter in the forest soils allows faster infiltration.

Macro roughness on the soil surface also slows water. Downed trees (logs) that fall across a slope and settle into the ground slow water and trap sediments. Decaying logs are highly absorbent, holding water and releasing it slowly during dry periods. Remnants of logs and blown-over trees with up-tipped roots create a pit-and-mound topography that interrupts water flow and traps sediments.

The cumulative effects from burrowing creatures to leaves, branches and trunks, soils and topography are responsible for minimizing erosion and flooding.

- Canopy and litter interception, stemflow, and throughfall assist in preventing erosion.
- Biotic and abiotic forces contribute to soil porosity in forest soils.
- Humic acid, the result of breakdown of organic matter, holds water in soils.
- A diverse micro- and macro-fauna population breaks down organic materials and creates soil pores.
- Most rainfall moves to streams by subsurface flow pathways where nutrient uptake, cycling, and contaminant sorption processes are rapid.

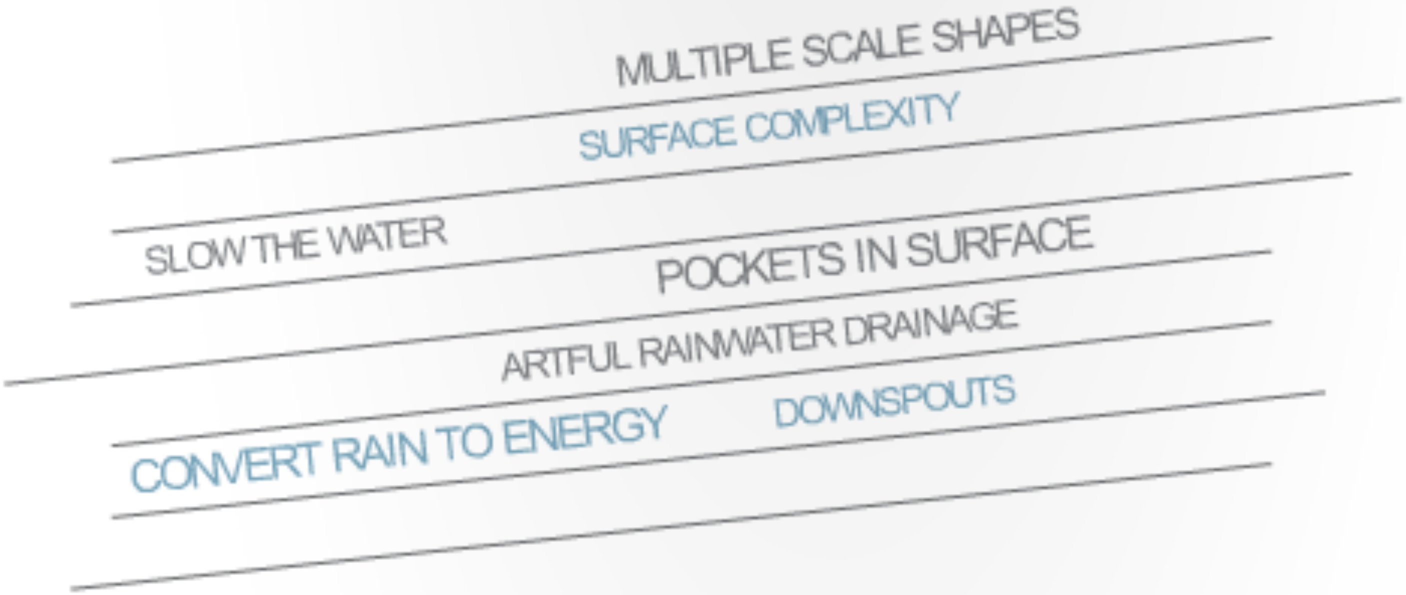
design principle

varied, multiple surface barriers increase infiltration

Varied and multiple structures reduce the velocity and energy of flow. Cumulatively, many structures slow flow long enough for it to infiltrate rather than flow overland and erode surfaces. These include horizontal, above-ground, and ground-surface structures that intercept; vertical structures placed in the path of flow that cause friction, creating turbulence that slows flow; porous structures in the surface that aid in infiltration and retention; and topographic features that increase surface roughness, resulting in temporary pooling.

Related design principles:

- Chemical compounds can increase holding capacity.
- Structures capture solid elements.
- Local materials decrease water flow.

