zq03

FALL 2012

About Zygote Quarterly

Editors

Marjan Eggermont

Tom McKeag

Norbert Hoeller

Contributing Editor

Raul de Villafranca

Offices

Calgary

San Francisco

Toronto

Mexico City

Contact

info@zqjournal.org

Cover art

Allium sativum

Elena Lapeña

Design

Marjan Eggermont

Colin McDonald

Creative Commons License

ISSN

1927-8314

Red Yucca bloom

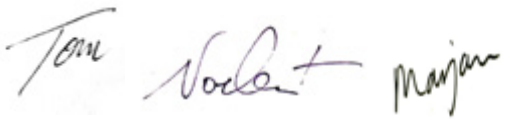
Photo: cobalt123, 2010 | Flickr cc

Inspiration and observation

Inspiration comes in many forms, and, if we look at the record, bio-inspiration is as old as history itself. Nobel laureate Erwin Shrodinger, in a series of lectures called "Nature and the Greeks", at University College, Dublin, 1948, gave a comprehensive historical account linking modern scientific thought and the earliest stages of Western philosophy. Within this ancient history are examples of direct observation forming a view of life in order to explain its great complexity and mystery: "How is one to live?", rather than "How is one to make a living?", seems to have been the primal motivation for scientific inquiry.

Bio-inspiration may be a redundant word. "To inspire" means, literally, "to breathe into", and its archaic translation was "to breathe life into". That, after all, is what many biomimetics are after: to breathe life into their solutions, whether it is a smart building, a transformative medical procedure, or a more vibrant business. The attributes of living things, metabolism, responsiveness, adaptability, growth, and evolution are all useful to emulate, if not to imitate slavishly. The successful problem solvers have learned to first observe, then to translate, and then apply in an appropriate way.

It is in keen and steady observation that inspiration seems to first appear. The essential message of artist Elena Lapeña's plant portraits (page 72) is the imperative, "Look: this is beauty", and she shows us, like the botanist/photographer Karl Blossfeldt before her, a way to look. In this issue we also feature three men who were inspired to their vocations, as well as their discoveries, by such observation. John Crowe was intrigued by tardigrades as a teenager, Wes Jackson had an epiphany about the efficiency of prairies, and Wilhelm Barthlott became deeply fascinated in his study of plants. Architect Ilaria Mazzoleni, also featured, came to her focus through a wide observation of what others saw, and drew her own conclusions about how to apply it in her work. Finally, the many artists and designers within the exhibition, Nature's Toolbox, have asked us to observe Nature in different, idiosyncratic, ways. We salute each of them, artist and scientist, designer and inventor, who has cared to look.

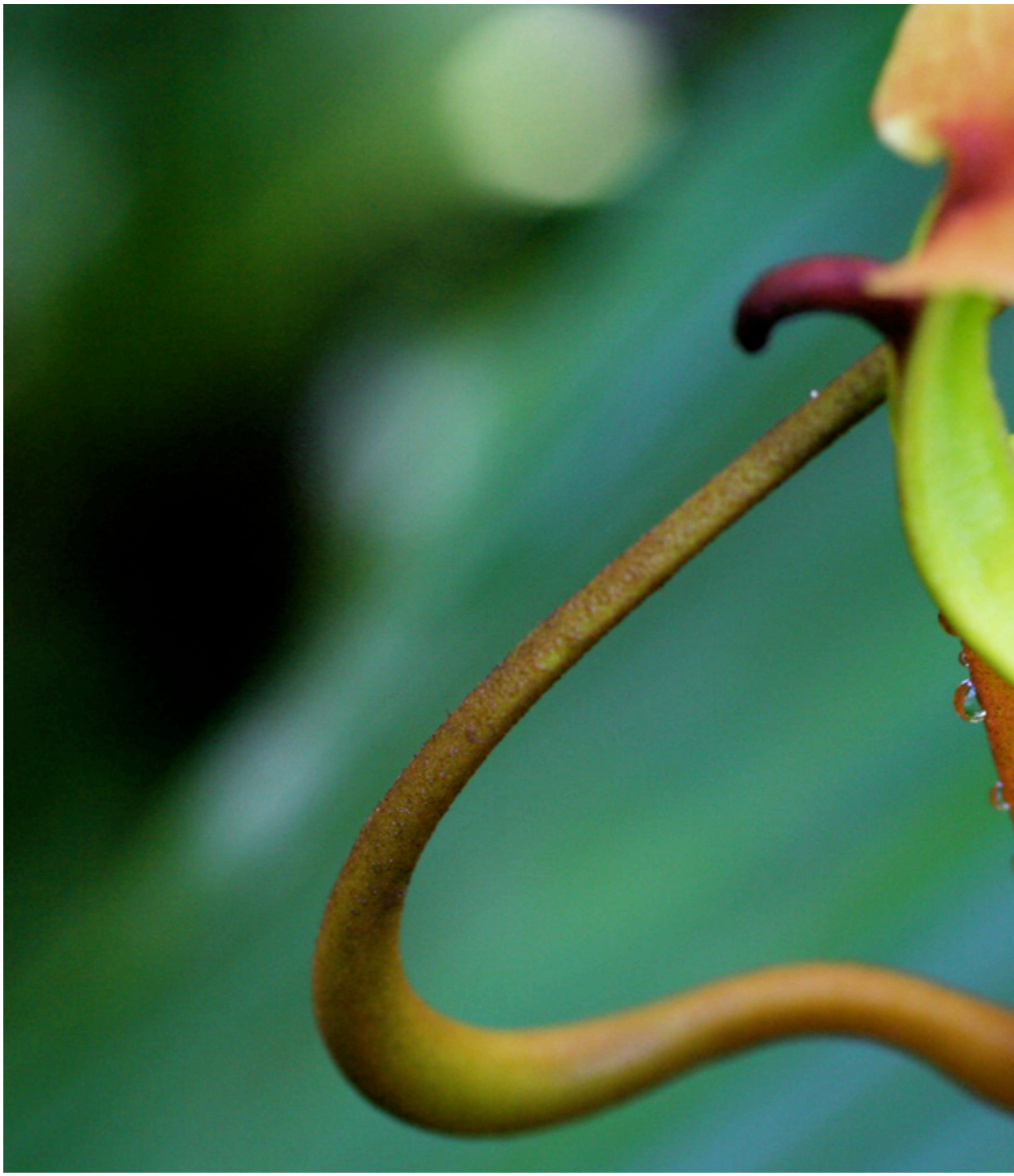


Tom McKeag, Norbert Hoeller, and Marjan Eggermont

Aloe

Photo: cobalt123, 2010 | Flickr cc

Join us at our new web location, zqjournal.org, as we muck around in swamps, cross the prairie, and get lost in the weeds. All to the betterment of our world, we think you will agree. Learn how one of the hottest biomimetic laboratories in the world has pushed material slickness to a new level. Find out how those rolling grasslands could solve our food crisis, and feast your eyes on the luscious photographs of Spanish artist, Elena Lapeña. Try out the design translation tool that the BIDlab at the University of Toronto is developing and see if it works for you. Take issue or side with our guest opinion writer, sustainability expert Jeremy Faludi: his thoughtful consideration of biomimicry's place in green problem solving may surprise you. Finally, join us in thanking and welcoming Architect and Professor Raul de Villafranca of Mexico City to our guest editorship. Raul brings a wealth of experience to our fold and we are grateful for his contributions. In sum, enjoy your read and thanks for all your support.



Pitcher plant

Photo: The Rocketeer, 2011 | Flickr cc

Case study
Return of the Swamp Thing

Tom McKeag

fall 2012

Article:
Case study

Author:
Tom McKeag

Return of the Swamp Thing: the Wyss Institute Finds a New Inspiration for a Slicker World

Swamp Thing I: The Original Version

In Buddhist lore the sacred lotus is renowned for its ability to emerge unblemished from the dirtiest muck of Asian wetlands. Such is the messy nature of life on this earthly plane, the texts say, and we all should emulate the plant's ability to avoid having any of it stick to us.

The sacred lotus is an aquatic perennial that spreads by rhizomes. Its floating leaves can reach sizes of 60 centimeters in diameter while the overall plant can sprawl up to 3 meters. It has the ability to regulate the temperature of its flowers, apparently in order to be receptive to insect pollinators. Its seeds are also remarkably viable after long dormancy; successful germination of 1300-year-old seeds has been accomplished. The seeds, flowers, young leaves and roots are all edible and many parts are used in traditional medicine. It is the national flower of both India and Vietnam and, besides being forever linked with the Buddha, is associated with the Hindu gods Vishnu and Lakshmi.

While a hundred generations of devotees have puzzled over how to achieve the plant's non-attachment metaphorically, it wasn't until 1988 that a German botanist by the name of Wilhelm Barthlott wondered how he might do so literally. The Director of the Bonn Botanic Garden, Barthlott had had a long career investigating evolutionary development by comparing the anatomy of plants. He had become fascinated by the slippery nature of plant surfaces (cuticles) when he had realized in 1974 that some of his specimens never needed cleaning before being put under the microscope. He compared hundreds of species in a quest to find the slickest. His ultimate champion was the sacred lotus (Nelumbo nucifera).

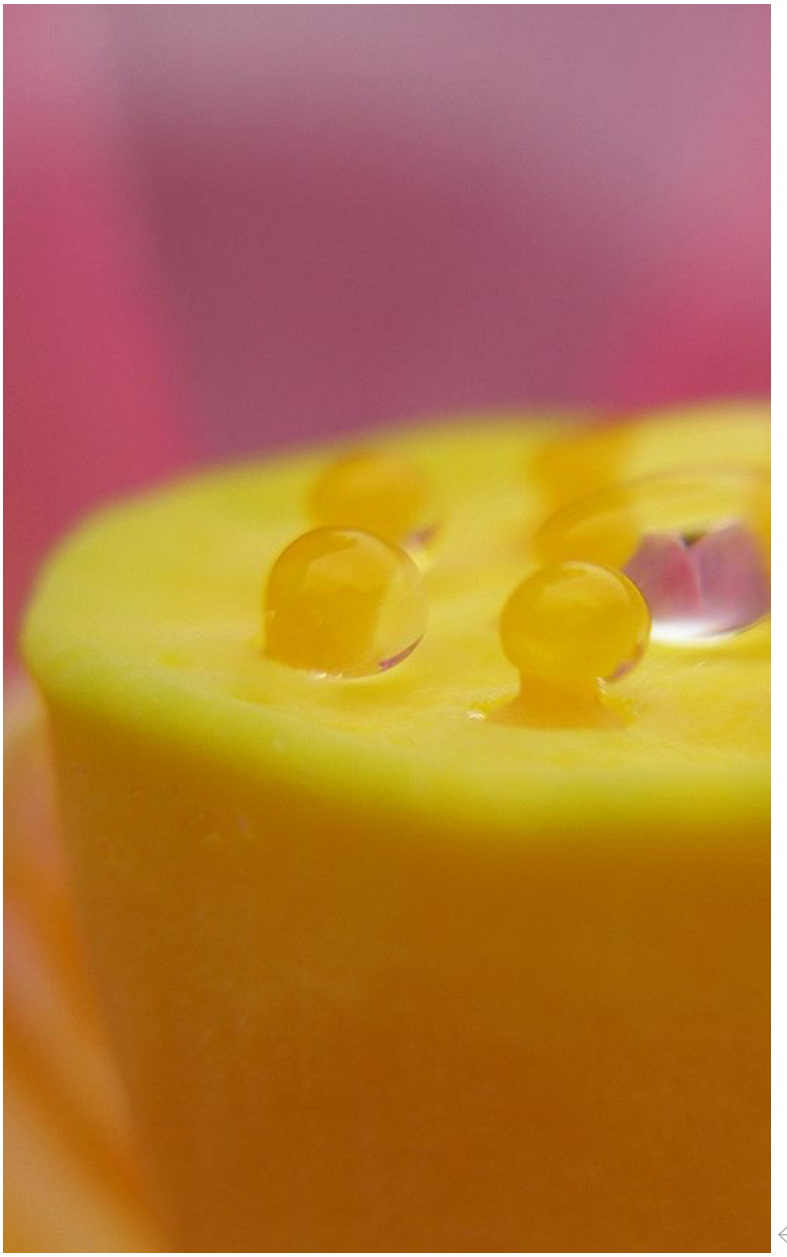
Barthlott discovered something counter intuitive about the lotus: the surface of the plant, rather than being ultra-smooth as one would expect, was actually quite bumpy. Of course, one had to look closely to see the bumps, and Barthlott's discovery was enabled by a relatively new device, the scanning electron microscope (SEM) brought to market in 1965. Now scientists could see things at the micro and nano scale. The typical electron microscope could magnify specimens from 10 to 500,000 times and was not restricted by the power of an objective lens or the shortest wavelength of visible light (about 200 nanometers). One could now see the rough form of large molecular structures like ribosomes and the clear outlines and interiors of cells (1 mi-

Water

The nature of water itself is what makes both of our swamp solutions work. Water is a so-called polar molecule, meaning that its two atoms, oxygen and hydrogen, have opposite charges, positive and negative. They are joined by covalent bonds, meaning that they share an electron between them, and because oxygen attracts that negatively charged electron more strongly it takes on a negative charge while hydrogen assumes a positive charge.

Because of this, water molecules stick easily to each other, head to tail, so to speak, in weak bonds and to other surfaces with appropriately charged molecules. It is the reason why salt (sodium chloride) dissolves so easily in water, the positive sodium quickly bonding with the oxygen, and the negative chloride bonding with the hydrogen. It is also the reason why water can cling to the sides of a glass, or, more importantly in nature, to the walls of xylem in, say, a redwood tree.

In the case of the lotus, the polar attraction of water to itself is stronger than its attraction to the minimal surface of the plant. In the case of the Pitcher Plant, the water and the micro fibrous solid surface form a thin sheet in which the water molecules are held in place by both their attraction to each other and to the solid.



Lotus flower

Photo: tanakawho, 2007 | Flickr cc

crometer and above). This power revealed the structure of plant cuticles to Barthlott as an intricate topography of architectural shapes.

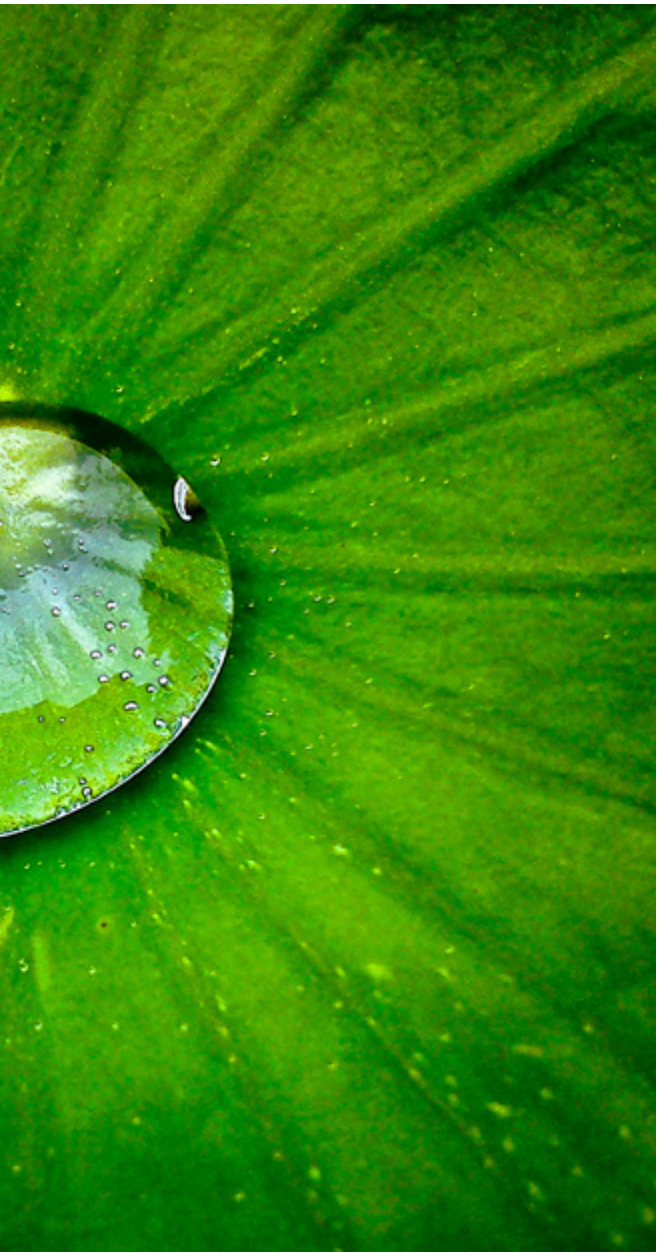
Here is what the new tool revealed: water molecules were beading up on the dimpled wax micro surface of the leaf, and, as the water rolled off, these individual beads were riding on the tops of the bumps. A layer of air, therefore, separated the water from the solid surface of the leaf at the base of the bumps. This buffer created a condition in which the attraction of the water to itself (cohesion) was stronger than its attraction to the leaf (adhesion). Hence, the beading up. With the water nicely balled up and skipping over the tops of the bumps, dirt and debris were sucked into the surface tension of the water beads and carried off the plant.

Barthlott realized later that the phenomenon was not unique to the tissue of the lotus, but was of a physical, and therefore universal, nature. Any micro surface so configured and made from a hydrophobic substance could produce this effect. It was then that the scientist became the technologist.

A one-man promotional machine, Barthlott spent the next decade trotting his slippery invention around to chemical manufacturers. Eventually, the breakthrough, known as the "Lotus-Effect®" was patented and presented to the public in 1997. It has made its way into many coating products, the best known being *Lotusan* paint, a liquid pigment containing silicone microchips that mimic the effect when spread on a surface. Its main advantage is its self-cleaning properties and the paints have been applied to both buildings and vehicles.

Drop on lotus leaf

Photo: Pison Jauji, 2011 | Flickr cc



The Lotus-Effect® is a great example of a passive structure doing work that might otherwise have cost a lot of energy. It is also emblematic of the adage that "scale matters". The micro topography of the surface works to advantage because it is appropriately scaled to the size of water molecules. It therefore influences and takes advantage of the phenomena associated with the polarity of those molecules (see sidebar).

While the Lotus-Effect® was a conceptual and technological breakthrough, it has had its application limits. Artificial lotus surfaces, relying on a cushion of trapped air between the micro bumps, do not repel all liquids, particularly those with a low surface tension such as oils. The surface plane has to be tilted quite a bit above horizontal to be effective (high contact angle hysteresis) and the treatment fails under pressure or physical damage to the surface: liquids can be pushed through into the air cushion by additional pressure and imperfections in the solid surface can afford places where droplets can adhere.

Manufacturing a relatively precise surface to prevent this is fairly costly, but it nevertheless does not guarantee that, over time, the wear and tear of use won't degrade or halt its performance. While the self-cleaning performance of the lotus leaf depends on physical structure rather than biological processes or material, the maintenance of the surface is very much in the realm of bio-miracles. The plant "breathes" its renewing wax coating up through the cuticle with exhaled gases where it self organizes into a fresh layer. Technological translations have yet to mimic this process.

Swamp Thing II: The New Inspiration

These limits had led a team at the Wyss Institute for Biologically Inspired Engineering at Harvard to search for a superior biological model for slickness. Their initial goal was to synthesize a material that was "omniphobic" and repelled everything. Their search brought them back to the swamp. There they found Nepenthes, the Pitcher Plant, a sly and devious character that lives throughout the Malay Archipelago. Nepenthes has more than one trick to play in the "red in tooth and claw" game.

Life is not easy for a bog plant. Despite the fecund character of the place, the soils are very acidic and nutrient poor. Moreover, because they are saturated with water they are often oxygen deprived or anoxic. Without oxygen, organic matter does not break down and nutrients are not made available. What's a plant to do? Many of them, the Pitcher Plant included, have evolved to put meat on the menu.

Being a plant presents several disadvantages in chasing down prey, however. If you are stationary and in a spot that you didn't choose, then you had better come up with a pretty good strategy to get your prey to come to you. The Pitcher Plant has just such a strategy to supplement its more traditional harvesting of soil nutrients.