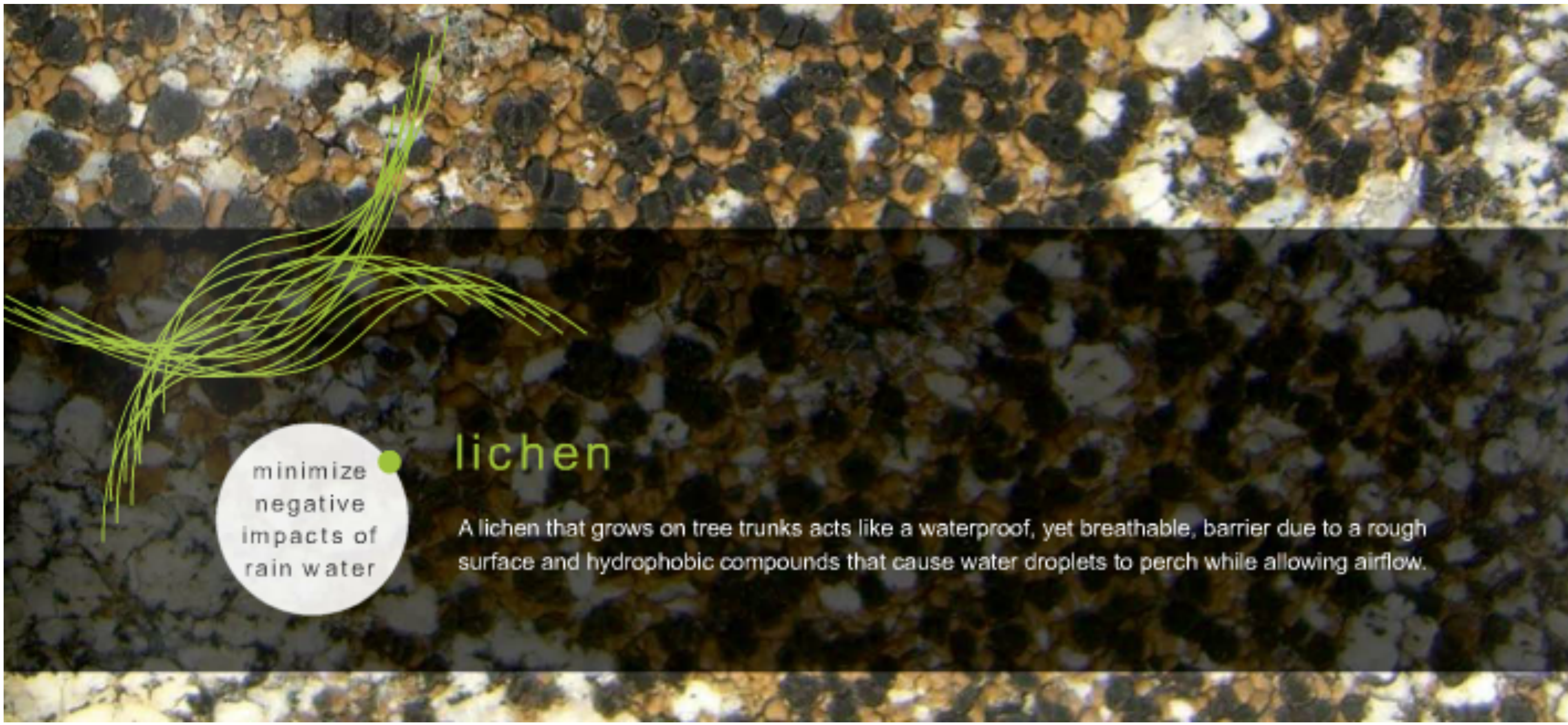


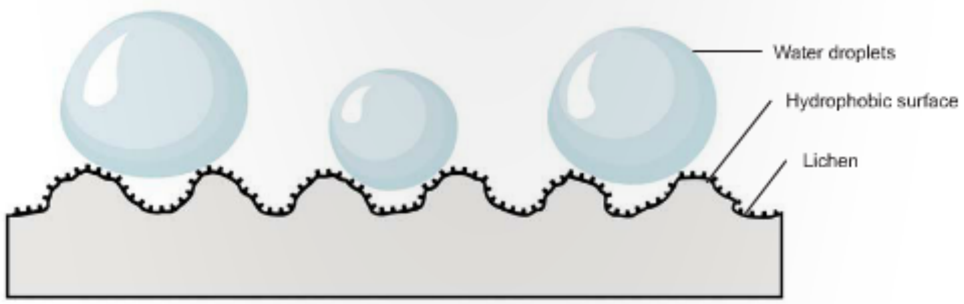
BaDT brainstorm

design ideas

Application Ideas

- Use shape on multiple scales to reduce the flow of water over surfaces. For example, create surface complexity on a roof or building facade.
- Consider vertical and horizontal structures that can slow the movement of water. This could include built elements such as buildings, parking structures, and awnings or natural elements such as landscaping, water features, terracing, and green roofs.
- Create a layered or pocketed system that increases infiltration and slows water velocity. For example, rather than direct down spouts, create an artful rainwater drainage matrix that forces the water to “meander.”
- Convert rainwater descending from roofs and gray water descending through the plumbing of a tall building into energy with micro-hydro technology. In the case of a meandering downspout system, there are even more opportunities to generate energy. Make energy generation information available to building users in real time.


minimize negative impacts of rain water
lichen
A lichen that grows on tree trunks acts like a waterproof, yet breathable, barrier due to a rough surface and hydrophobic compounds that cause water droplets to perch while allowing airflow.



nature's design

rough surface, hydrophobic spaces create air flow

The lichen *Lecanora conizaeoides* grows on tree trunks, using the tree for support and access to light and water. It does so without harming the tree.

Lichens are compound organisms, meaning they consist of symbiotic partners — algae embedded in a fungal matrix. The algae and the fungi live together as one organism, mutually supporting each other with the algae photosynthesizing sugars and the fungi providing a protective home for the algae. The rough surface of the fungus, with structures of different sizes layered on one another, keeps water droplets perched on top rather than coming in contact with the whole surface. Channels between the structures are coated with hydrophobic compounds called hydrophobins, so that the channels remain dry, allowing air to reach the algae. This combination of rough structure and hydrophobic compounds produces a biological analogue of a waterproof, breathable garment.

Lichens play an important role in ecosystems, thriving in places where plants can't grow, thus adding to the total energy-gathering, carbon-fixing ability of the ecosystem without competing with other plants. They are also a food source for insects and mites and provide shelter either directly as structures or by being incorporated onto insects' bodies as a form of camouflage.

- Lichens are compound organisms made up of symbiotic partners.
- Lichens grow on trees without drawing nutrients from them or causing harm.
- Lichens photosynthesize even during rain.
- The fungal partner in *Lecanora* sheds water due to a rough surface combined with a hydrophobic compound.
- The algae partner retains access to air for gas exchange.
- Lichens are important components of the forest ecosystem.

design principle

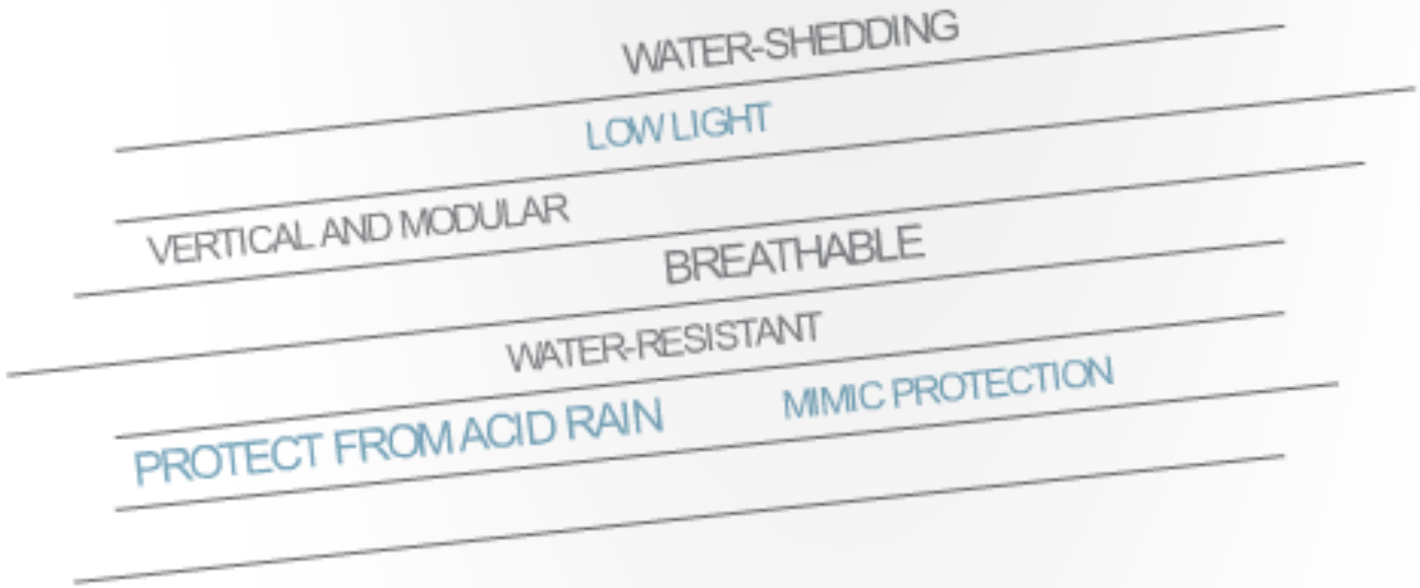
rough surface, hydrophobic spaces allow air flow

Breathable, water-shedding surface made of hydrophobic compounds combined with multi-layered roughness.

A water droplet is made up of highly polar molecules. If put in a situation where its molecules are more attracted to each other than to a surface, it will form a sphere. A series of peaks with hydrophobic valleys will keep a sphere of water molecules perched on top, rather than seeping into the spaces between the peaks. This facilitates water rolling off a surface. At the same time, the spaces between the peaks stay dry and air can flow through them. This creates a breathable, yet waterproof, surface.

Related design principles:

- Symbiosis provides opportunities to find mutual benefits through relationships.
- Symbiosis provides opportunities for one organism to gain from another without harming the host.
- Empty spaces can provide sites for compatible uses.
- Solar energy is captured during rain.