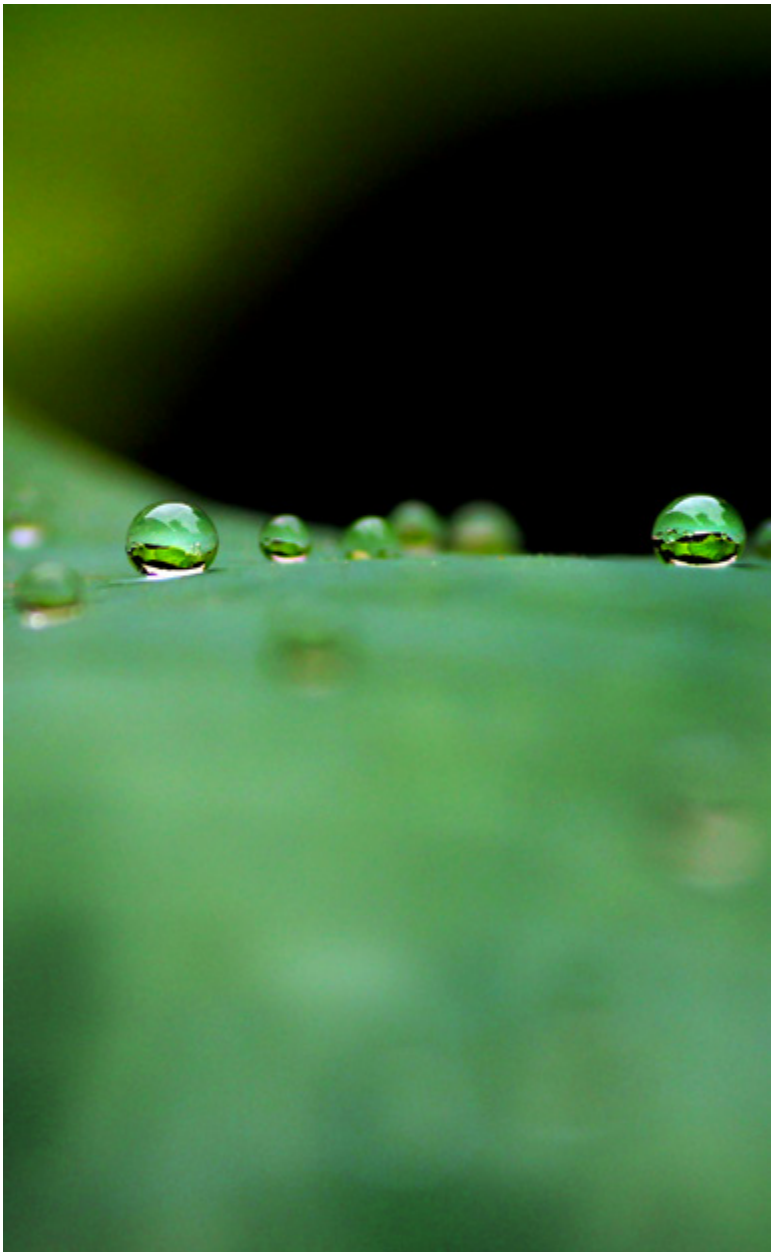
The plant lures animals, from insects to amphibians to rats and even birds, into a modified leaf that forms a bowl. It does this by a combination of color, nectar and scent. The color, usually red, is caused by anthocyanin pigments in its leaf walls and mimics the red found in meat. The nectar is usually laid down in a trail on the flange or flap of the bowl-shaped leaf, and the scent is either produced by the plant or is a result of the decaying victims already in the bowl. Within the bowl, water collects and contains viscoelastic polymers (read that "goo") that help further disable flying insects' wings.

The plant receives nitrogen and phosphorus from its decaying victims through several glands at the base of the bowl, and also hosts a variety of "boarders": insect larvae, spiders, mites, even crabs. While they feed every day on victims' parts, their patient landlord is actually just waiting for them to process the material and redeliver it as fertilizer in the form of defecations. There is one species, Nepenthes lowii, which has evolved a mutualistic relationship with a mammal, the tree shrew, by providing nectar in exchange for its droppings.

Research by Bohn and Federle in 2004 had revealed the unique properties of the plant's peristome, the rounded lip of the bowl. Overlapping wet cells formed anisotropic ridges in which an aqueous solution was held in surface tension as a thin film. The edge formed, in effect, a tiny Slip 'n Slide, and even ants, with their oiled footpads, could not get a grip on the surface and would aquaplane to their doom.

A Different Paradigm

The Pitcher Plant, as the Harvard team's top candidate for study, offered a completely different paradigm for liquid repellency performance. The material structure of the plant was more important for its voids than for its solid matrix, for it was the liquid that did the work of sliding insects to the waiting bowl. The matrix was there merely to hold this liquid in place. Once this became the contact material, the liquid medium brought additional characteristics: liquids typically organize themselves by molecular bond-



Drops on lotus leaf 2

Photo: tanakawho, 2012 | Flickr cc

Wetlands

Both of the living inspirations for our slippery surface solutions live in wet ecosystems in Asia. Wetlands comprise about 6% of the world's land area (approximately 12.8 million square kilometers), yet account for a disproportionate share of biological diversity and productivity. Forty percent of all the world's species are estimated to live in wetlands, including 12% of all animals.

Wetland ecosystems, bogs, fens, swamps, marshes and open water perform many vital functions like flood and erosion control, fishery production, carbon sequestration and water supply. The World Wildlife Fund estimates that the economic value of wetlands could be as much as $70 billion per year.

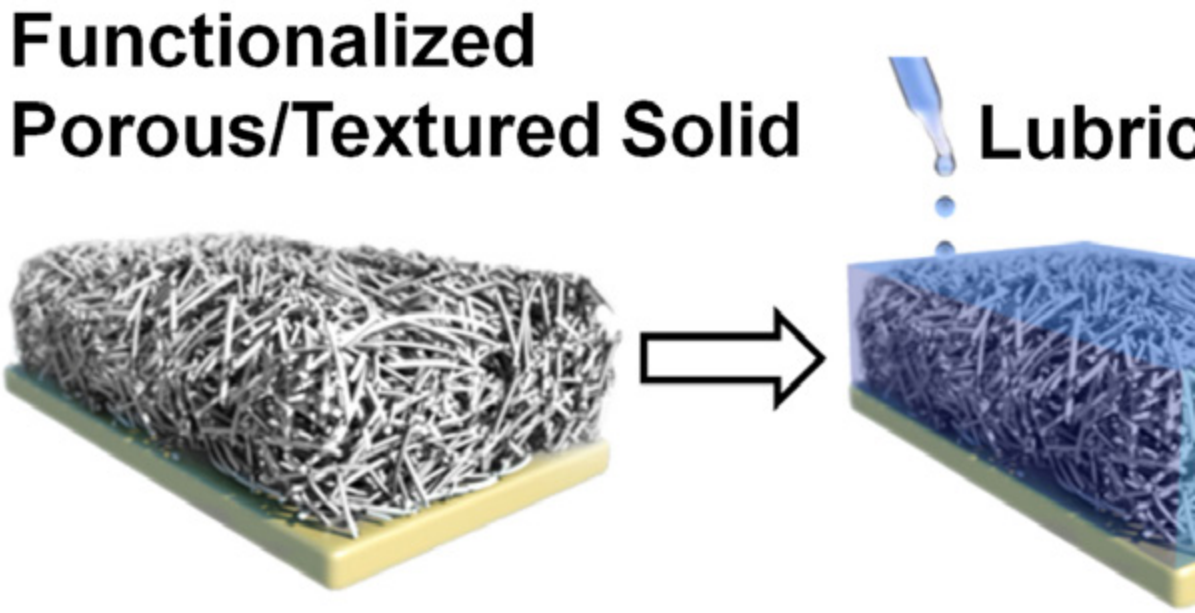
In addition to having a functional value in regulation, production, and carrying capacity, wetlands are also a repository of information. The diverse organisms that are interrelated within these ecosystems have much to teach us. Mangroves, for example, are being studied for their method of desalination, an increasingly vital strategy in a water scarce world.

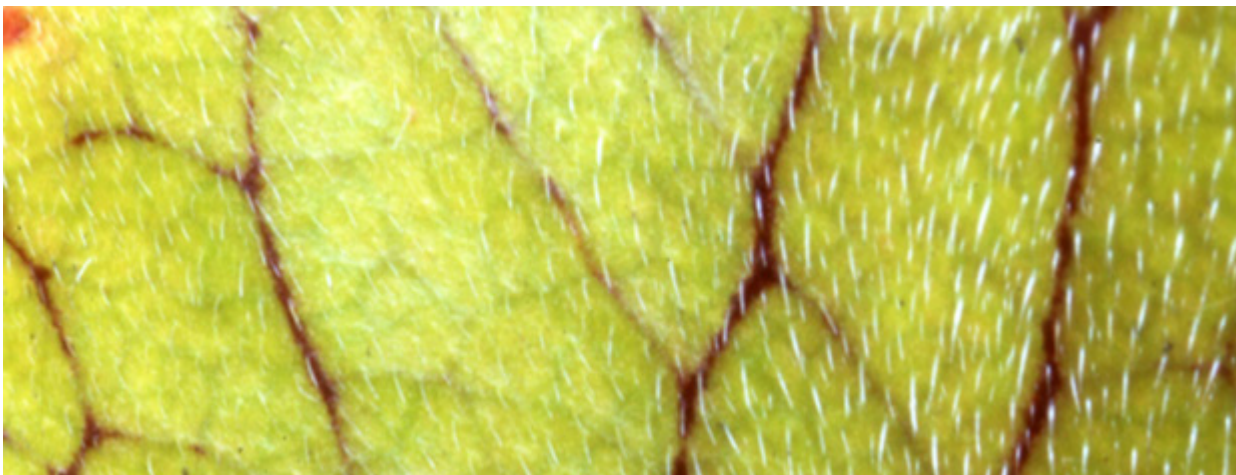
These lessons will be lost if the present rate of habitat destruction continues. It has been estimated that over half of the world's wetlands have disappeared since 1900.

fall 2012

Article:
Case study

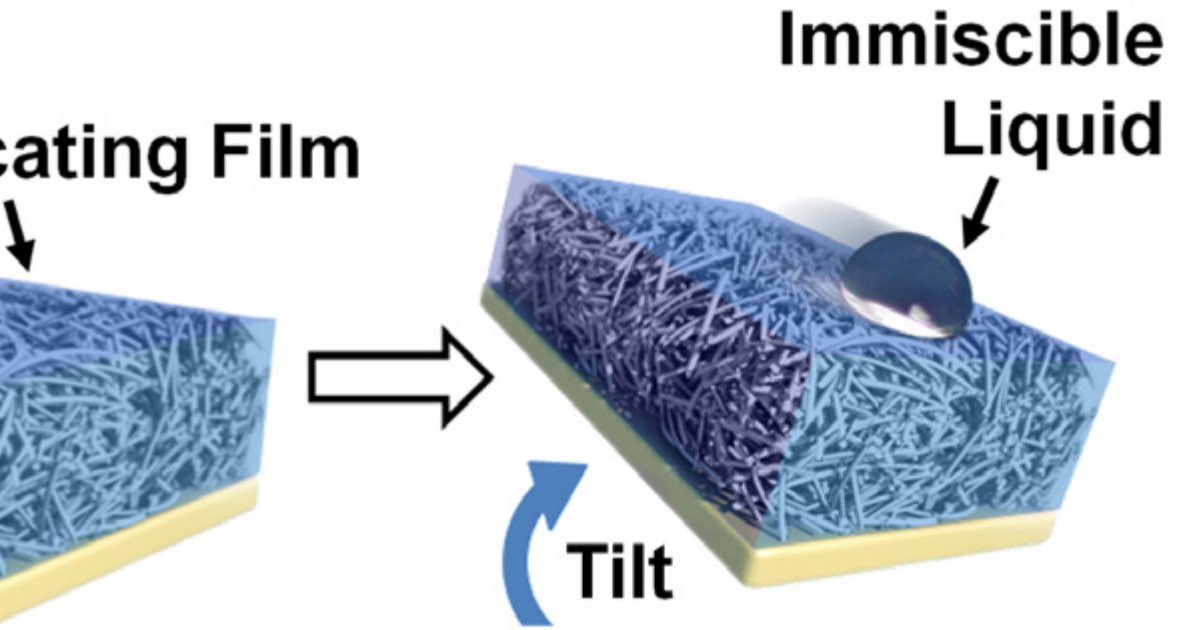
Author:
Tom McKeag

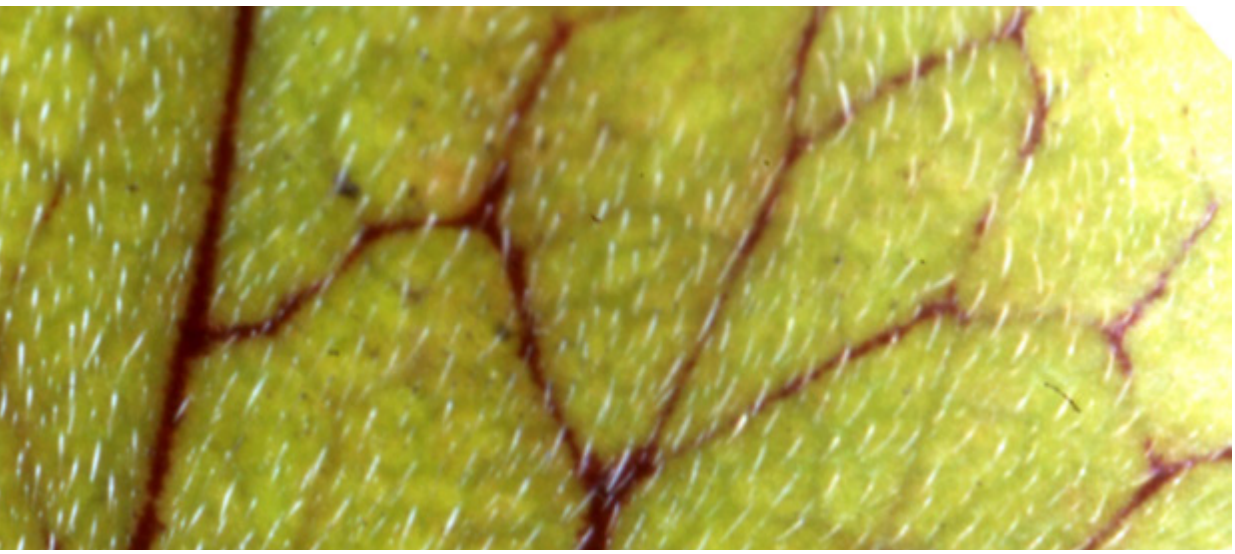




SLIPS structure

Image courtesy of Joanna Aizenberg, James C. Weaver, Tak-Sing Wong | Wyss Institute at Harvard University





Detail of a Sarracenia (pitcher plant) leaf

Photo: Science and Plants for Schools, 2006 | Flickr cc

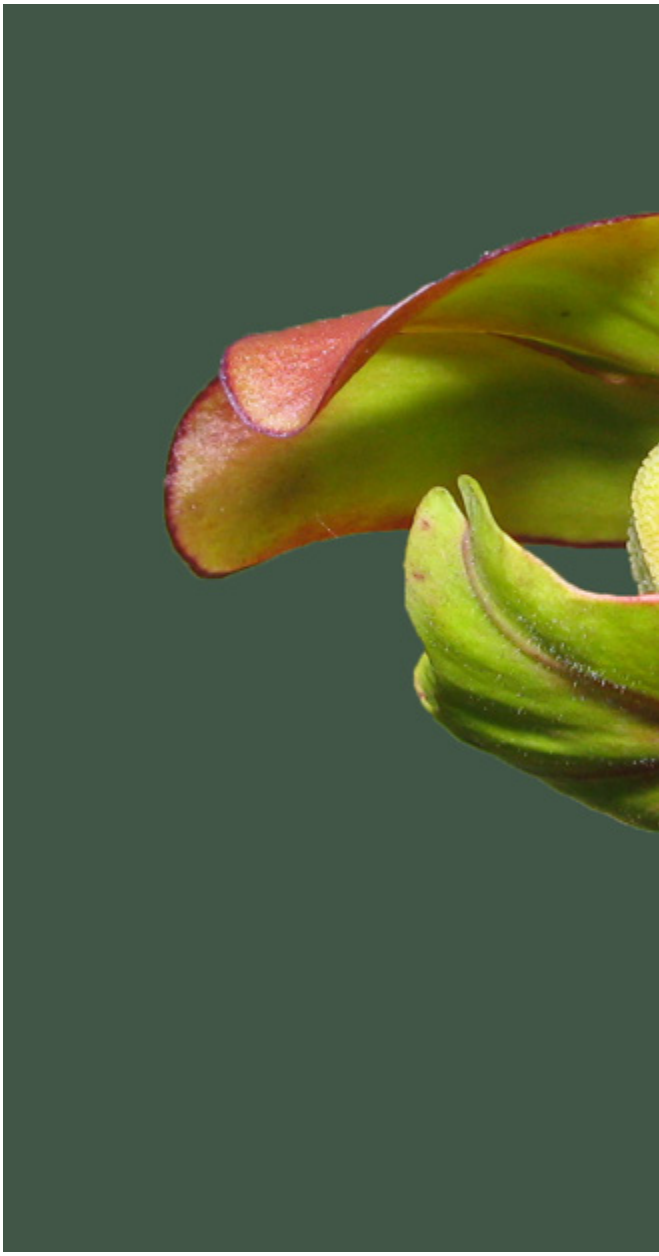
ing, and they can fill gaps in solids automatically, thus adding the benefits of self-organization and self-healing.

The Design Challenge

The Harvard team needed to produce a substrate that was fully wetted by lubricating liquid. This material must prefer to retain this liquid over any other that was poured on it. The lubricating liquid must be immiscible with other liquids, in other words, not able to be blended.

The team experimented with two general types of materials, a porous solid which was more or less a random matrix like the material of the pitcher plant's peristome, and a perfluorinated fluid which mimicked its aqueous solution. Perfluorinated compounds (PFC's) have unique properties to make materials stain, oil, and water resistant, and are widely used in diverse applications. Teflon, the best- known slippery material, is made from PFC's, and the 3M stain resistant coating product, Scotchgard, was also made from them. PFCs persist in the environment as persistent organic pollutants, but unlike PCBs (Polychlorinated biphenyls), they are not known to degrade by any natural processes due to the strength of their carbon–fluorine bond.

They used two types of porous solids: one made from Teflon nanofibrous membranes, and another made from epoxy-resin-based nanostructured surfaces molded from silicon masters. These solid materials were typically 60-80 micrometers thick with pore sizes of 200 nanometers, 300 nanometers, and 500 nanometers. For an idea of relative size, consider that the head of a pin is about 1-2 millimeters across. One millim-



Current loss rates are in the order of 24 hectares (60 acres) per hour globally. In the United States a majority (89%) of this loss is from conversion to agriculture. Global climate change is a relatively new and ominous threat to coastal wetlands, and the continued destruction of Asian peatlands (where Nepenthes lives) is, ironically, a major contributor to this condition. Peatland conversion accounts for 7% of all fossil fuel CO_2 emissions. Protection of these habitats is fundamental to the ecological and economic health of the world. Protection will also give us a chance to learn more innovative techniques from organisms like the sacred lotus and the pitcher plant.

Pitcher plant flower

Photo: sandy richard, 2008 | Flickr cc

eter is equal to 1,000 micrometers or 1,000,000 nanometers. Human hair and red blood cells are in the micrometer range, about 60-120, and 7-8 micrometers across respectively, while DNA is in the nanometer range, about 2.5 nanometers in diameter.

For fluids, they tested 3M Fluorinert FC-70 as well as Dupont Krytox 100 and 103. When the team had matched the surface chemistry and roughness of the two materials, a known volume of the liquid was poured onto the substrate and capillary action achieved a uniform liquid surface level.

The Results

The random matrix of Teflon nanofibers that they filled with the low-tension perfluorinated proprietary liquid from 3M (Fluorinet FC-70) was a very slick success. They have called their product SLIPS (Slippery Liquid Infused Porous Surface), and it does, indeed, appear to repel everything: blood, oil, even ice cannot form on its surface. The researchers claim that their artificial surface outperforms its natural counterparts and all other liquid-repellent products in its capacity to repel water, hydrocarbons, crude oil and blood. Things slip off at a mere 2.5-degree angle and liquids that would stain other slippery surfaces completely exit the surface. Unlike current Lotus-Effect® surfaces, the new matrix functions at pressures up to 680 atmospheres, and is virtually unaffected by minor mechanical damage, being able to restore liquid-repellency within 1 second or less.