BaDT brainstorm

design ideas →

Application Ideas

- Lichens can photosynthesize during a rainstorm. Developing a water-shedding surface treatment for solar panels may allow them to be more effective during low-light, stormy conditions common in the temperate broadleaf biome.
- If the building is thought of as an analogue to the tree a lichen grows on, a conceptual application could be installing a micro-solar system on a building's vertical surface. This discrete micro-solar system could be modular and interconnected so that if one section failed, the overall system would continue to operate.
- Lichens work like a breathable, water-resistant fabric. In a humid climate, a building skin that is both waterproof and breathable can provide a more comfortable interior.
- Lichens shed water effectively, which protects from acid rain. A building surface or structure applied to the building surface that mimics the lichen may protect from the damages of acid rain.
- The way that lichens shed water could be incorporated into structures used to capture water, resulting in less adherence and therefore more complete capture and fewer opportunities for buildup of algae and biofilms.

APPENDIX B

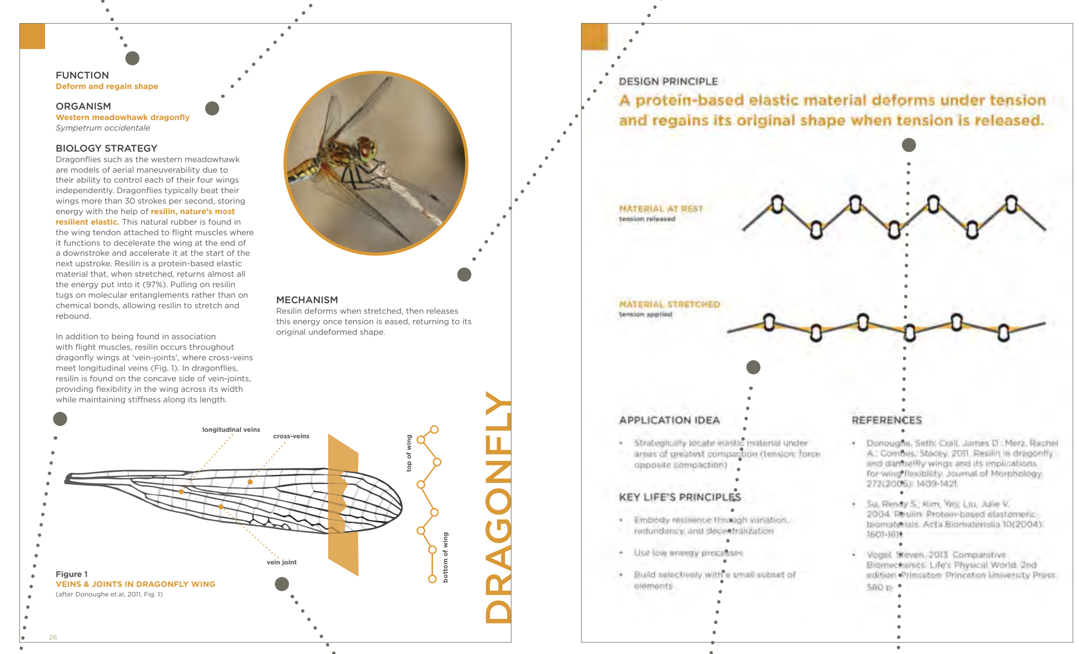
LOCAL GENIUS STORIES

HOW TO READ A LOCAL GENIUS STORY

Function
Function describes what the organism or ecosystem does and what we want our design to do. Function is the bridge between biology and design.

Organism
The common and scientific name of the local genius.

Mechanism
How the strategy works, specifically. Mechanism is usually written as just 1-2 sentences.



Biology Strategy
This section tells the story of the biology strategy or adaptation used by the organism to achieve the function. The story is a translation of biological research, often times as reported in the primary literature, into words that can be understood by a non-biologist.

Strategy Illustration
A diagram or illustration to support the Biology Strategy.

Design Principle Illustration
The illustration supports the written design principle and facilitates application of it in design.

Design Principle
The idea or underlying principle of the biology strategy, stated without reference to the biology. The design principle is succinct, usually written as just one sentence, and is what we emulate in design, what we use to generate biomimetic design concepts.

DRAGONFLY

FUNCTION
Deform and regain shape

ORGANISM
Western meadowhawk dragonfly
Sympetrum occidentale

BIOLOGY STRATEGY
Dragonflies such as the western meadowhawk are models of aerial maneuverability due to their ability to control each of their four wings independently. Dragonflies typically beat their wings more than 30 strokes per second, storing energy with the help of **resilin, nature's most resilient elastic.** This natural rubber is found in the wing tendon attached to flight muscles where it functions to decelerate the wing at the end of a downstroke and accelerate it at the start of the next upstroke. Resilin is a protein-based elastic material that, when stretched, returns almost all the energy put into it (97%). Pulling on resilin tugs on molecular entanglements rather than on chemical bonds, allowing resilin to stretch and rebound.

In addition to being found in association with flight muscles, resilin occurs throughout dragonfly wings at 'vein-joints', where cross-veins meet longitudinal veins (Fig. 1). In dragonflies, resilin is found on the concave side of vein-joints, providing flexibility in the wing across its width while maintaining stiffness along its length.

MECHANISM
Resilin deforms when stretched, then releases this energy once tension is eased, returning to its original undeformed shape.

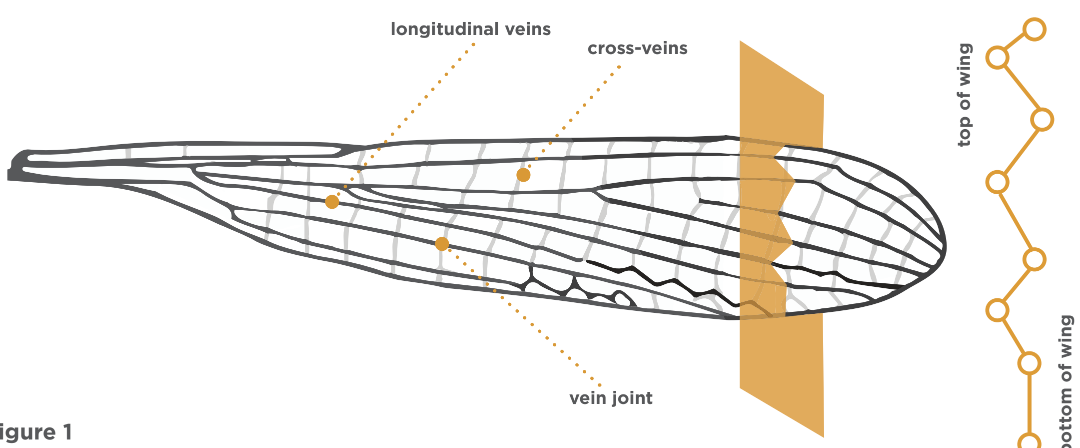
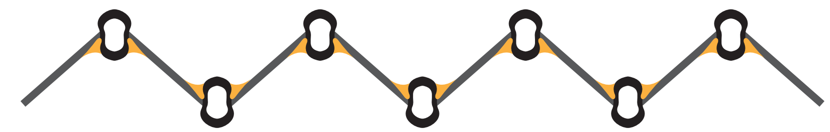


Figure 1
VEINS & JOINTS IN DRAGONFLY WING
(after Donoughe et.al, 2011, Fig. 1)

DESIGN PRINCIPLE
A protein-based elastic material deforms under tension and regains its original shape when tension is released.

MATERIAL AT REST
tension released



MATERIAL STRETCHED
tension applied

APPLICATION IDEA
- Strategically locate elastic material under areas of greatest compaction (tension: force opposite compaction)

KEY LIFE'S PRINCIPLES
- Embody resilience through variation, redundancy, and decentralization
- Use low energy processes
- Build selectively with a small subset of elements

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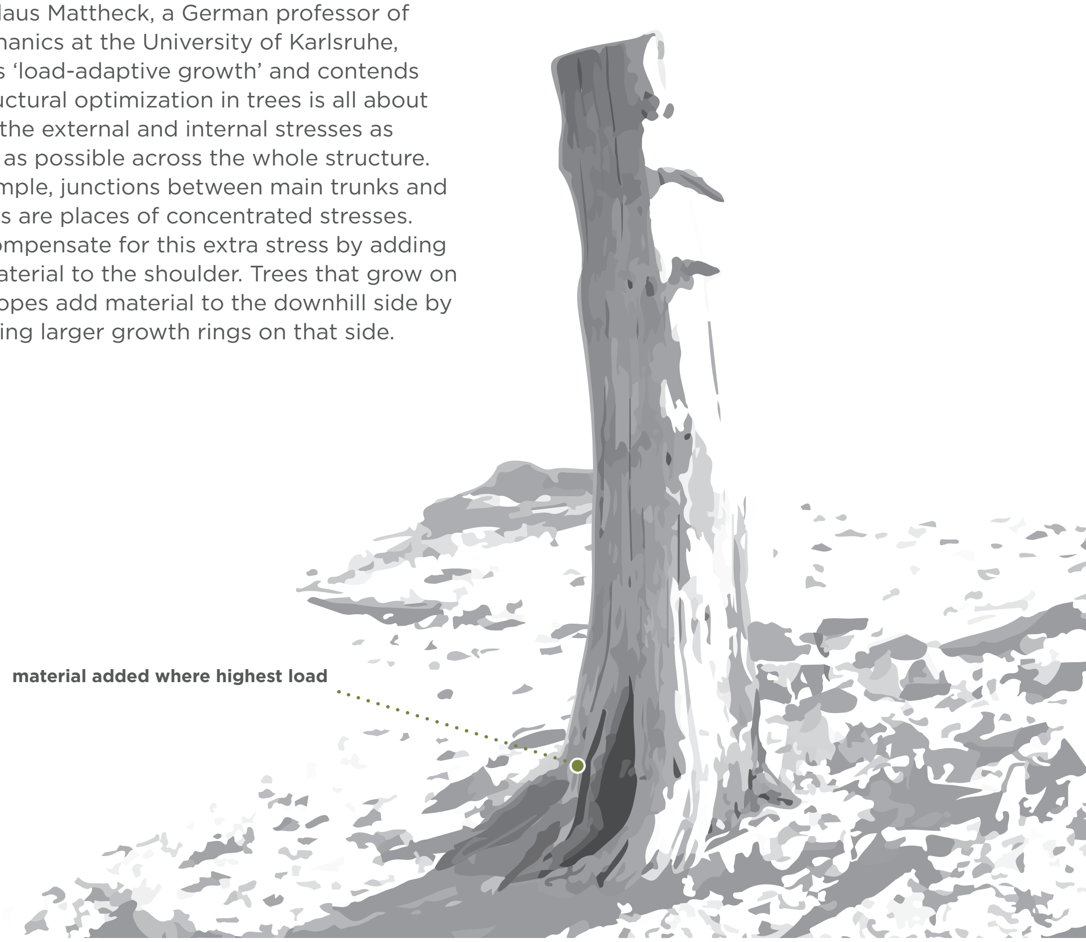
FUNCTION
Uniformly distribute stress