Reporting in Nature, the researchers highlighted the benefits of the new repellency method:

> *The premise for our design is that a liquid surface is intrinsically smooth and defect-free down to the molecular scale; provides immediate self-repair by wicking into damaged sites in the underlying substrate; is largely incompressible; and can be chosen to repel immiscible liquids of virtually any surface tension. We show that our SLIPS creates a smooth, stable interface that nearly eliminates pinning of the liquid contact line for both high- and low-surface-tension liquids, minimizes pressure-induced impalement into the porous structures, self-heals and retains its function following mechanical damage, and can be made optically transparent.*
>
> (Nature, Vol 477, Sept 22, 2011)

Applications

Lead researcher Dr Tak Sing Wong reports the new biomaterial has performed well at low temperatures and high pressures and he believes it to be more slippery than Teflon, the reigning slick solid of our industrial world. It would be useful for a range of biomedical, industrial and other applications, such as pipe coatings, self-cleaning public surfaces and de-icing applications. Not the least, its transparency potential and self-cleaning make it an excellent choice for lenses, sensors and solar cells.

> *No synthetic surface reported until now possesses all the unique characteristics of SLIPS: negligible contact angle hysteresis for low-surface-tension liquids and their complex mixtures, low sliding angles, instantaneous and repeatable self-healing, extreme pressure stability and optical transparency. Our bioin-*

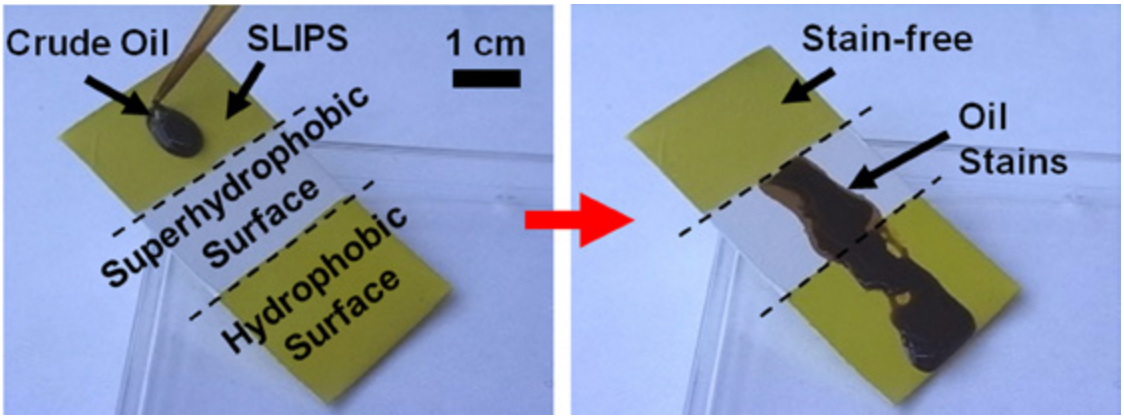
Pitcher plant

Photo: John Guest, 2011 | Flickr cc

fall 2012

Article:
Case study

Author:
Tom McKeag

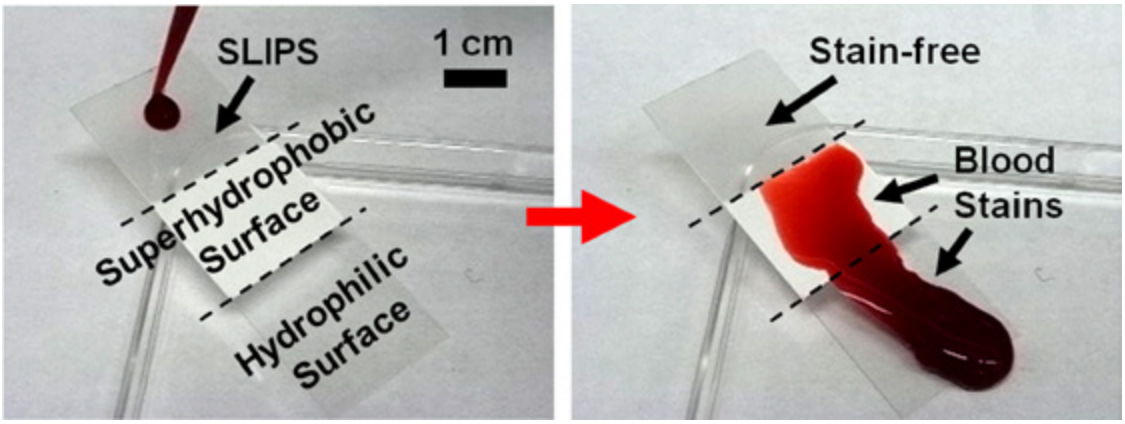


SLIPS surface

Image courtesy of Joanna Aizenberg and Tak-Sing Wong | Wyss Institute at Harvard University

Pitcher plants

Photo: ggallice, 2008 | Flickr cc



SLIPS surface

Image courtesy of Joanna Aizenberg, Ben Hatton, Tak-Sing Wong | Wyss Institute at Harvard University

spired SLIPS, which are prepared simply by infiltrating low-surface-energy porous solids with lubricating liquids, provide a straightforward and versatile solution for liquid repellency and resistance to fouling.

Implications

The SLIPS development has taken self-cleaning surface techniques from rolling beads of water (and the dirt that they collect) off a microscopically bumpy surface to sliding liquids and solids alike along a thin film. It has quite a few technical implications.

Because low-surface-energy porous solids are abundant and commercially available, and the structural details are irrelevant to the resulting performance, one can turn any of these solids into highly omniphobic surfaces without the need to access expensive fabrication facilities. Any liquid film is inherently smooth, self-healing and pressure resistant, so the lubricant can be chosen to be either biocompatible, index-matched with the substrate, optimized for extreme temperatures, or otherwise suitable for specific applications. With a broad variety of commercially available lubricants that possess a range of physical and chemical properties, we are currently exploring the limits of the performance of SLIPS for long-term operation and under extreme conditions, such as high flow, turbulence, and high- or low-temperature environments.

Here are a few of the possible applications for this new technology:

• Biomedical Fluid Handling: nonabsorbent surfaces could save precious liquids, prevent spread of pathogens, avoid fouling of intravenous tubes and speed the delivery of medicine.

• Fuel transport: Reducing drag at the liquid/solid interface would mean increased flow and savings in the energy needed to move commodities like crude oil. Moving the liquids in heating and cooling (and perhaps hydraulic) systems in SLIPS lines might lead to improved efficiency or performance.

• Anti-fouling: prevention of biofilms on surfaces could mean energy savings in avoided mechanical or chemical cleanup of marine vessels and the prevention of infection sources on medical devices.

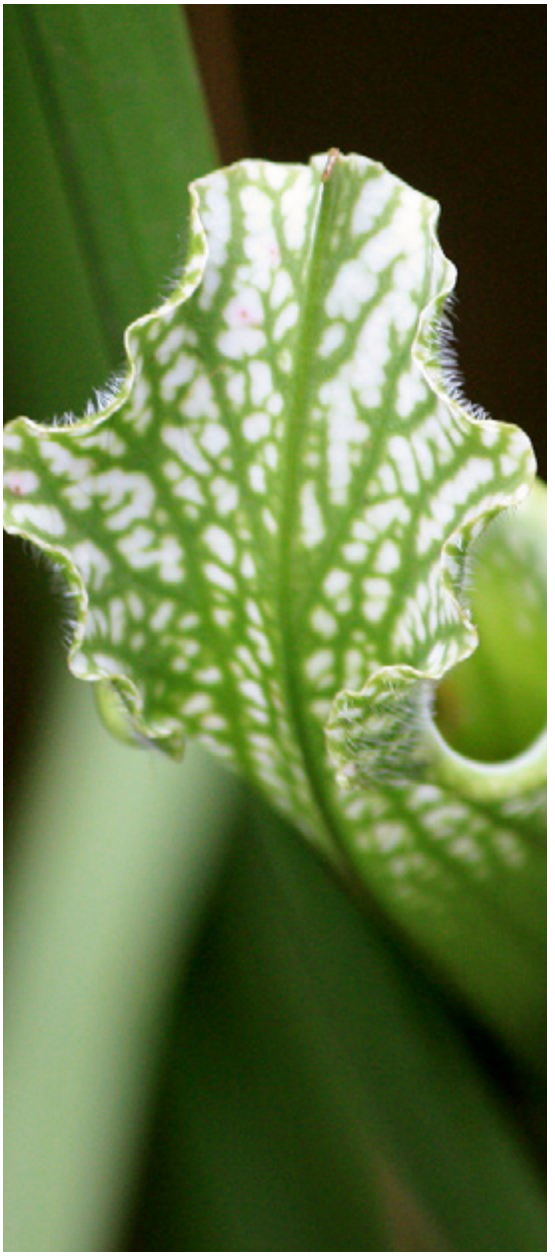
• Anti-icing: vehicles of all kinds might no longer need high pressure or chemical treatments to de-ice. Medical devices could operate in low temperature environments.

• Self-cleaning windows: could mean the end of expensive and sometimes hazardous manual washing, savings in the energy used for artificial lighting.

• Self-cleaning optical devices: could mean increased output for solar panels, avoided maintenance for sensors, increased accuracy and precision for field optics.

While it is early in the development of the SLIPS innovation, several factors suggest that it may take its place in the limited pantheon of biomimetic devices that have been distributed en masse.

Like Velcro, this material replaces one that needed more precision and effort to work and there-



Sarracenia Trumpet Pitcher Plant

Photo: Kate's Photo Diary, 2009 | Flickr cc

fore had a more limited range of applications. Consider the effort of tying a shoelace versus slapping a flap of fabric against another surface. Now think of the various surfaces, angles and situations in which a cloth ribbon laced through a row of holes simply does not work.

Like the Lotus-Effect®, another bona fide commercial success, the SLIPS device depends on its passive structure to take advantage of a universal physical dynamic in order to do work, in this case, capillary action and the immiscibility of certain liquids, among other processes. Passive structures that do this are said to "surf for free" and are critical to solving problems in a resource-limited world.

Finally, the wider range of applications, the potentially improved performance and greater dependability may actually come at a lower cost. Manufacture of this type of material, while having a significant environmental issue associated with persistent organic pollutants, appears cheaper than comparable processes, all because the new paradigm has leapt over the old. That's not bad for a lowly bog plant that eats bugs for a living.

References:

Wong, T. S., S. H. Kang, S. K. Y. Tang, E. J. Smythe, B. D. Hatton, A. Grinthal, and J. Aizenberg. 'Bioinspired Self-repairing Slippery Surfaces with Pressure-stable Omniphobicity'. *Nature* 477, no. 7365 (2011): 443–447.

NOVA: Forest Floor

Isabella Kirkland | 2011 | archival ink jet print

61.75" H x 50.75" W | Courtesy of Feature Inc., New York

Exhibition *Nature's Toolbox: Biodiversity, Art, and Invention*

Randy Jayne Rosenberg

fall 2012

Article:
Exhibition

Author:
Randy Jayne Rosenberg

***Nature's Toolbox* is an innovative traveling exhibition featuring con**temporary artworks from around the world across a wide range of media. It is an engaging, informative, and entertaining exhibition that links nature's bounty to our everyday challenges. It is a celebration of both biodiversity and human ingenuity.

Awareness is the first critical step in changing our individual and collective outlook from one that exploits nature to one that nurtures it; and from a mindset that separates us from the natural world to one that makes us part of it.

Art can help build awareness. Indeed, nature and science are inextricably linked to art in the environmental realm. While science measures the health of the planet, art helps us visualize our complex relationship to the natural world. Art has a unique set of tools to represent our world: irony and allegory, metaphor and humor. Science provides facts while art tells stories.

People are hungry for positive images of the future. Effectively told, stories can have a powerful impact in determining how our future unfolds. The stories at the heart of "Nature's Toolbox" offer fresh perspectives and solutions, demonstrating that humanity is itself, an essential piece of this system, and the salvation not just of nature, but ourselves.

"Nature's Toolbox" aims to light a path between our everyday activities and the loss of species and biodiversity. It will show how biodiversity contributes to the quality of our lives through health, climate, energy, culture, design and sustenance. Its goal is to demonstrate the potential to harness nature's designs to build a future in which human needs are met in harmony with nature.

Randy Jayne Rosenberg

Curator, "Nature's Toolbox: Biodiversity, Art & Invention"

Executive Director, Art Works For Change

For additional information about the exhibit, please see:

www.artworksforchange.org/exhibitions_NT.htm

Scientists believe that of all living species on Earth, only 10 to 15 percent have been cataloged and assigned a place in their taxonomy. The NOVA series focuses on species of flora and fauna that are new to scientific literature within the last 20 years. Each of the four prints depicts plants and animals specific to a different layer of the rainforest — floor, understory, canopy, and emergent, or topmost layer. These organisms are from many continents and would never live together in real life, the images are idealized scenes, existing only in the artist's imagination.

NOVA: Canopy

Isabella Kirkland | 2011 |archival ink jet print |

61.75" H x 50.75" W | Courtesy of Feature Inc., New York

NOVA: Emergent

Isabella Kirkland | 2011 |archival ink jet print |

40" H x 72.5" W | Courtesy of Feature Inc., New York

NOVA: Understory

Isabella Kirkland | 2011 |archival ink jet print |

61.75" H x 50.75" W | Courtesy of Feature Inc., New York

fall 2012

Article:
Exhibition

Author:
Randy Jayne Rosenberg

"Two Sides of One Branch" is comprised of three systems combined with tree branches: x-rays of a human hand, a human skull, and VLSI (Very Large Scale Integrated) circuits. The work points to the all-pervasive tree structure as a highly efficient matter, energy, and information-distribution network. Tree structures are forms that recur consistently in organic and inorganic systems alike. They may appear as fingers of rivers, cracks in rocks, branches of roots, snowflakes, cytoskeletons, brain cells, circuit boards, and replicated and mimicked in very VLSI circuits as well as Internet and telecommunications networks.

.

Circuit from the Two Sides of One Branch series
Ken Rinaldo | 2004 | x-ray, tree branch, mixed media | 24" H x 17" W x 6" D

fall 2012

Article:
Exhibition

Author:
Randy Jayne Rosenberg

Brain from the Two Sides of One Branch series

Ken Rinaldo | 2004 | x-ray, tree branch, mixed media |

24" H x 17" W x 6" D

Hand from the Two Sides of One Branch series

Ken Rinaldo | 2004 | x-ray, tree branch, mixed media |

40" H x 27" W x 6" D

fall 2012

Article:
Exhibition

Author:
Randy Jayne Rosenberg

What is biodiversity?

The variety of life on Earth is commonly referred to as biodiversity. The number of species of plants, animals, and microorganisms, the vast diversity of genes in these species, the different ecosystems on the planet, such as deserts, rainforests and coral reefs are all part of a biologically diverse Earth. Almost all cultures have in some way or form recognized the importance that nature and its biological diversity have on their survival and prosperity, and the need to maintain it.

Biodiversity represents the extraordinary variety of living creatures and ecological communities growing and interacting with one another throughout the world. It is the richness and complexity of species and ecosystems throughout the planet — continually acquiring and adapting under constantly changing conditions.

Chalmers' work is often symbolic of the hierarchical relationship that human beings have to all species: our superior relationship to nature and the idea that we think of nonhumans as lesser species, as represented by the American Cockroach. She also points out the many ways we are remarkably similar to this recent immigrant to America. Her video work provides a portal to see close-ups of the place where human and insect desires become one, and the dance of survival and consumption.

.

Safari, We Rule, Squish

Catherine Chalmers | 2008 |3 HD videos with audio

Collaborating in the Darkness, Hive Scan 4 from the Hive Scan Series
Aganetha Dyck and Richard Dyck | 2001-03 |digital photograph, edition of 5 | 31" H x 25" W

The drastic increase in the use of toxic pesticides has also taken their terrible toll on bees. According to a recent estimate, 95% of the wild bees in North America have died in the last few years due to lowered resistance to mites, and farmed honeybees are being kept alive, as Aganetha puts it, by "all sorts of trial and error and tons of medication" (Dyck 1999). And now there is the new worry that genetically modified crops are killing and/or mutating butterflies and other insects in disastrous numbers. Dyck most recent research asks questions about the human ramifications should honeybees disappear from earth.

.

Collaborating in the Darkness, Hive Scan 19 from the Hive Scan Series
Aganetha Dyck and Richard Dyck | 2001-03 |digital photograph, edition of 5 | 31" H x 25" W

Why is biodiversity important?

Does it really matter if there aren't so many species?

Biodiversity supports ecosystem productivity where each species, no matter how small, has an important role to play. And each loss in the chain of an ecological system weakens that system and its ability to support life in all its many forms.

Although many humans do not realize it, biodiversity is a fundamental building block of our ability to exist. Every day, biodiversity provides us with food, water, medicine, oxygen, energy, detoxification of waste, stabilization of the climate, recreation and tourism, and many other essential products and services. These are things that cannot be created by technology, even with vast amounts of money; they are beyond human's ability to artificially replicate. As a result, it is critical that we ensure the continued survival of the species that make these valuable things possible.

How do humans affect biodiversity?

Human activity has altered nearly half of the planet's surface, at times impinging on Earth's life-support systems. This is a result of population growth and the overconsumption and use of natural resources required for us to live our everyday lives.

Human actions have also played a role in changing the climate. The change is due to increased atmospheric concentrations of carbon dioxide and other gases, which cause increased land and ocean temperatures, along with changes in weather and sea level. With those changes comes a change in species. Climate affects the reproduction and migration cycles of millions of creatures, as well as the length of plants' growing seasons, species distributions and population, and the frequency and severity of pest and disease outbreaks. Scientists believe that the change in climate over the next few decades will cause a much higher rate of species loss and extinction than in the past 10,000 years — as many as a quarter of all land-based species.

What happens when a million species vanish from the planet? Could we eventually be one of them?

What can we learn from nature about how to flourish?

Biomimicry is the science and art of mimicking nature's best biological ideas in order to solve human design challenges. Nontoxic adhesives inspired by geckos, energy-efficient buildings inspired by termite mounds, and resistance-free antibiotics inspired by red algae — all are examples of biomimicry happening today, and none too soon. Humans may have a long way to go to living sustainably on Earth, but millions of species with time- tested genius are available to show us the way.

Biomimicry asks us to rediscover life's best ideas to change the course of things. How does nature harvest energy? How does it manufacture things waste-free? How does it package, transport, shelter, feed, and heal? Every day, it does this things in a waste-free, nontoxic way, powered only buy sunlight and the elements. The more our world functions like the natural world, the more likely we are to endure on this planet that is ours, but not ours alone.

fall 2012

Article:
Exhibition

Author:
Randy Jayne Rosenberg

Influenced by landscape painters such as Thomas Cole and Casper David Friedrich, Nix creates and expresses intense emotions through both beauty and horror. She uses natural disaster to challenge the notion that we live in a friendly and predictable universe that is under our control. As a non-traditional photographer, she constructs her subject matter, "building the world" on a table-top in a miniature scale..

.

Natural History from The City series
Lori Nix | 2005 | Chromogenic archival print | 21" H x 62" W | Courtesy of ClampArt, New York

Aquarium from The City series
Lori Nix | 2007 |Chromogenic archival print | 32" H x 42" W | Courtesy of ClampArt, New York


ROCKY MOUNTAINS

fall 2012

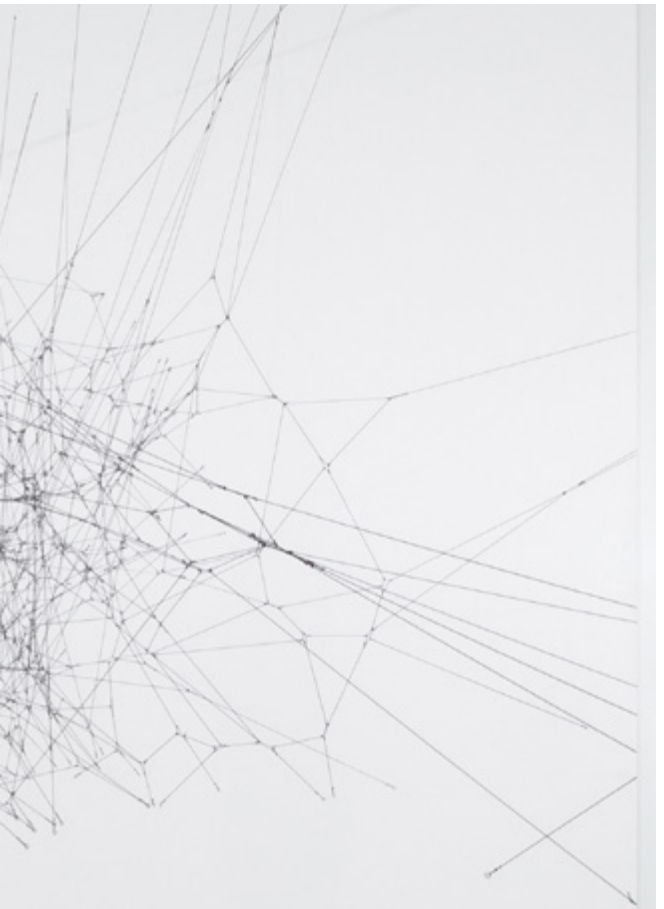
Article:
Exhibition

Author:
Randy Jayne Rosenberg

Focus on 14 Billions

Tomás Saraceno | 2010 | c-print, edition of 6 |

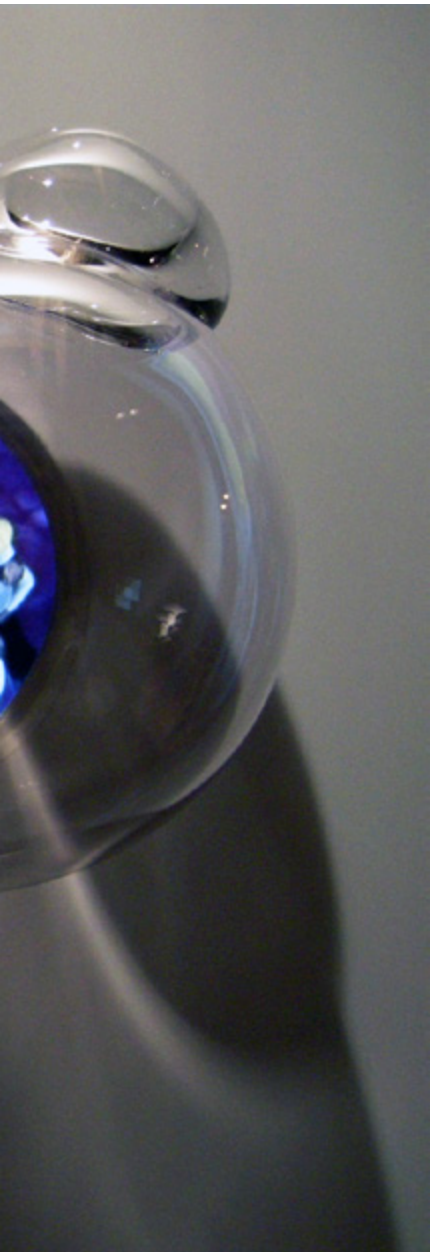
Courtesy of Tanya Bonakdar Gallery, New York



Saraceno uses the imagery of spider webs to map the origin and structure of the universe. Spider webs are made without intense heat, pressure, or toxic chemicals, yet are stronger, pound for pound, than steel or Kevlar. They are inspiring the design and construction of suspension bridges, surgical sutures, textiles, and many other things.

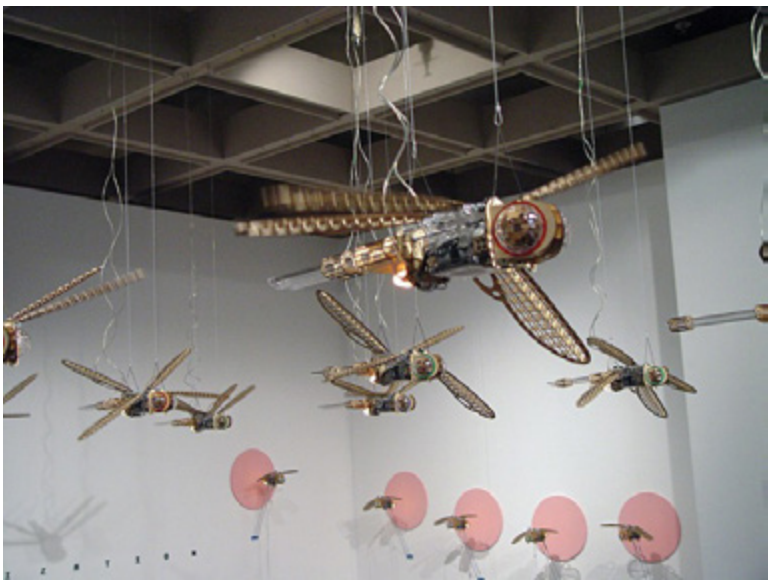
Bee-Doublebubble (Why Did the Bees Leave?)

Katja Loher, Switzerland | 2012 | Video-sculpture, hand-blown glass, 9:00 minute loop with audio | 14 x 14 x 10 inches



Loher's surreal kaleidoscopic worlds are populated by realistic figures. Groups of worker bees, portrayed by humans in constantly changing constellations, need to complete the tasks of pollination that once occurred naturally by the bees themselves, and without human interference.

Hsu's giant robotic insects are highly engineered. Inspired by childhood dreams and cartoon characters, Hsu created mechanical creatures crafted to reveal their skeleton and bone structure with the desire to portray their "inner selves" and the notion that they possess individual characteristics such as curiosity, loyalty, and sociability. These biomimetic creatures, along with bees, lobsters, and flies, are the robotic inspiration for a number of purposes such as search and rescue in the aftermath of disaster, spying and reconnaissance, searching for land mines, pollinate crops, weather mapping, and traffic monitoring.



Odonata

Joyce Hsu, Hong Kong | 2011 | Mixed media kinetic sculpture

fall 2012

Article:
Exhibition

Author:
Randy Jayne Rosenberg

As a pan-Asian icon in modern consumerist society, waribashi - disposable wooden chopsticks - pose a problem to our environment through deforestation and destruction of forest habitats. Every year, throughout the world, hundreds of billions of waribashi are thrown away after a single use. Deforestation is one of the largest contributors to the loss of biodiversity.

The Waribashi Project

Donna Ozawa, Japan | 2012 | 90,000 wooden chopsticks installation | 84 x 192 inches

Clematis

E.V. Day | 2010-11 | Chromogenic archival print | 74" H x 74" W | Courtesy of Carolina Nitsch, New York

Day's image was photographed at the impressionist artist Claude Monet's estate in Giverny, France, The work by Day is from a series called "The Seducers." The flower—plucked, pressed and scanned digitally to 18 times its original size—is vibrantly alive and sensuous. Its large-scale enveloping sensation places the viewer in the perspective of the creature entering the blossom, asking us to consider how the function and design of the flower attracts and lure pollinators with the sweet promise of reproduction.

Sucrose Walls

Don Gensler and Maria Paz Gutierrez | 2006| 3 panels 6 x 2 feet each PMMA (33%) and Sugar (66%) | digital fabrication and manual casting

In the pursuit of material optimization, material intelligence has arisen as a response to the desire to create matter that can internally respond to external conditions as a living entity. SucroseWalls examines the application of "material intelligence" as a mode of inhabitation and the advantage of using sugar, seen as an agricultural surplus. Sugar is characterized by being both a strong economic resource in many developing countries but also associated as a material of high-embodied energy. Sucrose- Walls, a translucent material providing light diffusion and thermal insulation, attempts to open new opportunities to use a known matter in unexpected ways..

fall 2012

Article:
Exhibition

Author:
Randy Jayne Rosenberg

Art Works for Change presents Nature's Toolbox: Biodiversity, Art, and Invention, with generous support from: The Nathan Cummings Foundation; the National Endowment for the Arts; The Adobe Foundation; and the Sprint Foundation. Exhibit venues are:

• The Field Museum , Chicago, Illinois, USA | May 22 – December 2, 2012

• The Leonardo, Salt Lake City, Utah | January 22 – August 5, 2013

• Ulrich Museum of Art, Wichita, Kansas | August 31 — December 17, 2013

Info@ArtWorksforChange.org

Oakland, California, USA

www.ArtWorksforChange.org

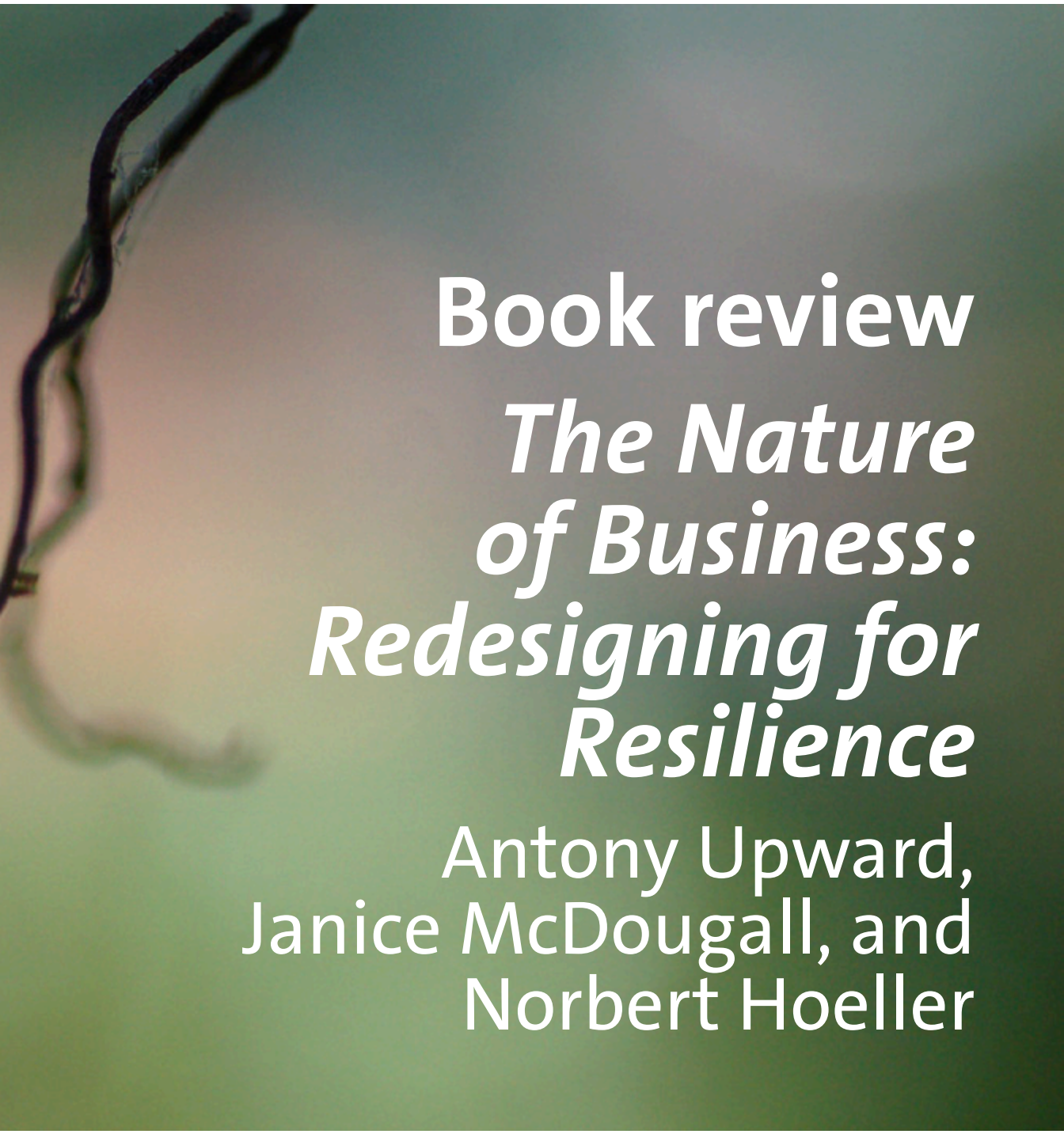
The photograph of the model house is created with thermo-chromatic tile used as a skin to regulate heat. The Dissipative System is a study into possible tectonics and materials for a new biomimetic building. It uses curved smart solar control glass for light transmission regulation. Dissipation Heat Sinks help passive thermoregulation in the building. Glazed ceramic cladding is used for interior and exterior of the shell. The ceramic has thermal color changing abilities to communicate functioning of heat system similarly seen in nature through the color, humidity, and temperature change in the exoskeleton of the beetle.

Dissipative System

Charles Lee, USA | 2011 |Digital prints and thermochromatic tile wall installation

Tree root

Photo: cameronparkins, 2009 | Flickr cc



Book review

The Nature of Business: Redesigning for Resilience

Antony Upward, Janice McDougall, and Norbert Hoeller

fall 2012

Article:
Book review

Authors:
Upward, McDougall, & Hoeller

The Nature of Business: Redesign for Resilience by Giles Hutchins

Prepared by Antony Upward, Janice McDougall and Norbert Hoeller based on a pre-publication draft.

Giles Hutchins is a Co-founder and Director of Biomimicry for Creative Innovation (http://businessinspiredbynature.com). He blogs at www.thenatureofbusiness.org; also see http://uk.linkedin.com/pub/giles-hutchins/0/a7b/15.

The author recently wrote a number of blog posts for the Network for Business Sustainability (hosted by UWO Richard Ivy School of Business)

- Hutchins, G. (2012). Transforming Towards the Firm of the Future – Thought Leaders – Network for Business Sustainability Retrieved 6/20/2012, 2012, from http://nbs.net/transforming-towards-the-firm-of-the-future/

As per the author's introduction, the book is "intended for those interested in exploring and undertaking transformation change within organisations: leaders, change agents, academics and entrepreneurs".

Keywords: Change Management, Organization Design, Organizational Effectiveness, Organizational Resilience, Sustainability

The book explores the transformation of organizations through the lens of biology and human systems. It raises questions, not necessarily answering them, for the purpose of "prompting right action towards positive transformation".

The author suggests that the art and science of business is at a critical juncture, one in which there is great potential for the organization of the future to "create the conditions conducive to life" [1], rather than carry on a course of life inhibiting actions, structures, processes and products. The challenge is to "perceive the Earth as an animate, living system in which humans play a constructive, not destructive, part".

By including the word "(re)design" in the title the author is signalling that he wishes to be considered part of the emerging group of business thinkers (with a tradition stretching back to the early days of Cybernetics) who believe that design thinking involving abduction or informed guessing needs to play a key role in setting and executing business strategy. Given the increasing complexity of business, evidence often does not exist for new and potentially worthwhile strategies which are required to help fix our current "mess"[2].

Structure

The book is divided into 9 modules, each unfolding important aspects (challenges and opportunities) of the transformational journey. Each module presents an executive summary, puts forward a well-researched and documented argument to assist the reader in both "thinking


The
NATURE of
BUSINESS
Redesign for resilience
Giles Hutchins

and doing" and ends with a series of questions to deepen the reader's exploration of the module topic.

The modules are organized sequentially in terms of the process of thinking and then doing. Although it is possible to select a specific module based on where the reader is on the journey, the most benefit is afforded by reading the book in its entirety.

Content Summary

The author believes that the history of human evolution (evidenced in social, industrial and technological change) has created both liberating and constricting transformation. He feels this is most apparent in the separation between human and non-human worlds which has enabled us to "capitalise on the fruits of science, industry and global economics. Conversely, it is also what underwrites the parallel dysfunction and destruction of our social and ecological systems."

The "ecological, social and economic crisis now upon us is as much a crisis of spirit as it is a crisis of resources". And thus, the author sets out his purpose for the book, a beacon, an inspiration to tools and techniques that re-engage the human spirit with the non-human world for the betterment of "all the children of all the species" [3]. He does not suggest that he has a model nor "the answer", but rather offers this book as a part of the emergence of a system of right thinking in order to add to and continue the dialogue for models and their application.

Transformational times call for transformational change

In this module Hutchins puts forward the argument that business, as a human construct, is wholly within our control. He suggests that we do not need to be swept along by the economic models we have created, but that business can deliver value for itself, communities, societies and the non-human world as a function of doing good business.

He maps out the history and thinking of the "firm of the past", with its economic, technological and organizational/social mores and offers an appreciative view to the organization of the future, suggesting that we keep those things we do well that enhance value and let go of those things that contribute to today's mindset of exploitation without regard for consequence (sole focus on short term results, individual excellence over team contribution, reductionism over systems thinking, etc.).

Nature as Teacher

Module 2 explores nature's wisdom as a model and mentor for right thinking and good design.

The overarching theme of the module relates to the impact of dynamic, synergistic and interconnected relationships in nature and how these lessons might be applied to the organisation of the future. He explores sources of inspiration such as:

- evolutionary adaptation and the adaptive cycle
- the roles of diversity, emergence feedback loops and the power of limits

- soil, fungi, and swarms as applied to industrial ecology, product and process design.

He suggests that one way of reconnecting to nature's wisdom is to learn from shamanism and its engagement with all matter as a living thing, nested in a larger system of living things of which humans are but one part. He encourages the reader to get outside and become a keen observer of the natural world, not only for the benefits of rest, relaxation and health, but as an abiding source of inspiration as to how the world of business could work.

Firm of the Future

In this module the author presents an argument which concludes with identifying the various necessary elements he believes are required in the design of a "firm of the future". He uses the increasingly well known "six capitals model" from the International Integrated Reporting Committee. He explores both the "business model" and also the "business ecosystem". Applying lessons from nature and life principles put forward by The Biomimicry Institute he uncovers six "business principles for the firm of the future" (resilience, optimizing, adaptive, systems-based, values led, and life supporting). For each of these principles the author presents examples and supporting arguments.

Sustainability and the Firm of the Future

This module suggests that in order to follow the nature inspired business principles presented in module 3 businesses need to "embrace the opportunity of providing net positive value for the economy, society and environmental it serves – this is real business and good business sense".

The author argues that "the journey toward the firm of the future is about business survival, transformation and evolution" which naturally includes being sustainable. A maturity model for this journey is introduced in which it is suggested that one of the business principles, being "values-led", has particular significance for longer term resilience and hence creating the conditions which lead to sustainable outcomes for an organization.

The module then proceeds to discuss two aspects of being values-led: the value an organization produces (its nature and who receives that value) and the values of the people (and hence the organization) which conceive and produce that value.

The module concludes by introducing the framework "people, process, product place" for exploring the key aspects of a complete organization. The author suggest that a successful design for a firm of the future ought to consider each of these framework elements and build a response to each using the six "business principles" from module 3.

Human nature and nurture

In this module Hutchins focuses on "right relations" and the power we have as individuals, groups, communities, societies and global humanity to positively adapt, transform our ways of being and be guided by values over all other measures of success and progress.

Red-billed Oxpecker, Buphagus erythrorhynchus

Photo: Arno & Louise Wildlife, 2009 | Flickr cc

Red-billed Oxpeckers on a Giraffe

Photo: Tarique Sani, 2010 | Flickr cc

He suggests that the "'new world of work' changes the game for individuals and employers", educational institutions and the communities they serve in creating value through the application of values in our relationships with each other and the world around us. This journey begins with the self and understanding the nature of energy/intention and its efficiency as a means of propagating information. "All life communicates through energy fields." We have the ability, opportunity and obligation to understand how our thoughts influence our perceptions and how those influence the interconnected world in which we live.

He cites examples of how once we had this understanding. We know how to organize our businesses and communities to be holistic, synergistic, "organic, adaptive and responsive", primarily through the breaking down of organisational silos, distributing capabilities and redesigning processes in a learning organization model. One model is a "chaordic" organization, "always on the border between order and chaos, providing malleability and durability".

His call to empowering, networked and values-led leadership is at both the individual and organizational level. He sees the evolution of the organization from the management of people to the engagement of employees to the empowerment of stakeholders. In this organization of the future, stakeholders have a direct say in the process and products that are created for mutual benefit in a system of reciprocity.

In order to achieve such mutual benefit, he calls on the reader to make time to "think", improve our thinking skills and work together to think better in groups. He concludes that transformation will happen through the application of these seven "tips": silence, sense, strategy, small steps, stakeholders, systems and solutions.

Catalysts for transformation

Hutchins discusses four enablers of transformation to the "firm of the future":

1. Collaboration enables interconnections that cut across traditional boundaries both within and between businesses, increasing resilience by "encouraging sharing, creativity, empowerment and innovation." Examples include turning a linear supply chain into a business ecosystem and a traditional employer/employee relationship into a more open and creative working environment.

2. Innovation at personal, organizational and extra-organizational ('open innovation') levels.

3. Education brings all stakeholders to a common level of understanding in terms of values, challenges and opportunities.

4. Inspiration "provides us with the ability to explore uncharted waters."

Techniques for transformation

This module describes Biomimicry for Creative Innovation's 5E cycle, guided by the business principles from nature that were introduced in Module 3:

1. Explore all aspects of the systems (organizational, societal and natural) that affect the organization, such that the organization has

the relevant information to guide future development in a proactive manner. Applying systems thinking is essential to gain a holistic rather than a reductionist perspective.