ORGANISM
Ponderosa pine
Pinus ponderosa var. scopulorum

BIOLOGY STRATEGY
Ponderosa pine trees grow throughout the Colorado Front Range from the border of the prairie and foothills, up to 10,000 ft elevation, depending on topography. Along the Front, 300-500 year old trees are frequent, a testament to their ability to withstand many forces, including those generated by fire, wind, snow loading, and steep slopes. Trees react to these external stresses and internal damage by adding wood at mechanically weak points.

To distribute stress uniformly, trees such as ponderosa pine add wood at points of greatest mechanical load. **The biological method of shape optimization is simple: at places of higher load, extra material is grown, i.e. thicker tree rings.** Claus Mattheck, a German professor of Biomechanics at the University of Karlsruhe, calls this 'load-adaptive growth' and contends that structural optimization in trees is all about making the external and internal stresses as uniform as possible across the whole structure. For example, junctions between main trunks and branches are places of concentrated stresses. Trees compensate for this extra stress by adding more material to the shoulder. Trees that grow on steep slopes add material to the downhill side by developing larger growth rings on that side.

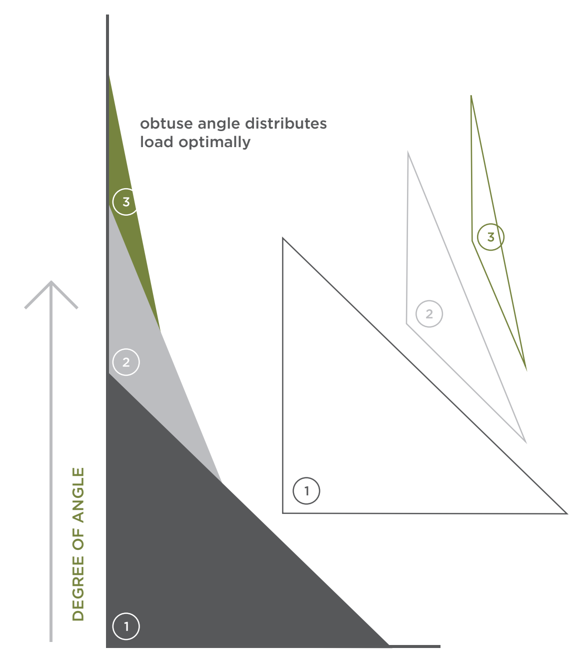
MECHANISM
To distribute stress uniformly, trees add wood (grow thicker rings) at points of greatest mechanical load.



PONDEROSA PINE

DESIGN PRINCIPLE
Add material at points of greatest mechanical load to uniformly distribute stress.

APPLICATION IDEA
- If there is compression on road and tension on road edge, obtuse angle from road to ditch optimally distributes load (after Mattheck, 2006, Figures 5-7).



KEY LIFE'S PRINCIPLES
- Be resource efficient
- Use life-friendly chemistry
- Be locally attuned and responsive

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FUNCTION
Repel water

ORGANISM
Pleasing fungus beetle (chitin)
Gibbifer californicus

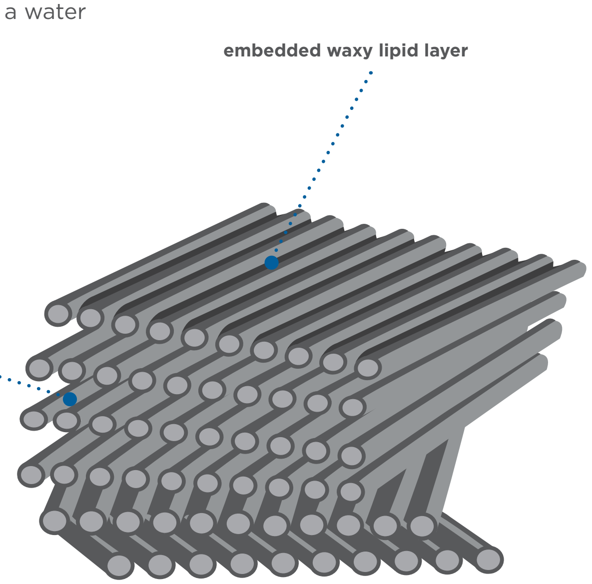
BIOLOGY STRATEGY
The pleasing fungus beetle is found locally in stands of ponderosa pine and aspen, especially near bracket fungi that grow on rotting logs. Here, adult beetles lay their eggs and once hatched, the larvae feast on the bracket fungi. Adult beetles are shiny black with blue or purple elytra (hardened wing covers) with black dots. This shiny cuticle or exoskeleton is waterproof thanks to the components of this natural composite.