2. Evaluate on a broad range of internal and external attributes, not only the short-term metrics of time and money. One tool is a "resilience audit" that evaluates how business systems might deal with potential disruptions.

3. Envision what an ideal organization would look like based on the context, core values and purpose, without being encumbered by conventional thinking.

4. Empower by "creating conditions that enable people to transform the vision into reality", acknowledging new ideas and then building on them.

5. Execute by bringing to bear all the internal and external resources and relationships to achieve the vision while maintaining core values.

Inspiration for transformation

Hutchins expands on the examples used throughout the book by exploring four companies in depth:

- Adnams, a small UK brewery
- Ecover, a mid-sized Belgian manufacturer of ecological cleaning products
- Tata Corporation, an Indian conglomerate
- Virgin Group, a UK conglomerate

Each case study looks at the organizations from the perspective of resilience, optimisation, adaptability, systems thinking, values-based leadership and a focus on life supporting initiatives.

Conclusions

Hutchins points out that the pressing challenge we face are relatively recent in human history and suggests that changing our business paradigm can "go a long way to addressing the root cause of our many pressing challenges." He echoes William McDonough (author of Cradle to Cradle) in asking us to "love thy neighbour as thyself" but encompassing the entire web of life and aspiring to transform our economy through 'good growth'. Biomimicry provides inspiration and models that help us "play by the rules of nature" while encouraging individual flexibility and authenticity.

Notes and Further Reading

The book closes with an extensive list of references organized under modules one through nine. An additional list of works covers the vast range of ideas this book raises and discusses

Commentary

Much has been written on the evidence that we are approaching multiple natural tipping points which will have disastrous impacts on the ability for all life to flourish [4]. However, far less has been written on understanding the challenges of solving our "mess" through a business / organizational lens. The author's stated goals

Dec. 24, 1968: Earthrise

Photo: NASA Apollo8

and signalled approach is critically necessary for business designers. These goals are also extremely challenging.

The author has done an admirable job of assembling a highly diverse, and often highly incongruent, set of knowledge to paint one of the first trans-disciplinary pictures of organizations: their economic, social and environmental contexts as well as their operational and change processes. He has also attempted to offer a window on how nature might act as an inspiration for organizational designs which will proactively avoid and perhaps correct these messes.

Hutchins celebrates diversity of thought and adaptability to location/culture, focuses on individual transformation as the key to organizational change and provides hope that today's business models can be changed. The thought-provoking questions at the end of each module engage the reader, encourage further dialog to 'get the ball rolling'.

The author's choice not to focus on defining sustainability is sensible since this can distract from the significant journey ahead. However, he misses the opportunity to directly connect the business principle of resilience introduced in module 3 and the ability of an organization to sustain both itself and the systems it is a part of; although module 4 does explore in detail how sustainability becomes embedded in the transformation to a 'firm of the future'. The book might benefit from inspiring definitions such as the one by noted Industrial Ecologist John Ehrenfeld: "... sustainability: the possibility that human and other life will flourish on this planet forever [5]."

Most of the examples of inspiration appear retrofitted to outcomes. Little evidence is presented that any of the business examples were intentionally modelled from nature. Most of the examples involve larger companies and multinationals. There are few if any natural systems which have a common global identity due to the importance of local conditions. In addition, the current laws under which most firms incorporate make it difficult to envision how large corporations can consistently create the conditions in which human and other life can flourish.

More examples might have been drawn from the small and medium enterprise (SME) sector, which after all makes up the majority of the private sector globally in both number of companies and percentage of jobs. SMEs are far more nimble. As a result, it seems likely that some SMEs already have the close connections between values and value which the author strongly advocates as a "firm of the future" design principle [6], particularly those involved in Transition Towns (http://www.transitionnetwork.org/), the Business Alliance for Local Living Economies (http://www.livingeconomies.org/) and Benefit Corporations (http://www.bcorporation.net/). SMEs could provide a rich vein of examples of the author's suggested design principles, providing practical guidance on how to implement the recommended design principles. SMEs might also allow a more holistic assessment of the 'firm of the future' based on the P10 and R10 scales described in module 7. It is understood that Hutchins plans to explore SMEs in this regard through his further work and research.

The author refers to nature both for inspiration but also uses it as a metaphor, without making

the distinction clear. An example is relating a "physical membrane" to organizational boundaries. Organizations are socially constructed by groups of humans where each of those humans realizes their involvement in the organization [7]. There is nothing physically "real" about the boundary of the organization; the boundary will likely be perceived differently (at least in minor ways) for each stakeholder involved in socially constructing the organization and certainly it will change over time.

The nature's principles discussed in module 8 (resilient, optimizing, adaptive, systems based, values led, life-supporting) are abstractions that would benefit from additional detail. What factors allow natural systems to be resilient, such that external disturbances do not reverberate and cause systemic collapse? When does investment in greater resilience reduce the ability to adapt or even fail? How does optimization in nature avoid states that are locally optimal when better solutions are 'just over the hill'? What are the analogies to 'systems based' and 'values led' in nature, where (with notable exceptions) brain capacity is limited? Natural systems must be life-supporting to persist and there are many examples of cooperation, yet the mechanisms remain elusive.

The term 'good growth' would benefit from further definition and discussion as to how it relates to ecological economics [8] and slow (or no) growth [9] concepts. Our access to rich reserves of fossil fuels has led to unprecedented individual prosperity and population growth. Like a Type I species that takes root in a disturbed landscape where resources are abundant, we feed off energy. Unlike a Type I species that can go dormant when those resources become depleted, we will need to relearn how to live within a reasonable share of 'current solar energy', much as we did prior to the Industrial Revolution.

This book tackles an inherently trans-disciplinary field involving formal sciences (e.g. design science, information systems), psychology (e.g. world views, belief systems and personal change), sociology (e.g. organizational, management science, environmental sociology, ecological economics etc.), biology, chemistry and (geo)physics. Research in these areas has largely remained within individual disciplines and the systems thinking required to make sense of the whole is not well advanced. At the societal level we lack a common conception of a holistic, systems-based goal for society to replace the model that GDP growth is the key engine for increasing individual's income and hence enable humanity to flourish. There is a growing understanding that many other factors play a role, such as environmental quality and distributional equity.

With this context in mind, the scope and complexity of the challenge for any author to attempt a book with these goals becomes clear. This book not only seeks to understand the "mess" through the organizational / business lens which has an extremely limited base of empirical knowledge, but also tentatively suggests solutions, using nature as inspiration, for which there is even less research underway.

Lastly, this book would be more powerful if it was positioned explicitly as:

• A manifesto suggesting more forcefully and explicitly the high-level design principles for the "firm of the future". The book includes many elements which might be classified as design prin-

Namibie Etosha Girafe

Photo: Patrick Giraud, 2006 | Wikimedia Commons

ciples, but they tend to be spread out across multiple modules and not summarized or integrated for practical action.

• A call to action for both the practitioner and academic to close conceptual and practical knowledge gaps discussed above. The book has many after-the-fact examples where it appears desirable outcomes have been achieved more by luck than diligent application of the design principles. It might have been better to imagine examples and then issue a call to action to researchers and practitioners to test them and report on results, an approach used by McDonough and Braungart in *Cradle to Cradle*.

We are getting ahead of where the knowledge frontier currently exists, however *The Nature of Business* is a brave, necessary, valuable and helpful contribution to moving the frontier forward. Let the conversations and explorations of "right action towards positive transformation" flourish – and quickly.

Antony Upward is a Graduate Student of Sustainable Organizational Design at York University Faculty of Environmental Studies / Schulich School of Business and a Sustainability Business Architect and Principle of Edward James Consulting Ltd (http://www.Edward-James.biz/AntonyUpward). He is a founding member of the OCADU Strategic Innovation Lab Strongly Sustainable Business Model Group (http://slab.ocad.ca/SSBMs_Defining_the_Field).

Janice McDougall is a Certified Human Resource Professional (CHRP) with many years of business and social-profit experience. She is a Partner in Goodman, McDougall & Associates Ltd./The Learning Sanctuary (httpd://www.gmaltd.com), a husband/wife Human Resources consulting firm that provides facilitation and total rewards programs, services and strategies to a wide variety of organizations - public, private, government and social profit.

References

1. Benyus, J. M. (1993), *Biomimicry: Innovation Inspired by Nature*. William Morrow and Company.

2. Martin, R. L. (2009). *The design of business: why design thinking is the next competitive advantage*. Boston, Mass.: Harvard Business Press.

3. McDonough, W., Braungart, M. (2002), *Cradle to Cradle*. North Point Press.

4. Rockström, J. (2009). A safe operating space for humanity. *Nature, 461*(7263), 472.

5. Ehrenfeld, J. ,2008, *Sustainability by design: a subversive strategy for transforming our consumer culture*. New Haven: Yale University Press

6. See Bamberg, J. (2006). *Getting to scale: growing your business without selling out*. San Francisco, CA: Berrett-Koehler. *For SME examples where ex-anti the business people may have chosen to follow the authors espoused design principles for "firms of the future".*

7. Gharajedaghi, J. (2011). *Systems thinking: managing chaos and complexity : a platform for designing business architecture (3rd ed.)*. Burlington, Mass.: Morgan Kaufmann.

8. Lawn, P. A. (2001). Scale, prices, and biophysical assessments. *Ecological Economics, 38(3)*, 369-382. doi:10.1016/S0921-8009(01)00172-0.

9. Victor, P. A. (2008). *Managing without growth : slower by design, not disaster.* Cheltenham, UK ; Northampton, MA: Edward Elgar.

Publication Details

The Nature of Business: Redesigning for resilience
by Giles Hutchins

For North America:

New Society Publishers

www.newsociety.com/Books/N/The-Nature-of-Business

PB ISBN: 978-0-86571-737-4

Ebook ISBN: 978-1-55092-535-7

Published April 2013, available now for pre-order

For UK & Europe:

Green Books Ltd.

www.greenbooks.co.uk/natureofbusiness

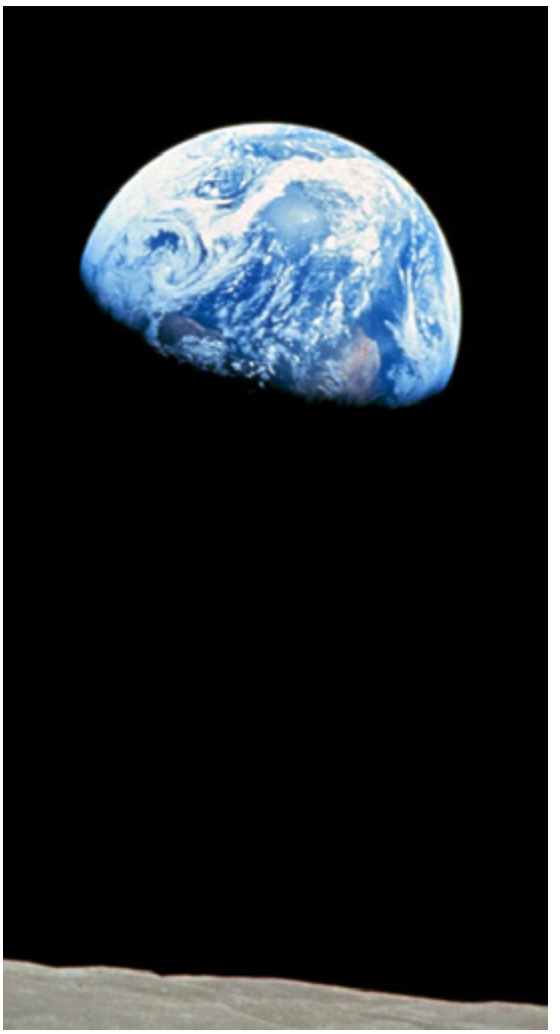
Published September 2012

Print edition ISBN 978 0 85784 049 6

PDF format ISBN 978 0 85784 049 3

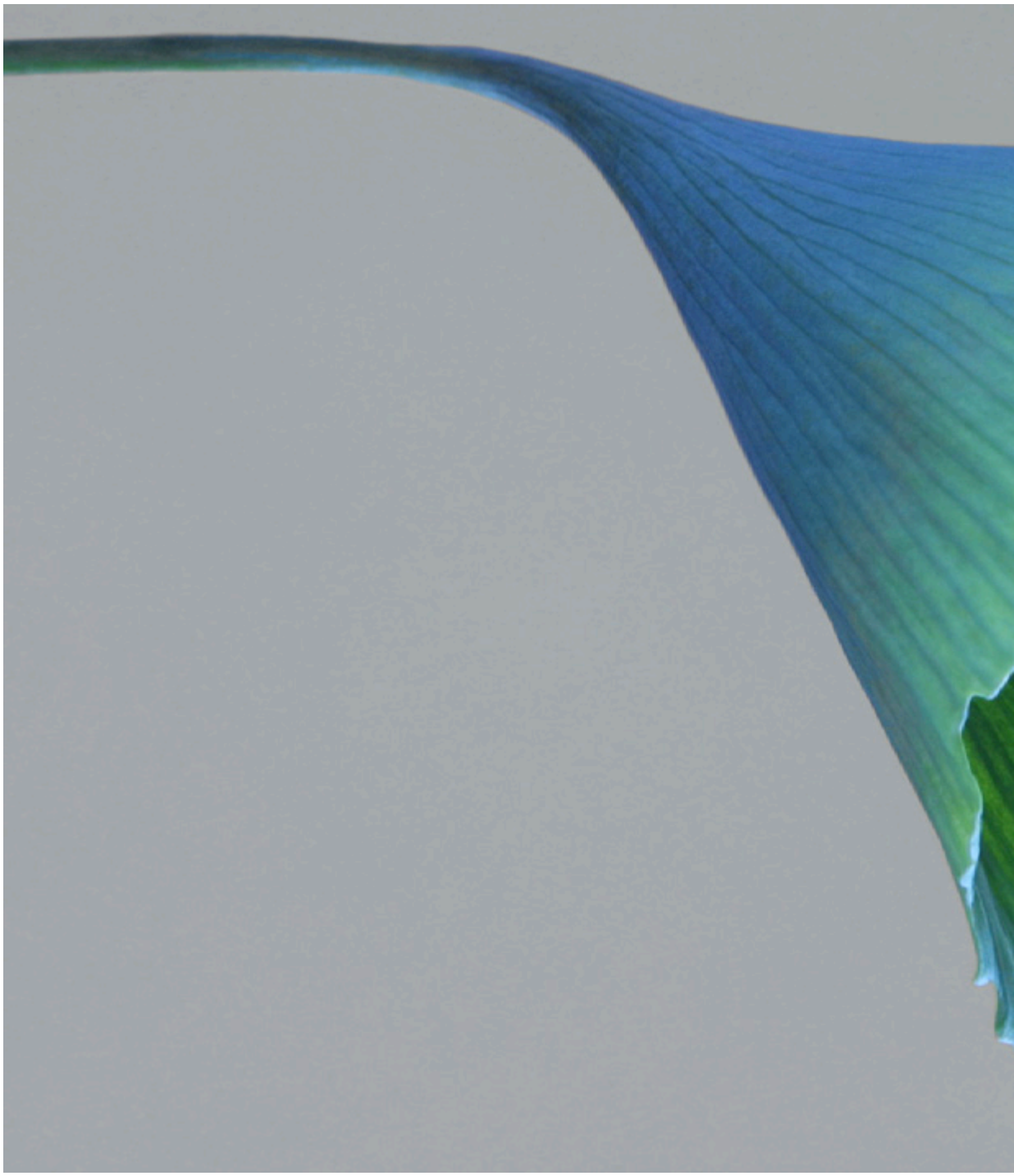
ePub format ISBN 978 0 85784 050 9

The format of this book review was based on Concordia University's How to write a book report and a book review (retrieved 2012/07/02 from http://library.concordia.ca/help/howto/bookreports.html)



Dec. 24, 1968: Earthrise (detail)

Photo: NASA Apollo8



Ginkgo biloba

Elena Lapeña| Flickr cc

Portfolio

Elena Lapeña

Elena Lapeña is an artist, researcher & professor in the Departament of Drawing in the Faculty of Fine Arts at the University of Vigo, Spain.

Could you tell us about your background and how you got started in the field of art and photography?

My interest in art has focused on painting, drawing and photography as ways to speak about the world of appearances, with its mute enigmas, its visual metaphors. I´m interested in contemplative states of art, the stopped time of painting, the slow arrow of beauty.

Mi interés por el arte se ha centrado en la pintura, el dibujo y la fotografía como maneras de contar el mundo de las apariencias, con sus enigmas mudos, sus metáforas visuales. Me interesan los estados contemplativos del arte, el tiempo detenido de la pintura y la lenta flecha de la belleza.

What kind of techniques do you use for your work? Do you use any software?

I row where the winds go. A pencil, a brush, a shadow, a trace, the erasing of time, are matters with which I work my ideas. My real software is my thinking. I´m interested in technique when it is a riddle, I prefer that an image has the double appearance of a photograph and a drawing, so that the interpretation of the reader can be free, wilder. I like a technique that rises towards the qualities of shadows.

Mis remos varían según los vientos. Un lápiz, un pincel, una sombra, una huella, el borrado del tiempo, son materias con las que trabajo las ideas. Mi verdadero software es el pensamiento. Me interesa la técnica cuando es un enigma, prefiero que una imagen tenga la doble apariencia de una fotografía o un dibujo, para que la interpretación del lector sea más libre, más salvaje. Que la técnica alcance la cualidad de las sombras.

How has your art/style changed since you first started?

My style depends on ideas and on atmospheric conditions, on climatology. In my first works in Madrid there was excess black, an accumulation of dark bile typical of melancholic temperament. Since I live in Galicia my work is very much colorful, contrasting its dull skies. I could say that over time my style has become more geometrical, or mathematical, more mental. I apply economy of means, I seek the strange, the limits between fiction and reality, and a kind of attention in the gaze.

Mi estilo depende de las ideas y de las condiciones atmosféricas, de la climatología. En mis primeros trabajos en Madrid había exceso de negro, una acumulación de bilis negra propia del temperamento melancólico. Desde que vivo en Galicia mi obra tiene mucho más color en contraste con los cielos apagados. Podría decir que con el paso del tiempo mi estilo se ha vuelto cada vez más geométrico, o más matemático, más mental. Me caracteriza la economía de medios, busco lo extraño, los límites entre la ficción y la realidad, y un tipo de atención en la mirada.

Asphodelus albus

How does photography influence the way you see the world? Do you feel that you see things around you differently?

I´m interested in the light of photography, which was really the subject of painting, the camera obscura that changes colors and profiles of the shapes. Transformation happens through art lenses, that let me see different worlds. Optical laws of photography allow me to look at mental architectures, at macrocosmos. I see what I think, and I think a lot about shadows and vanishing.

Me interesa de la fotografía la luz, lo que siempre fue el tema de la pintura, la cámara oscura que cambia los colores y el perfil de las formas. Como la pintura, la visión. La transformación se produce a través de los cristales del arte, que me deja ver otros mundos diferentes. Las lentes ópticas de la fotografía me permiten ver arquitecturas mentales y macrocosmos. Veo lo que pienso, y pienso mucho en las sombras y en todo lo que se desvanece.

Who/what inspires you creatively? What do you 'feed' on the most?

I´m inspired by art as much as by nature. The botany that can be found in literature and art. The asphodelus in The Odyssey, the flowers of evil in Baudelaire, the thistle in the hand in Dürer's selfportrait, or the box Chris Kelving was taking to Solaris in Andrei Tarkovsky film.

Me inspira tanto el arte como la naturaleza. La botánica que se encuentra en la literatura y en el arte. Los asfódelos de la Odisea, las flores del mal de Baudelaire, el cardo que sostiene Durero en su autorretrato de 1493 o la caja que llevaba Chris Kelvin a la estación Solaris de Andrei Tarkovsky.

What are you working on right now? Any exciting projects you want to tell us about?

Corintia is the name of my last work, a collection of forms abstracted from the pencil of Nature. Mycenaean, Byzantine and Corinthian elements appear evoked in tendrils, lilies and acanthuses. Ars gratia floris. Natural paradises make possible artificial paradises. Proletarian plants transformed into orderly architectures release from the indeterminacy and chaos of Nature.

Corintia es el título de mi trabajo más reciente. Es una colección de plantas sustraídas al lápiz de la naturaleza. Elementos micénicos, bizantinos y corintios aparecen evocados en pámpanos, lirios y acantos. Ars gratia floris. Los paraísos naturales hacen posible los paraísos artificiales. Las plantas proletarias, aisladas sobre fondos uniformes o vacíos, se transforman en arquitecturas ordenadas, liberadas de la indeterminación y del caos de la naturaleza.

Corintia is a set of inflorescences, shoots, corollas, cylinders, cones, spheres... Among more reviled flowers, among weeds, I select the ones at the edges of paths, those which are not merchandise. It´s a kind of return trip, a reading in reverse. Natura artem fingit. In nature I found primigenius shapes of art, drawings made with the law of minimum effort, geometry, immediacy, simplicity and abundance of details, Renaissance and Baroque. It´s a garden of botanical enigmas: *Agapanthus africanus, Asphodelus*

albus, Crocosmia crocosmiiflora, Digitalis purpurea, Kalanchoe, Laserpitum siler, Nigella damascena. My next project is Solaris, a collection of circular drawings made in a different station than Tarkovski´s *Solaris*, but likewise odd. Slow rhythm.

Corintia es un conjunto de inflorescencias, vástagos, corolas, cilindros, conos, esferas... Entre las flores más denostadas y las malas hierbas, selecciono las que hay en el borde de los caminos, las que no son mercancia. Es una especie de viaje de retorno, una lectura del revés. Natura artem fingit. En la naturaleza encuentro formas primigenias del arte, dibujos realizados con la ley del mínimo esfuerzo, simplicidad, geometría, inmediatez, sencillez y profusión de detalles, renacimiento y barroco. Es un jardín de enigmas botánicos. *Agapanthus africanus, Asphodelus albus, Crocosmia crocosmiiflora, Digitalis purpurea, Kalanchoe, Laserpitum siler, Nigella damascena*. Mi próximo proyecto es Solaris, una colección de dibujos circulares realizados en una estación diferente a la de *Solaris* de André Tarkovski, pero igual de extraña. Ritmo lento.

What is the last book you enjoyed?

I have revisited Stevenson´s *Treasure Island*, but with renewed eyes, after reading his Memories. This summer I have chosen books with islands, *The Encantadas*, or *Enchanted Isles* of Herman Melville, *Victory* of Joseph Conrad, and a great tale, a piece of floating ice, *The Artic* of Javier Sagarna.

He vuelto a leer *la isla del tesoro* de Robert Stevenson, pero con nuevos ojos, después de su memoria para el olvido. Este verano he escogido libros con islas. *Las Encantadas* de Herman Melville, *Victory* de Joseph Conrad y un extraordinario cuento, un pedazo de hielo flotante, *El ártico* de Javier Sagarna.

What are your favorite 3-5 websites, and why?

I used to connect with El País (online newspaper) and Noticias 24 horas (online newscast) to know what´s happening in the world. Actual political situation in Spain is terrifying, government wants to destroy sanitary and educative services in the name of the crisis...Google books also helps me in my investigations in Vigo University.

Utilizo El país, 24 horas noticias, para saber lo que sucede en el mundo. La situación política actual en España es espeluznante, quieren acabar con la salud y la educación pública en nombre de la crisis... El buscador de google book me ayuda como artista investigadora de la Universidad de Vigo.

What's your favorite motto or quotation?

A sentence of James Joyce´s *Ulysses*, speaking about the mistakes of an artist of genius, when Steven Dedalus says: "His errors are volitional and are the portals of discovery".

Una frase de James Joyce en *Ulises*, hablando de los errores de un artista de genio, cuando Steven Dedalus dice: "Sus errores son voluntarios y son los pórticos del descubrimiento".

Errors are marks of authenticity of works of art, because forgers don´t copy failures, they don´t recognize the beauty of intentional imperfection. If an archer throws his arrow out of target, his error can be a wise shot in a far-off target.

Los errores son marcas de autenticidad de las obras de arte, pues los falsificadores no copian los fallos, ni reconocen la belleza de lo imperfecto intencionado. Si un arquero lanza la flecha fuera de la diana, su error puede ser un acierto en una diana más lejana.

Elena Lapeña has a doctorate degree from the Faculty of Fine Arts at the Complutense University of Madrid; her thesis was entitled El temperamento melancólico (The melancholy temperament). She is a professor of drawing in the Faculty of Fine Arts at the University of Vigo (Spain) and a researcher in DX5 (Digital & graphic art research).

Solo exhibitions:

Corintia (2012, Open Ateliers Westelijke Eilanden, Ámsterdam).

Collection of plants (2009, House of the 100 windows, Coro, Venezuela).

Acrobats (1999, Orient Gallery, Santiago de Cuba).

About air (1998, Ars and Design Provincial Center, La Habana).

International group exhibitions:

Solaris [2011, FLU, Belgrade (Serbia).

PUC, Campinas (Brasil), Académie Royale des Beaux Arts, Liège (France), University of Québec, Tríos-Rivières (Canada)].

Solar ventilator (1997, Kulturmodell, Passau, Germany),

Chesire whale (1995, 9 with something, Edinburgh, Scotland).

Ice-ver (1989, The Australian Video Festival, Sydney).

Spanish group exhibitions:

Air of sphinx (2011, Pontevedra).

Hiroshima (2006, Estampa, Madrid).

Jayavarman´s smile (2004, House of Arts, Vigo).

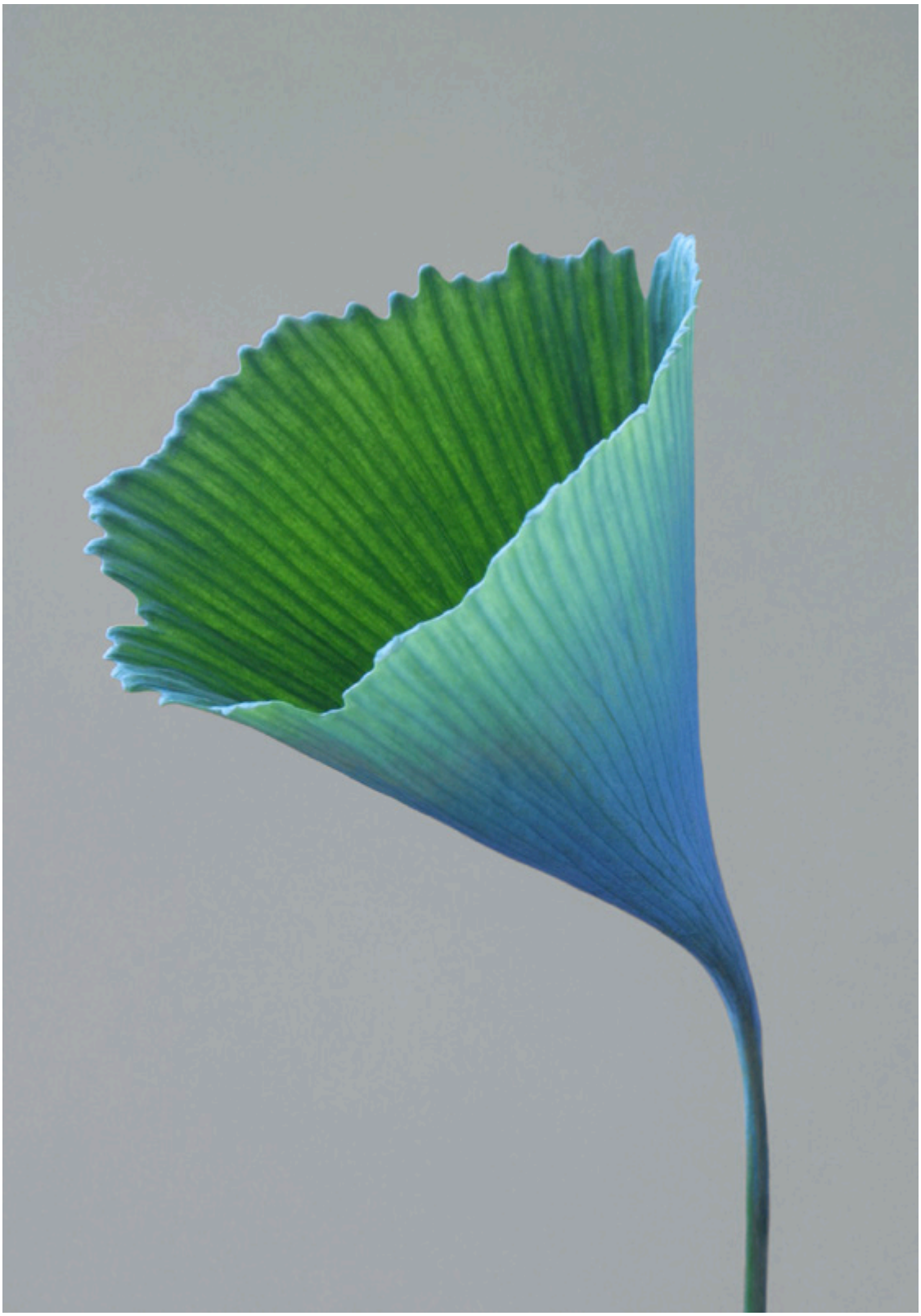
Tightrope walker (1999, Abel Lepina Gallery, Vigo).

The cup of tea is hidden under the cypress (1989, Fine Arts Circle, Madrid).

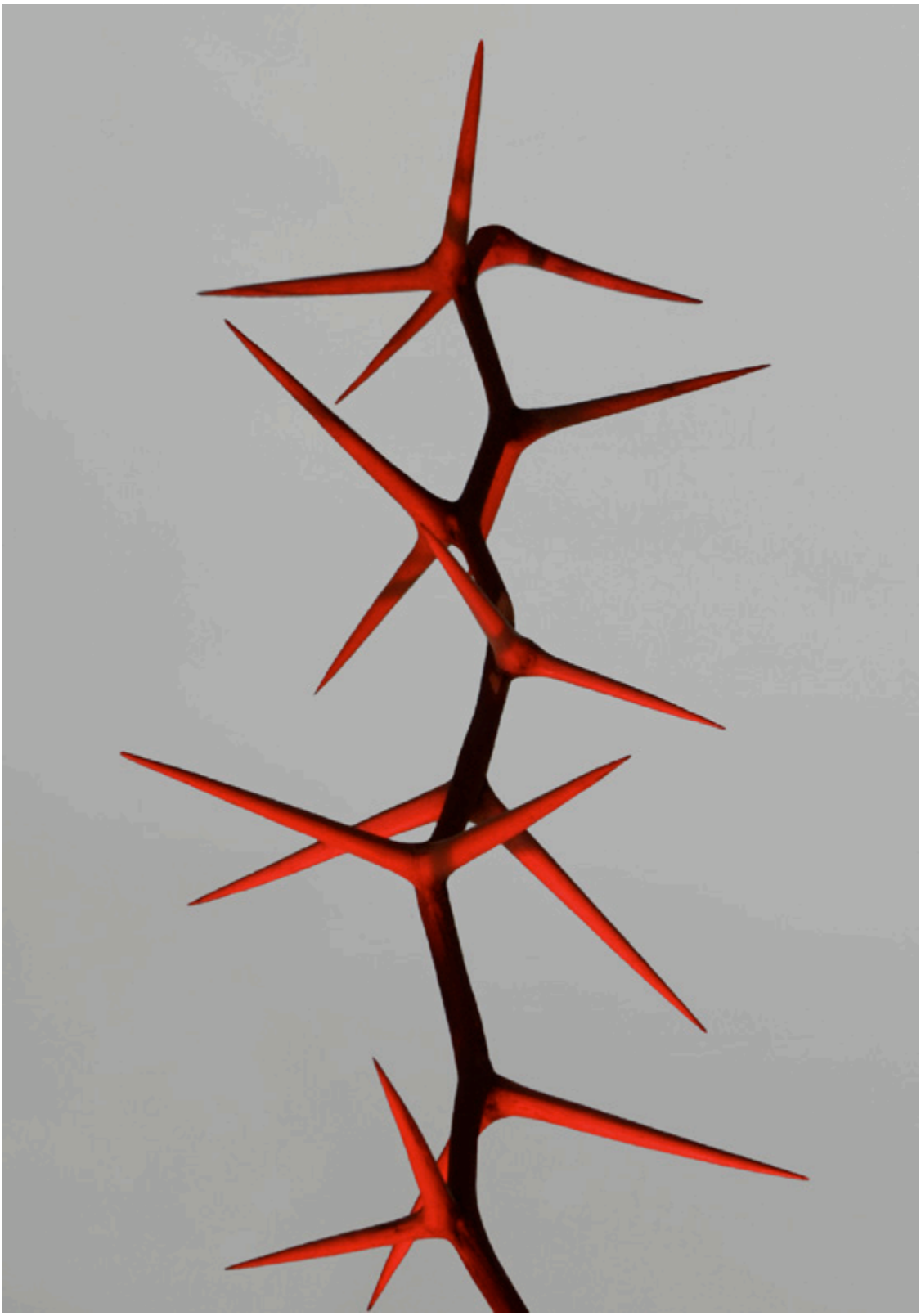
Slept tree (1988, Circuits, House of ring, Madrid).

Elena Lapeña is the author of the following articles: Patinando en un rasguño (Skating in a scratch, 2012), Del faro a la ventana (From the lighthouse to the window, 2007), Del espejo de Claude Lorrain a otros extensores sensoriales (From the Claude Lorrain´s mirror to the other sensory extensors, 2006), Una pala de nieve o el calor de un cuadro en el bolsillo (A snow spade or a picture´s heat in the pocket, 2004).

She supervises doctorate and masters students in ESAP, Porto (Portugal) and at the University of Vigo.



Ginkgo biloba



Prosopis juliflora

Hydrangea hortensia

Agapanthus africanus

Digitalis purpurea

Crocosmia crocosmiiflora

Eschscholtzia californica

Allium sativum

Alien Egg

Photo: Bushman.K, 2011 | Flickr cc

People
Interviews with
Wes Jackson, John Crowe & Ilaria Mazzoleni

Interview
Wes Jackson

Interview with Wes Jackson

Wes Jackson, President of The Land Institute, was born in 1936 on a farm near Topeka, Kansas. After attending Kansas Wesleyan (B.A Biology, 1958), he studied botany (M.A. University of Kansas, 1960) and genetics (Ph.D. North Carolina State University, 1967). He was a professor of biology at Kansas Wesleyan and later established the Environmental Studies department at California State University, Sacramento, where he became a tenured full professor. He resigned that position in 1976 and returned to Kansas to found The Land Institute.

Dr. Jackson's writings include both papers and books. His most recent works, Nature as Measure (2011) and Consulting the Genius of the Place: An Ecological Approach to a New Agriculture (2010), were both published by Counterpoint Press. The Virtues of Ignorance: Complexity, Sustainability, and the Limits of Knowledge (2008) and Rooted in the Land: Essays on Community and Place (1996), were co-edited with William Vitek. Becoming Native to This Place, 1994, sketches his vision for the resettlement of America's rural communities. Altars of Unhewn Stone appeared in 1987 and Meeting the Expectations of the Land, edited with Wendell Berry and Bruce Colman, was published in 1984. New Roots for Agriculture, 1980, outlines the basis for the agricultural research at The Land Institute.

The work of The Land Institute has been featured extensively in the popular media including The Atlantic Monthly, Audubon, National Geographic, Time Magazine, Yes! Magazine, The MacNeil-Lehrer News Hour, and National Public Radio's "All Things Considered." Life magazine named Wes Jackson as one of 18 individuals they predict will be among the 100 "important Americans of the 20th century." In the November 2005 issue, Smithsonian named him one of "35 Who Made a Difference." He was included in Rolling Stone's "100 Agents of Change" in March, 2009 and in Ingram's "50 Kansans You Should Know" in January 2011.

Wes Jackson is a recipient of the Pew Conservation Scholars award (1990), a MacArthur Fellowship (1992), Right Livelihood Award (Stockholm), known as "Alternative Nobel Prize" (2000), and the Louis Bromfield Award (2010). He has received four honorary doctorates. In 2007 he received the University of Kansas Distinguished Service Award and was one of the 2011 recipients of the University of Kansas College of Liberal Arts & Sciences' Distinguished Alumni Awards. Garden Club of America awarded him the Elizabeth Craig Weaver Proctor Medal in 2012.

In addition to lecturing nationwide and abroad, Dr. Jackson is involved outside The Land Institute with a variety of projects including being a Post Carbon Institute Fellow, a Councillor with the World Future Council and a member of the Green Lands Blue Waters Steering Committee.

What are your impressions of the current state of biomimicry/bio-inspired design?

Well, it seems to be getting more attention. This idea of following nature's designs considering how late we are in the industrial period is long overdue given the consequences of fossil fuel

The Land Institute Research Plots

Photo courtesy of Wes Jackson and The Land Institute

The Land Institute Research Plots

Photo courtesy of Wes Jackson and The Land Institute

use, global warming and what the industrial mind has done to the land and water. All of this is causing people to look to nature's arrangements that have evolved over millions of years using contemporary sunlight. People seem to be realizing that the extractive economy is coming to an end. It is good to have articulate folk such as Janine Benyus make an issue of this.

What do you see as the biggest challenges?

The biggest challenge is to stop economic growth. It's dependent upon energy and material nonrenewables; and nature's sinks are filling up. As the awareness of that becomes greater we will have to look elsewhere. The industrial world has had its chance to think about how we can have a renewable approach to the world. So, the challenge now is for more people to have more ecological knowledge soon and not wait on the consequences of deficit spending of natural resources to reduce our options. We're in the midst of a drought right now in the Great Plains and Midwest. People are paying attention to food and water now, but will it last once we get some rain?

What areas should we be focusing on to advance the field of biomimicry?

I hope the biomimicry advocates won't allow themselves to get stuck with how to make a stronger cable simply by looking at a spider's web. That could be just another way to exercise human cleverness. The challenge for biomimicry advocates is to look at nature's wisdom in the broad sense, not in a human cleverness sense, which means, I think, to feature ecosystem thinking.

How have you developed your interest in biomimicry/bio-inspired design?

By looking at the prairie, which needs no nonrenewable inputs. I didn't think of biomimicry as a "field" when I started thinking of the prairie as an analogy or analog or measure (never a template) for a sustainable agriculture. Probably Janine Benyus came up with the word and I saw it was appropriate for what we are doing.

What is your best definition of what we do?

I don't think strong advocacy is merely something to do. It looks like there's growth in the number following the idea. People seem to find it intrinsically interesting. They don't seem to need to be persuaded. I see no rebellion against the idea of biomimicry.

I don't believe there is a tight definition for everybody that's at work on the idea. At the Land Institute we look to nature's ecosystems, at the prairie as a standard or measure. We've talked about the importance of imitating the prairie's structure in order to be granted the functions. The structure of a prairie features perennials grown in mixtures. Then, we go to the next step and ask what are these mixtures? There are four functional groups: warm season grasses, cool season grasses, legumes and members of the sunflower family. We don't know how many species are there as a result of some ecological imperative and how many of them as a result of

some history. So, that's the ecologist's point of view; and that's the way we work. That approach is very different from someone, going back to the earlier example of some strong metal or organic thread and comparing it to a spider's web. So, it seems to me it kind of escapes tight definition. Biomimicry people look at nature's designs and see where they're applicable for helping us move from a world that has regarded nature as something to be subdued or ignored and the sort of world where we look to nature as a sort of standard or measure. So, it's more of an operating philosophy. Explicit examples are all over the place.

By what criteria should we judge the work?

I can only tell you from the point of view of our work here. We start with the question of: What was here? What was here was prairie. And then the next question is: What will nature require of us here? And the third question is: What will nature help us do here? I don't know if you count those as criteria or not but those are our three operating questions.

What are you working on right now?

The Land Institute is devoted to perennializing the major crops – the grains. We're also supporting the perennialization of upland rice in China. We have colleagues there. The goal is to put our species in mixtures so we can have an agriculture that functions pretty much like a native prairie with the prairie as our standard or measure against which we'll be judging our agricultural practices. We do so because the prairie doesn't have soil erosion beyond natural replacement levels. It runs on contemporary sunlight. With species diversity there is chemical diversity, meaning it would take a tremendous enzyme system on the part of an insect or pathogen population to create an epidemic. A prairie will fix its own nitrogen biologically. It uses contemporary sunlight instead of being dependent upon fossil carbon; and it features material recycling. To study such a system requires ecologists who, whether they know it or not, are learning about "nature's wisdom." Plant breeders are more inclined to feature "the human cleverness" approach and that is what we are mostly about now at The Land Institute. We believe, however, that human cleverness should always be subordinate to nature's wisdom.

In the Genesis myth there is the Tree of Knowledge and the Tree of Life. Adam and Eve partook of the fruit of the Tree of Knowledge, were driven from the garden and from then on the angel with the flaming sword has denied access to the Tree of Life. The Tree of Life as I see it, is symbolic of nature. In our time we're asking the angel to sheath the sword because we have to have access to the Tree of Life, which is, I would say, the ecosystems operating within the ecosphere.