In beetles, chitin is a tough, flexible component of a complex matrix of materials that create a passive physical surface barrier to water. As such, insects rely on their chitinous cuticle to resist desiccation. Chitin is composed primarily of polysaccharide fibers (bonded sugar molecules much like cellulose in wood) in a protein matrix. These fibers are stacked, with each layer slightly rotated relative to the orientation of the underlying layer, much like plywood (Fig 1). This fiber-protein complex holds a very thin waterproofing waxy lipid layer, less than 0.2 microns thick, that is secreted onto and integrated with the complex to ensure a water balance is achieved.

Photo: Kati Fleming, 2009 | Wikipedia Commons

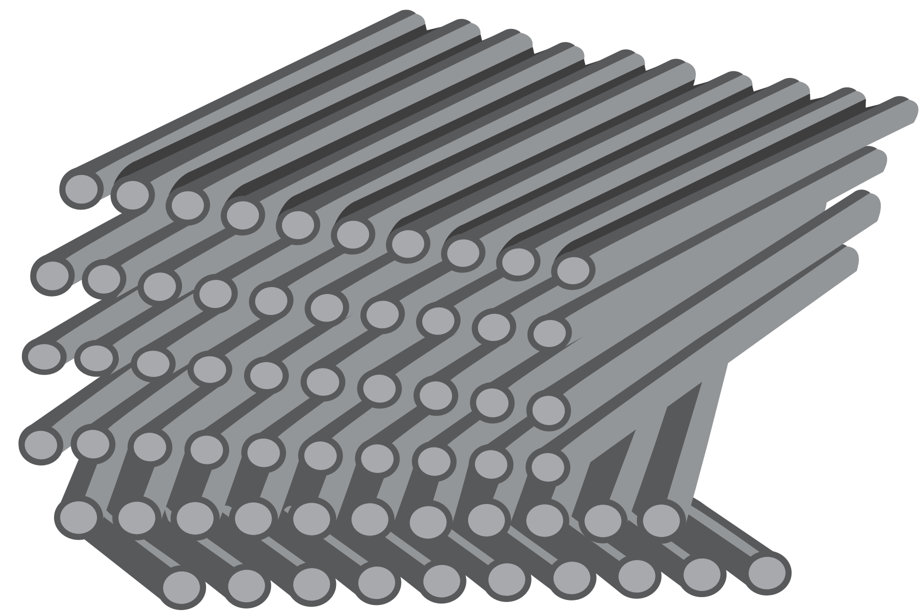
MECHANISM
Stacked chitin fibers, each layer slightly rotated relative to the underlying layer, in a protein matrix holds a thin waterproof waxy lipid layer, less than 0.2 microns thick, to achieve an effective water balance within the insect.

Figure 1
FIBER ORIENTATION & WAX LOCATION IN CHITIN



PLEASING FUNGUS BEETLE

DESIGN PRINCIPLE
Layers of fibers oriented at slightly different angles in a protein matrix hold a thin waxy lipid layer that collectively creates a physical surface barrier to water.



APPLICATION IDEA
- Explore creation of ‘complexes’ with fiber orientation into which waterproofing lipid layer might be integrated.

KEY LIFE’S PRINCIPLES
- Use readily available materials and energy
- Build selectively with a small subset of elements
- Fit form to function

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- Wikipedia.org

FUNCTION
Minimize deformation under stress; regain original shape

ORGANISM
Rocky Mountain Elk (bone)
Cervus canadensis nelsoni

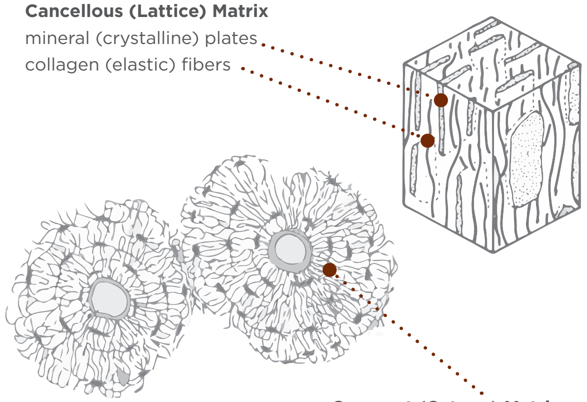
BIOLOGY STRATEGY
Bone is a strong 'rigid material', a composite that responds to stresses with only minimal deformation. Bone has greater compressive strength and higher work of fracture (resistance to cracking) than concrete. Evolutionarily, the invention of bone provided fitness for large body size, as found in large mammals such as the Rocky Mountain Elk. Within a single long bone such as a femur, there are two types of bone tissue: cancellous and compact bone. The complex structure of these two types of bone give them strength, light weight, and some flexibility.