How did you get started in biomimicry/bio-inspired design?

It was 1977. I had been reading the General Accounting Office study about the money being spent for soil erosion by the Soil Conservation Service. It looked to me like soil erosion was as bad in 1977 as when the Soil Conservation Service had been formed back in the mid-30's during the Roosevelt administration. I thought how can this be? We had thousands of miles of ter-

The Land Institute Research Plots

Photo courtesy of Wes Jackson and The Land Institute

races, grass waterways. We had various scientists within SCS and the esprit de corps devoted to stopping soil erosion was huge. After reading the report, I again started reading about the history of earth abuse through agriculture. Going back over the 10,000-year period we've had agriculture, I realized that the plow and the hoe stand behind the first systematic effort to disturb the ground. To get an annual seed to germinate like wheat or corn or soybean – any of the grains – much of nature has to be subdued or ignored. About the same time I took my students on a field trip to the Konza Prairie 70 miles away. On that field trip it became clear that the prairie is a sustainable system while the fields of wheat, corn and soybean were all dependent upon the extractive economy. The main difference: the prairie has perennial mixtures. Our crops are annual monocultures. Why not breed perennials? Well, where to start? A relative of wheat? A relative of sorghum? Or a relative of sunflowers – which are all annuals. See if we can perennialize them? How about collecting some wild perennials, domesticate them and turn them into grain producers? Some 70% of our acreage worldwide is devoted to grains and those happen to also be about 70% of our calories. So, if we're to solve the 10,000-year-old problems of agriculture we're going to have to deal with the grains.

Which work/image have you seen recently that really excited you?

It's interesting to visit the research plots our gifted young scientists have established. For instance, we're eating now the Kernza, which is a plant that has been developed by Dr. Lee DeHaan. It's a relative of wheat and a perennial. It's not farmer-ready yet; but will be in about nine to ten years especially if the farmer can be working alongside an agronomist or an ecologist. I think that will happen. Dr. Shuwen Wang is a molecular geneticist working to develop perennial wheat. He uses chromosome markers to assist in breeding (he is not doing gene splicing). Dr. David Van Tassel is making good progress with the sunflowers – some perennial sunflowers - which are an important oil seed crop. You look at the bottle in your pantry and you'll see that. He is also working on Illinois bundleflower, a legume. Dr. Stan Cox has a winter-hardy sorghum; but that too is going to take a lot of breeding. Various scientists around the world now have our germplasm and research efforts, whether we're talking about Manitoba (some of our guys just got back from there), Nepal, Australia ... I already mentioned we are supporting the perennialization of upland rice in China. So, I think this effort has enough of a life of its own already that in the foreseeable future it can make it on its own.

What is your favorite biomimetic work of all time?

Our work here.

What is the last book you enjoyed?

You mean I enjoyed writing? I read in a lot of books all at once and never read the whole book. My book *Consulting the Genius of a Place* which came out in 2010, has gone beyond some of the earlier books I'd written. Of the books I've read, Painter's book on the collapse of complex soci-

eties, a book on conceptual revolutions. One of the old time books I keep going back to is *Environment, Power and Society* by H.T. Odum. I'm looking a lot at psychology now. I wonder why it is that people can't get a grip on global warming and the need to stop deficit spending; and why we can't get politicians to talk about the need to cut energy use; and why we can't get a discussion on the need to end economic growth and figure out how to take care of everyone?

Who do you admire? Why...

Well, Wendell Berry is both a friend and kind of my guru. I think Wendell's thought about these problems more carefully than anyone I know. But I also admire members of our Board of Directors. We have quite an intellectual bunch – Don Worster is a founder of environmental history. Angus Wright, currently our Chair, is a retired professor of environmental studies from California State/Sacramento. He knows more about the depth of the broad spectrum of environmental issues than anyone I know. David Orr is not on our board, but he is the most encyclopedic environmentalist I know. I've got a whole bunch of people that I admire and that I'm indebted to. In fact, in the acknowledgements of one of my books I told about how I don't have a mind of my own and that I have this huge debt to countless people.

What's your favorite motto or quotation?

If you're working on something you can finish in your lifetime, you're not thinking big enough. (Who said that?) Well, I said it. Because our work is long-term so it justifies our work.

What is your idea of perfect happiness?

I don't know if there is such a thing as perfect happiness but I would say that if you're able to use your education, your accumulated knowledge as a passport to responsibility rather than a passport to privilege, it's likely to increase your satisfaction, if not happiness. With the passport to privilege, we see many unhappy people. The passport to responsibility in the service of others or the ecosphere is satisfying. Gandhi said something like "The happiest are those who are in the service of others." As David Orr says, "It's all hands on deck time" and we've got to really think about how to help these young people where we can to get started on the transition they're going to have to make.

If not a scientist/designer/educator, who/what would you be?

Well, I think I might want to study art history since art has a way of telling about our journey almost as clearly as the written words about our journey. One goes back to the Greeks, the Romans, the Egyptians, go through Europe in the Middle Ages, the people's art has a way of shining through and giving some insight to those folk, what they valued and the world being seen without fossil fuels. Also, the history of ideas and the history of science seem interesting – I might want to get into that. That said, I'm trained in genetics and I've never once regretted that. I've been interested in heredity from childhood. All of that said, if I were smart enough I would want have most greatly benefitted from studying literature and writing.

Tardigrade Pm kenianus 300x

Image Courtesy of FEI Image captured by Oliver Meckes

[www.fei.com/resources/image-gallery/Tardigr-Pm-kenianus.aspx]

Interview
John Crowe

Interview with John Crowe

John Crowe is a Distinguished Professor Emeritus at the Univerity of California, Davis, and was a professor of Zoology and Molecular and Cellular Biology and Chairman of the Zoology Department there. He is a Elected Fellow of the American Association for the Advancement of Science, Corpus Christi College at Oxford, and of the Society for Cryobiology where he is a member of the Board of Governors and President. He is also a Board Member of the companies Biomatrica, San Diego, CA and Cellphire, Rockville, MD. He is Chairman of the Board of the Mondavi Center, Davis, CA. In addition to his teaching he has been active as an editor, serving on the editorial boards of the Journal of Experimental Zoology, Molecular Physiology, American Zoologist, Biochemistry, Cryobiology, and the Journal of Pharmaceutical Science, among others.

What are your impressions of the current state of biomimicry/bio-inspired design?

This is an exciting time for this new field. I say it's new, but actually it's been around a long time, although we didn't call it that until Janine's seminal book appeared. I must confess that I had never even heard the term until I was asked to come along and give a talk at one of the biomimicry meetings. I read Janine's book (Janine Benyus, *Biomimicry: Innovation Inspired by Nature*) and discovered that this is what we've been doing for decades but never realized it.

What do you see as the biggest challenges?

Using biomimicry to solve problems of interest in human welfare is an appealing approach that cuts across all disciplines: from agriculture to engineering to medicine. Education of the public about how effective this approach can be, and perhaps more to the point, educating industry and the granting agencies that fund the work is essential. Once you hear about what's going on in the field just about everybody buys into it. Janine's book went a long way towards crystallizing thinking in this regard, but more is needed.

What areas should we be focusing on to advance the field of biomimicry?

It is essential that the basic research that fuels the biomimicry approach be maintained. I am concerned that application driven research is again threatening to displace basic research as a critical scientific mission. Without that research the enterprise will come to a halt. Having said that, there is a vast reservoir of basic research that still needs to be exploited for biomimicry. The applied scientists who are interested in solving problems in human welfare need to be educated about what is already out there. That's a significant challenge. .

How have you developed your interest in biomimicry/bio-inspired design?

My own biomimicry work came from basic research on organisms in nature that survive complete dehydration. We studied their chemistry for many years and came to the conclusion that much of what permits them to survive the insults of drying can be understood from a few fundamental principles. We then realized that we could apply to those principles to preserve living cells and parts of cells. We called that "Lessons from Nature", and still do (although we should start using the biomimicry term). That approach has spawned numerous industries.

What is your best definition of what we do?

We seek to solve problems by studying how living things solve those problems in nature; nature has already solved many such problems, but we have to understand nature's solutions to take advantage of them.

What are you working on right now?

I'm retired from active research, but I still serve on boards for three companies that are using our research in industrial applications, and I am president of the Society for Cryobiology, the leading society with interests in preservation of biomaterials, pharmaceuticals, and the like by freezing and freeze-drying.

How did you get started in biomimicry/bio-inspired design?

I was a teenager in the 1950's, when post-sputnik money flowed freely for science, and particularly for science education. There was a massive effort to recruit bright kids to take up science as a career, and I spent three summers in university research labs as a result—at science boot camp, in effect. One of those summers I first read about interesting microscopic animals, particularly tardigrades, that can survive complete dehydration for decades at a time. I found that utterly fascinating when I was 15 years old and decided then that I had find out how they did this. Thirty-five years later I was discovering that what we had learned about these animals was leading to applications in the pharmaceutical and medical worlds.

What is your favorite biomimetic work of all time?

My own, of course. Just kidding. My favorite at the moment is the work of a new company, Biomatrica, who are using chemistry from nature to store DNA in the dry state. DNA is usually stored at liquid nitrogen temperatures, or in ultra low temperature freezers. Biomatrica's work is obviating the need for these freezers, saving enormous amounts of energy and greenhouse gases. Stanford University is beginning to shut down their DNA freezers!

What is the last book you enjoyed?

I read widely, and a lot. I'm in the middle of a fascinating detective series involving a violin maker

Tardigrade E granul 700x [also p. 9]

Image Courtesy of FEI Image captured by Oliver Meckes

[www.fei.com/resources/image-gallery/Tardigr-E-granul.aspx]

in Cremona right now. Just before that I read a book by Nicholas Mee on the Higgs boson, and just before that a book called *Cooking for Geeks*, and just before that a biography of the opera singer Birgit Nilsson.

Who do you admire? Why...

Lots of people, but Bill Clinton comes to mind, for his passion for the country and his leadership of the world.

What's your favorite motto or quotation?

The hotel manager in The Best Exotic Marigold Hotel: "Everything will be alright in the end, and if it's not alright, it's not yet the end."

What is your idea of perfect happiness?

A weekend of sailing and opera.

If not a scientist/designer/educator, who/what would you be?

When I was 14 or so I thought about a career in music, but by the time I was 18 and spent those summers in science boot camp I realized I would never be good enough as a performer. But I might have been an arts administrator. I think I could have been happy at that. Since retirement my interests in that direction have revived, and my wife and I now see about 20 operas a year, about 25 plays, and about 50 other performances (dance, symphonic works, chamber music, etc.). I serve on boards for three arts organizations, so I see how arts administration works. Yep, that would've been fun, but so is doing science.

Tardigrade Pm kenianus 300x

Image Courtesy of FEI Image captured by Oliver Meckes

[www.fei.com/resources/image-gallery/Tardigr-Pm-kenianus.aspx]

Ruby Throated Hummingbird

Photo: chrisdupe, 2011 | Flickr cc

Interview
Ilaria Mazzoleni

Ilaria Mazzoleni is an architect and the founding principal of IM Studio Milano/Los Angeles (www.imstudio.us). Since 2005 she has been a full time faculty at SCI-Arc in Los Angeles (www.sciarc.edu). Her professional and academic investigation relates to sustainable architecture and building technologies at all scales of design, with research focusing on Biomimicry - innovation in architecture and design inspired by the processes and functions of nature.

Collaborating with biologists and other scientists from top research institutions, her team's projects explore eco-systems which suggest methods of developing sustainable urban planning strategies and address solutions to global climate change. More detailed studies focus on natural processes and forms, and apply them to building façades.

Her current investigations use design as a vehicle to promote awareness about endangered species and emphasize the importance of biodiversity in regions around the world. IM Studio explores further the performative capacities of these organic systems through a juxtaposition between real and digital space.

Over the years, Ilaria Mazzoleni's work has been published internationally. She has participated in exhibitions and international conferences and is a regular contributor to architectural magazines.

What are your impressions of the current state of biomimicry/bio-inspired design?

Biomimicry is quickly developing and reaches out to all fields: expanding from engineering to design, architecture and the arts. As an architect, it is very exciting to see a field initiated only a few years ago easily gaining a critical mass and creating a real impact in producing change.

What do you see as the biggest challenges?

By being an actor and having constructive dialogues between the people that work in this field and beyond. The interdisciplinary nature of biomimicry is its strength, however the semantic confusion is currently limiting clear communication and proficient collaborations.

What areas should we be focusing on to advance the field of biomimicry?

In addition to refining biomimicry's semantics, as a critical step to elevating communication and shortening the learning process between disciplines, it is critical to facilitate advanced research useful to the business world. Biologists and designers are currently sitting at the same table, but missing are the ones that can bring their new ideas and concepts to the general public. I feel the next big change we need is in economics: at the macro level biomimetic experts should sit at the table with economists and policy makers, who are working around climate change issues, and can bring in a systems perspective. At the micro level, biomimetic experts should sit at the table with business executives and managers that make decision about taking products and services to market. No new biomimetic project, product and service can be successful if there is no involvement of all these parties.

How have you developed your interest in biomimicry/bio-inspired design?

Since my undergraduate studies at the Politecnico in Milano, Italy, my professor, Silvia Pi-

Weaver Ant Nest Making Crew

Photo: Troup 1, 2011 | Flickr cc

ardi, encouraged me to research methods to design buildings more sustainably. Over time I met more and more people with similar interests that helped me develop these initial thoughts, moving from the sustainable approaches to designing buildings to discovering inspiration directly from nature. While searching for ways of designing beautiful buildings that also performed environmentally, I stumbled upon a book, *Body Heat: Temperature and Life on Earth* by Mark S. Blumberg. This book opened my eyes to a new world, the one that the following book by Janine Benyus helped me to recognize as biomimicry. After teaching sustainable building systems one semester at SCI-Arc in 2004, I quickly learned that my students were interested in the topic, but not in the highly engineered way they were exposed to currently. The engineering of the building system solution leaves limited space for the creative mind of young designers, while nature's solutions provide an incredible "aha" moment for design, thus I started implementing courses in bio-inspired design and conducting more research based projects in my studio.

What is your best definition of what we do?

We are helping our species thrive. Someone said that we are not destroying our planet, but rather destroying ourselves. If we are not ok with this, we better do something to survive! And do it fast! Architecture has a powerful and influential position in this restorative effort, and being both a professional and an educator I feel a strong responsibility and desire for the active participation of leading the change.

By what criteria should we judge the work?

Improving the way we, with our buildings, insert ourselves in nature. We are biologically part of nature, but over time we have detached and separated ourselves from it. We need to return to thinking we are a part of nature.

What are you working on right now?

I am on the last editing phase of the book substantially influenced by biomimicry on the analogy animal skins / building envelopes, by CRC Press, due to be released in Fall 2012. The book will be organized in two parts: an introductory one, or Theoretical Framework, and an Applications one, with twelve case studies illustrating the developed methodology. The book is the result of my long lasting collaboration with biologist Shauna Price and includes the committed work with and by my students at SCI-Arc.

More recent research includes work on bio-inspired materials, and natural connections. My recent research examines how individual architectural elements might be improved by studying how nature has been solving morphological issues in relationship to material solutions.

How did you get started in biomimicry/bio-inspired design?

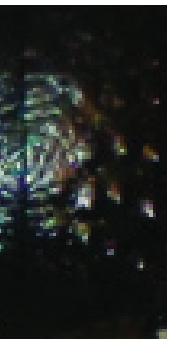
After an initial intensive research period, in which I read several books on evolution, animal biology and ecology, and had several conversation with my biologist friends, my first bio-inspired works emerged. As speculative projects, some of which were competition entries, others, like the ones

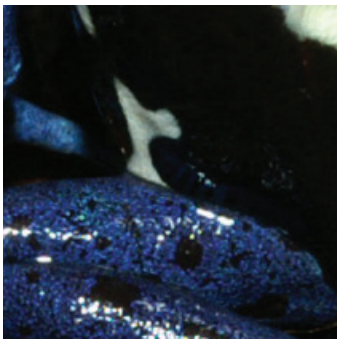
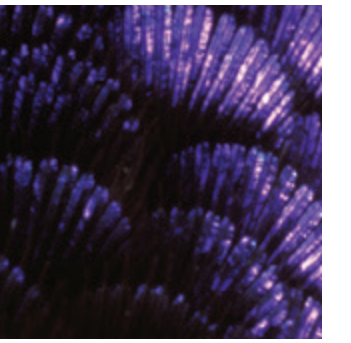
Polar bear on ice flow in Wager Bay (Ukkusiksalik National Park, Nunavut, Canada)

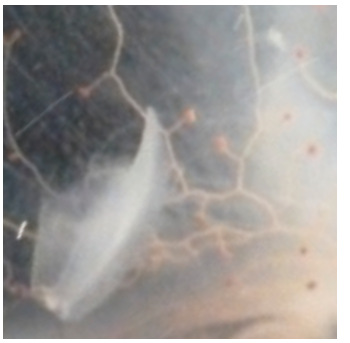
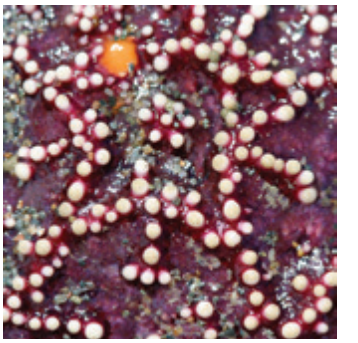
Photo: Ansgar Walk, 1996 | Wikimedia Commons

"Animal skin coverings"

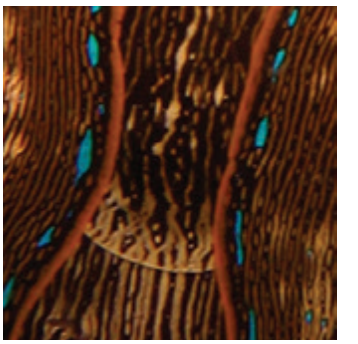
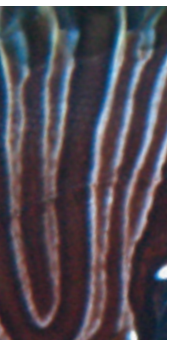
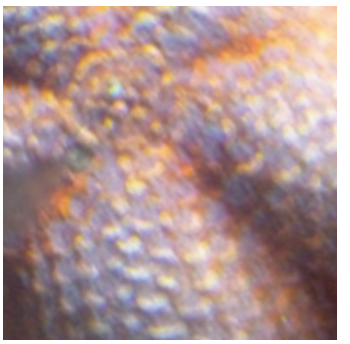
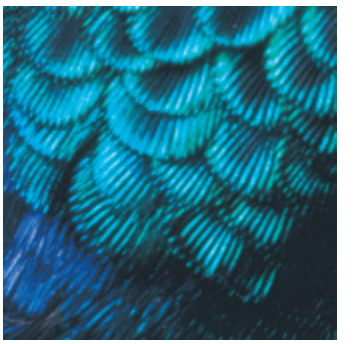
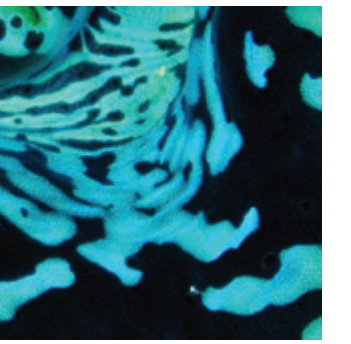
Courtesy of IM Studio, 2012





prepared for the 11th International Architectural Venice Biennale, *Out there, Architecture Beyond Building*, where I presented, invited by Stefano Boeri and the magazine Abitare, five projects inspired by five different animals.

Which work/image have you seen recently that really excited you?

Being in nature is the most powerful "image" I keep in my heart. I feel we have been relying upon, perhaps too much, the powerfully developed sense of sight. We read and explore with our vision, but this happens mostly at the level of digital explorations which limits our experiences to only one of our senses. While to really understand and feel "things" we need to immerse ourselves in them. Walking in the woods of my Alpine village is one of the most inspiring experience: all senses are so "taken" , so there, so awake, that all sorts of inspirations arise. What for many is considered only a physical exercise for me is a full body and mental immersion.

What is your favorite biomimetic work of all time?

An easy answer would be the work of Leonardo da Vinci, the first biomimetic designer! But I would like to mention the more contemporary work of Yoseph Bar-Cohen. I admire his breath and ability, as a scientist, to focus on his research, yet to act as a catalyst. He has been generously reaching out to many scientists helping spread their research. I admire that generosity and ability as it greatly contributes to built up interest for bio-inspired design.