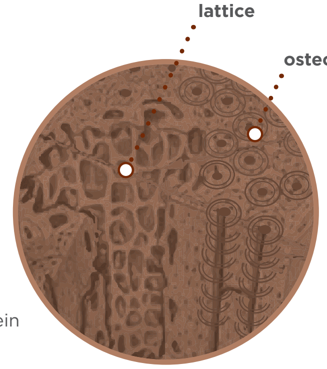
Cancellous bone is a **spongy composite lattice material** known as trabeculae ("little beams") that makes up 80% of mammalian bone. It is typically found at the ends and in the core of long bones, and has two main constituents. **Small inorganic crystals of phosphate, calcium, and hydroxyl ions make up ~50% of the volume. These tiny, brittle crystals are interspersed with neat layers of elastic collagen fibers, the other ~50%, in a protein matrix.** The continuous alternation between brittle and elastic material makes it fracture resistant. Studies of the latticework geometry in terrestrial mammals and birds have found that bone volume does not scale with size, but trabeculae in larger animals' femurs are thicker, further apart and fewer per unit volume than in smaller animals, increasing the larger animals' ability to withstand loads.

Photo: Daniel Mayer, 2011 | Wikipedia Commons

Compact bone forms the outer shell of most bones, is harder, stronger and stiffer than cancellous bone, and makes up 20% of the skeleton, but 80% of its weight. As such, it is much denser than cancellous bone and performs the key function of mechanical support. The structural unit of compact bone is the osteon. **Each osteon consists of a calcified matrix of parallel collagen fibers and protein arranged in concentric rings, typically several millimeters long and ~0.2mm in diameter, surrounding an open canal where blood vessels and nerves pass.**

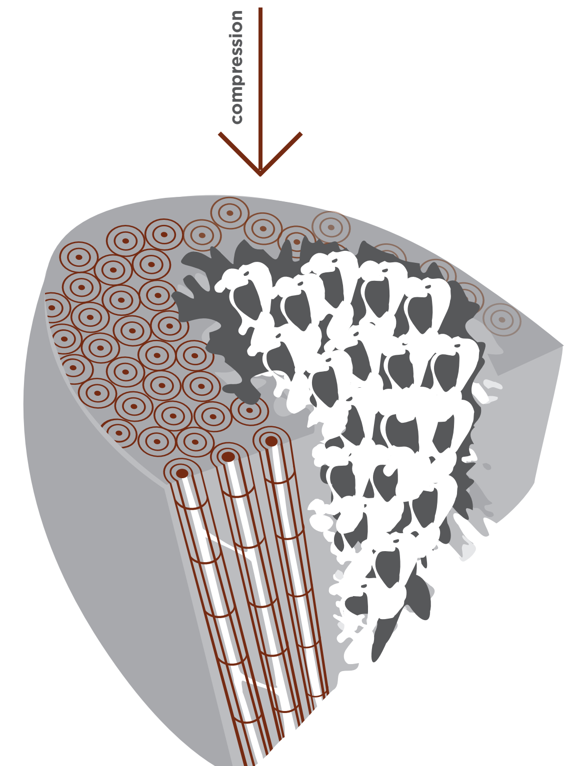
MECHANISM
Outer layer of compact bone and inner layer of cancellous bone experiences minimal deformation under loads then regains its shape. Cancellous bone is a spongy composite lattice material made of parallel layers of elastic collagen fibers and brittle inorganic crystals in a protein matrix. Compact bone consists of a calcified matrix of parallel collagen fibers and protein arranged in concentric rings.





ROCKY MOUNTAIN ELK

DESIGN PRINCIPLE
Composite lattice material (made of alternating crystalline and elastic components) surrounded by a harder material (composed of concentric rings of a calcified matrix of parallel elastic fibers) resists compression.



APPLICATION IDEA
- Mineralized fibers as construction element for road that handles shear and compressional stresses.

KEY LIFE'S PRINCIPLES
- Use life-friendly chemistry
- Fit form to function
- Replicate strategies that work

REFERENCES
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- Tributsch, H. 1984. How life learned to live. Cambridge, MA: The MIT Press. 218 p.
- Vogel, Steven. 2013. Comparative Biomechanics: Life's Physical World. 2nd edition. Princeton: Princeton University Press. 580 p.

Group name:

Alberta
Genius of
Place Project

SKETCH OR PHOTO OF THE ORGANISM

English name Latin Name

Strategy

DESIGN PRINCIPLE In plain English:

What the organism is doing?
How is it doing it?
Why is it doing it?

Description / images

References

BiomimicryAlberta