What is the last book you enjoyed?

I just re-read *Cats' Paws and Catapults: Mechanical Worlds of Nature and People* by Steven Vogel, which continues to be a source of inspiration for me. And I am looking forward to reading his forthcoming *The Life of a Leaf*.

Who do you admire? Why...

I admire people that are respectful of and curious about all aspects of nature. Not only about human nature but everything else that composes and is part of our lives. This higher level of respect is found in a few people who tend to be more straight forward, clear and open to diversity.

What's your favorite motto or quotation?

Aristotle said: "Nature does nothing uselessly".

What is your idea of perfect happiness?

Living fully which means action (contributing with what you can and what you know) and to continue learning. Doing what one likes with passion and full commitment. This way one would be a better person, for oneself and for the ones around him/her.

If not a designer/educator, who/what would you be?

A zoologist. I always liked the idea of field studies, traveling to remote places of the world to observe and learn about animals and their environments, document them and so ultimately... be inspired to improve the way we, humans, are transforming our planet.

info@imstudio.us | www.imstudio.us

Beaver

Photo: Travis S., 2007 | Flickr cc

Untitled

Photo: m4tik, 2010 | Flickr cc

Opinion
Biomimicry's Place in Green Design

Jeremy Faludi

fall 2012

Article:
Opinion

Author:
Jeremy Faludi

Biomimicry's Place in Green Design

Jeremy Faludi (LEED AP BD+C), is a sustainable design strategist and educator. He designed the prototype of AskNature.org for The Biomimicry Institute, and a bicycle he helped design was in the Cooper-Hewitt Museum's exhibit "Design for the Other 90%". He has taught green product design at Stanford University, Minneapolis College of Art & Design, and other schools, as well as businesses and conferences, and has contributed to five books on sustainability, including *Worldchanging: A User's Guide for the 21st Century*.

Biomimicry is an amazingly powerful tool, and paradigm, for sustainability. It's useful for designers, engineers, architects, even business people. However, like any tool and any method of thought, there are some things that it does very well, and other things that other tools do better. To use biomimicry to its fullest potential, we should understand what it's best at, where to complement it with other tools, and what other tools work best with it.

All Tools Are Paradigms, All Paradigms Are Tools

"When you have a hammer, every problem looks like a nail", they say. That's true of all tools: each one is its own world of thought, its own approach to problem solving. By the same token, any school of thought is also a tool, which we use to manage our world in some way. We notice this especially for hammers, a tool of limited function, and, conceivably, approach. If the problem you're solving is to make a magazine, you'll quickly realize that a hammer is not the best tool for the job. You might get interesting results, but if you try to make a magazine with only a hammer, it'll not only be really hard for you, but you'll have a difficult time convincing anyone else that they should do things your way. Biomimicry is an extremely powerful tool and paradigm for sustainability, but, in my opinion, it has its limits, as all tools do. Thus, if you know how to integrate it with other tools and paradigms (rather than trying to use it for everything), you'll go farther and bring more people along with you.

The more powerful a tool, the more powerful its paradigm, and thus the more people tend to use it for everything. For instance, you could make a magazine spread with Photoshop or with PowerPoint. Both are powerful tools, and each more relevant than a hammer, but each has its different approach, which makes some things easy and some things hard. The decisions you make as a result of their different paradigms has a big influence on what your resulting magazine spread will look like.

Sustainable design professionals are best off knowing what the right tools for their job are, and how to use them together. The questions, then, are: what kind of tool is biomimicry, what other tools are in the sustainability strategy toolbox, and how should you use them together?

Bee birth 1

Photo: Max xx, 2006 | Flickr cc

Kinds Of Sustainability Tools

There are several hundred documented sustainability tools, if not more. From recycling to The Natural Step to fair trade to the United Nations Environment Program's *Design for Sustainability* manual; each comes with its own paradigm. I won't summarize them all here, but I think all sustainability tools serve one or more of these three basic purposes:

- Suggesting specific design ideas (strategies)
- Setting priorities / focusing attention (objectives)
- Keeping score (metrics)

Tools that suggest specific design strategies are the most immediately actionable and understandable--they tell you what to do. The LEED building rating system, for example, tells you to use low-flow toilets, while Lunar's *Field Guide to Sustainability* tells you to avoid paint and make things modular. These are specific actions that serve larger goals, like saving water and encouraging recycling. Scores of people have made lists of strategies like this, and the best ones contain surprisingly creative strategies that you might not have thought of, or describe fine points of how to do them well, or describe pitfalls you should avoid. They are the voice of experience whispering in your ear, simulating a designer who has been in the trenches longer.

Tools that set priorities or focus attention help you decide on your design objectives. All real-world designers have limited time and limited budgets, so they must focus on where they get the biggest bang for the buck, just like a doctor must employ triage to decide what to treat first. Long lists of design strategies do no good without the wisdom of where and when to apply them. They are like a surgeon's scalpels and forceps--used only after the doctor has formed a diagnosis of what to operate on. For doctors, diagnostic tools are things like X-rays and physical exams. For green designers, diagnostic tools can be specific quantitative measures like environmental impact audits, laws, eco-label systems (like LEED, EPEAT, or Cradle to Cradle), and life-cycle assessments (LCAs). They can also be more abstract guidelines, like energy efficiency, or closed-loop material streams, or The Natural Step's four principles.

Tools that keep score yield the metrics you use to measure whether you met your objectives or not, and to compare different ideas to find the best. In the Olympics, they don't just tell people "go run faster", or "go throw something". They have races of well-defined distances, where success is measured in time, down to the millisecond. They have specific regulations for what acceptable shot-put or javelin hardware is, and for how distance is measured. That's how they tell the difference between the good and the amazing. Some tools for keeping score are sophisticated software that give numeric measurements, like LCA programs, or Ecotect and other building energy modeling software. But some are simpler--checklists in eco-label certifications (LEED, etc.), or environmental laws like the Reduction of Hazardous Substances Act (RoHS).

For the most effective design process, you need all three of these working together: a combination of powerful design strategies, aimed at your top-priority objectives, with clear metrics for success. Without all three, it's the luck of the draw whether you'll come up with something relevant and effective. Most design paradigms,

Bee birth 2

Photo: Max xx, 2006 | Flickr cc

therefore, try to incorporate two or three of them. The LEED rating system not only suggests specific design strategies, but also tries to measure your success by having points for different items, and tries to steer your priorities by having different items worth more points or fewer, and by some being required while others are optional. The same applies to most eco-labels, like Cradle to Cradle and EPEAT. It is similar for many environmental laws, like the Clean Air Act or the Waste Electrical and Electronic Equipment Act, though some environmental laws are simply metrics, like RoHS or cap-and-trade systems. LCA as a general field is only a measurement tool, but many LCA measurement methods, such as EcoIndicator and RECIPE, also suggest priorities by providing a single-score metric that all environmental impacts of all products or services can be measured with. Whatever parts of your product have the worst LCA score are the top priorities for improvement.

Biomimicry As A Tool

Where, then, does biomimicry fit into this? It's primarily a creativity tool for design strategies, a great source for new ideas. It's similar to other creativity tools, like Roger Von Oech's Creative Whack Pack, TRIZ or a well-facilitated brainstorming session.

Biomimicry is a wonderfully complex and rich tool for creativity. If you want the voice of experience whispering in your ear to make you a better designer, what more could you ask for than nearly four billion years of experience across the entire globe?

Biomimicry can also be useful in the realms of suggesting objectives and metrics (one of the pillars of the book Biomimicry is "nature as measure"), but it does so on a meta-level rather than a day-to-day level. For example, people have been measuring ecosystem services quantitatively for over a decade, but Janine Benyus was, I believe, the first to suggest that cities should perform the same level of ecosystem services that the pre-city natural landscape had. This is brilliant and audacious, raising the bar enormously for what it could mean to be a green city. But once that suggestion is made by the biomimicry practitioner, the actual measurement is done using the same ecological impact audits that had been used before; tools from Life Cycle Analysis (LCA), chemistry, civil engineering, and such. Similarly, when we measure the strength of a biomimetic material, we do so with the same engineering tools (and limited paradigms) that we apply to other materials. Biomimicry is a great inspiration for designing better quantitative analytical tools, but it isn't a quantitative tool itself. Biomimicry's role in "nature as measure" is mostly in suggesting what comparisons could be made.

Using Tools Together

Just like a hammer goes well with a measuring tape and blueprints, biomimicry goes well with other green design tools. It goes especially well with tools for setting objectives and metrics, such as quantitative analytical tools (Life-Cycle Assessment, carbon footprints, embodied water, etc.) or checklist-based certification systems (LEED, EPEAT, EnergyStar, Cradle to Cradle, etc.). Such systems help you target your creative explorations to your top priorities, so you get the

Bee birth 3

Photo: Max xx, 2006 | Flickr cc

biggest improvements for the time and money you spend in your biomimetic research. They also help you decide which of your biomimetic design ideas are the best ones to pursue, or, if none of them is good enough, if you need to go back into the woods for more critters.

Where and when do you combine these tools? I suggest a four-step process--two steps preparing for biomimicry and one following it. The first two steps define the problem.

First, use systems thinking and user-centered design thinking to set the boundaries of the problem. Define what need the product (or service) serves and what the whole system of the product is (both its whole life cycle and the larger context it fits into in the user's life).

Second, use quantitative measurement tools like LCA or eco-label certifications to determine your priorities and metrics for success. With LCA you find where the biggest ecological impacts are in that system, with eco-certifications you find the gaps between where you are and compliance.

These two steps help you clearly define what problem you'll be trying to solve with biomimicry, and what counts as success. As you probably already know, clear problem definition is half the battle.

Biomimicry is the *third* step, finding lots of clever and unique strategies to solve your problem.

Finally, the *fourth* step is to evaluate all these biomimetic ideas with the same quantitative measurement tool you used to set your original objectives and metrics (again LCA or eco-label). This helps you choose which of your many biomimetic ideas best solves the problem.

If none of the ideas fully solves the problem (which will usually be true in the first round or two), this step helps you iterate, because it redefines your problem definition and becomes steps one and two in your next go round of the same design cycle. This is a version of the Whole Systems + Life-Cycle Thinking design method created for the Autodesk Sustainability Workshop.

As practitioners of biomimicry know, it is a multidisciplinary process. That's because biomimicry itself is best done using other tools inside it. Physics, chemistry, and manufacturing, as well as biology, can all provide useful tools that help with the practice of biomimicry. Biology is good for the identification of an organism and the context that it lives in, to identify design strategies and how they might be relevant to your problem. But what then? Usually you need some physics or chemistry to understand how the strategy works.

Finally, manufacturing expertise is invaluable for translating the biological strategy into a buildable thing. Often the best biomimetic strategy is not the most ideal one from nature, but the one you can actually build. We should, of course, strive to go beyond standard "heat, beat, and treat" manufacturing, and advances in nanotech, biotech, and 3D printing will make it easier in coming decades, but biomimicry would be a far less useful tool if it couldn't help make things that ship this year. Bringing multiple tools together helps biomimicry work better.

Who Wields The Tools

Not everyone can be a master of all fields. Practitioners of biomimicry should already be used to working in teams of multiple experts. In any such teams, some fields of expertise will be deep, and other fields will be covered by those who are competent but not expert. You don't need an expert in everything at the table. One person alone can do biomimicry. Likewise, fitting biomimicry into a design process like the one described here does not require separate experts in everything. If you have the experts, great, but if not, you can wield all the tools yourself--doing a "good enough" LCA with simple tools, or designing for LEED without being a certified LEED AP. It's all a question of how many resources you have and how rigorous your requirements are.

Biomimicry will always have huge potential for designing better, greener products and systems. You can make it an even more focused and effective tool by complementing it with other tools in the right place and the right time. Biomimicry is best for generating design strategies, while other tools such as LCA and eco-certification scorecards are best for setting objectives and the metrics by which you measure success. You'll get better results and have more enthusiastic support from collaborators if you use biomimicry for what it's best at.

Bee birth 4

Photo: Max xx, 2006 | Flickr cc

Cross waves

Photo: dronir, 2009 | Flickr cc

Tools

Developing Cross-Domain Analogies using Natural-Language Sources

Norbert Hoeller

fall 2012 **Article:** Tools

Author: Norbert Hoeller

Developing Cross-Domain Analogies using Natural-Language Sources

This article is based on a review of selected literature authored by Prof. Li Shu and her team at the Biomimetic for Innovation and Design Laboratory (BIDLab), University of Toronto. (http://www.mie.utoronto.ca/labs/bidlab/).

What are the Tools?

BIDLab is developing tools and methods that help designers access and effectively use biological information relevant to engineering problems using natural-language online sources such as textbooks and journals.

Why are the Tools Needed?

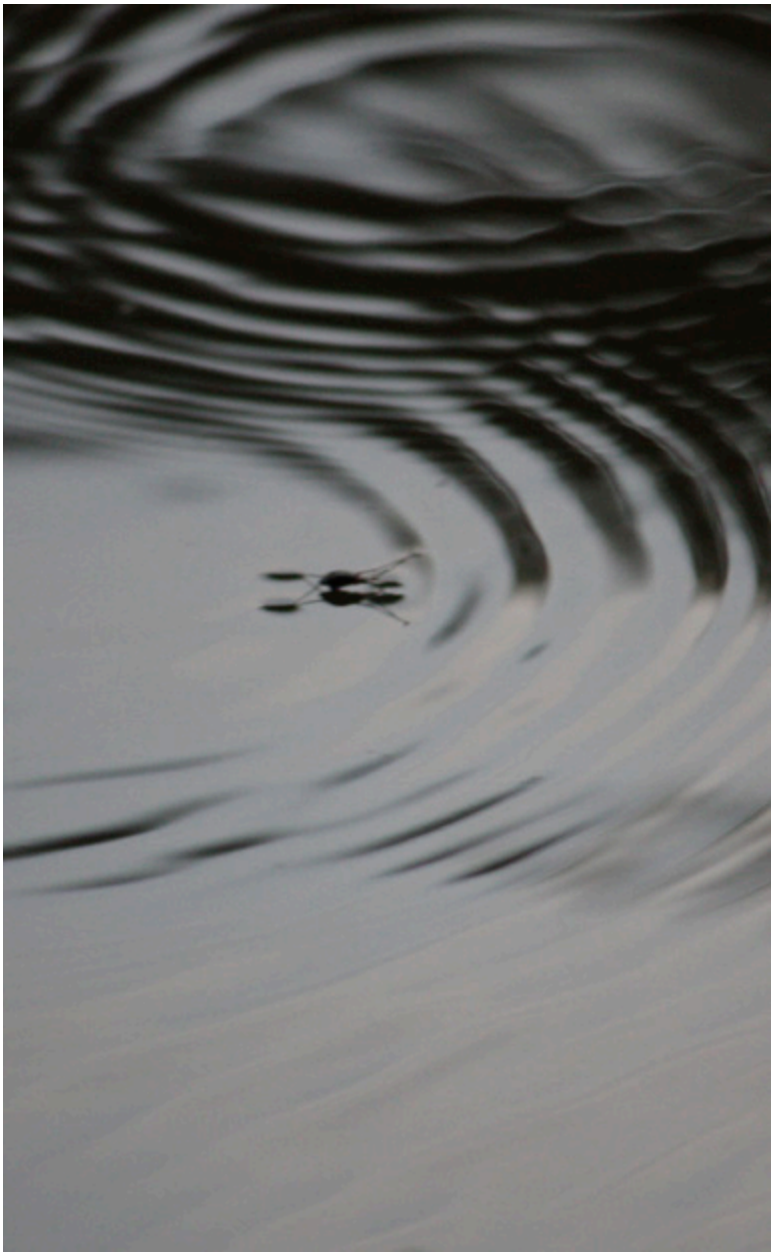
Successfully developing and using analogies between the biological and technical domains require finding biological information relevant to the technical problem at hand. Although various databases of biological information organized by engineering functions have been developed, so far none of them have proven to be sufficiently comprehensive due to the high resources required to select, organize and maintain the information. Searching existing biological references has been hampered by differences in the vocabularies of biology and engineering. Common keywords may have different meanings while different keywords may map to the same functions.

Even if relevant biological information can be found, designers often have difficulties mapping that information to the technical domain. Designers may develop incorrect analogies or fixate on specific words or strategies due to a poor understanding of the causal relationships in the biological source and the technical target.

Lastly, even correct analogies may only provide designers with shallow inspiration. Designers may become fixated on specific aspects of the analogy, directly copying the details of the biological process (biological transfer) or transferring the strategy but using the source biological entities (literal implementation). The challenge is to abstract both the process ('strategic accuracy') and attributes of the biological entities.

Who are the Tools For?

The methods developed by BIDLab are suited to designers who are looking for a systematic way of accessing biological information from a wide range of sources but lack in-depth biological expertise.



Waterstrider

Photo: Daniel Pink, 2009 | Flickr cc

Reasoning Using Analogies

According to the online Oxford Dictionaries, analogy is defined as:

"a comparison between one thing and another, typically for the purpose of explanation or clarification: an analogy between the workings of nature and those of human societies" (http://oxforddictionaries.com/definition/english/analogy)

We use analogies in every-day life when we try to explain a new concept. Since electricity cannot be directly observed, we may relate it to the flow of water. We often use analogies to past events in an attempt to predict the future or to persuade others about a point of view. Commentators have related the recent economic turmoil to the Crash of 1929 and the subsequent depression, although their inferences have not always been consistent.

Analogies can also be useful in scientific research and stimulating new ideas. If successful, analogies allow us to bridge from the known to the unknown. The Greeks (Chrysippus) and Romans (Vitruvius) made a connection between observable water waves and sound waves. Huygens suggested that our understanding of sound waves could help us understand light waves. Rutherford looked to the solar system to develop concepts on the structure of atoms. Bohr

What Phase of Development are the Tools In?

BIDLab has developed a biomimetic search tool for systemically mapping engineering terms to biologically meaningful keywords using an online version of the introductory university-level biology textbook *Life, the Science of Biology* (Purves, 2000). Various case studies have been published, including a redesign of snap fasteners assisting in remanufacturing, handling and assembly of extremely small parts, and the protection of lunar equipment from dust (Shu, 2010).

The biomimetic search tool uses an iterative approach of searching and analyzing natural-language biological resources to develop a set of biologically meaningful keywords for specific engineering functions. Recently, the process has been applied to the functional basis (Stone & Wood, 2000), a standardized way of modeling of engineering product functionality using a generic set of functions (represented by verbs) and flows (represented by nouns). Emphasizing verbs encourages designers to focus on more general biological functionality rather than limiting themselves to specific entities (Cheong, Chiu, Shu, Stone, & McAdams, 2011).

BIDLab has explored four levels of similarity between biology and engineering (Mak & Shu, 2004):

• anomaly, where the biological concepts are not properly understood or the students fixated on particular words without relating to the strategy described in the biological extracts

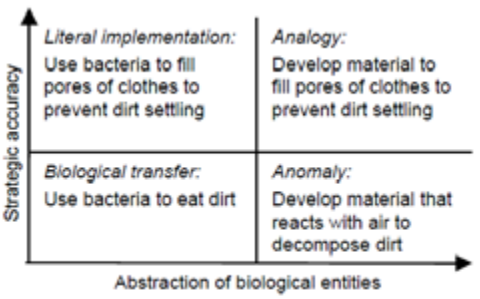
• biological transfer, where the designers are fixated on the biological actors at the expense of exploring the biological strategy

• literal implementation, in which both the biological strategy and the biological actors are carried over into the technical design

• strategic analogy, based on an abstraction of the principles derived from the biological phenomena

The figure below (Mak & Shu, 2004) shows examples of the four different similarity types from an experiment where students were asked to develop alternative ways of cleaning clothes (without using water, detergents or solvents) based on the following biological extract.

> *Barriers and local agents defend the body – skin is a primary innate defense against invasion. The bacteria and fungi that normally live and reproduce in great numbers on our body surfaces without causing disease are referred to as normal flora. These natural occupants of our bodies compete with pathogens for space and nutrients, so normal flora are a form of innate defense.*



The goal is to develop strategic analogies that accurately transfer biological concepts to the technical problem at a level of abstraction that avoids a literal or superficial translation of bio-

Among grey mass

Photo: Magda's Cauldron, 2008 | Flickr cc

thought the nuclei of atoms were similar to drops of water that could oscillate if bombarded with energy (Gorman, 1998, chap. 2.4).

Retrieving analogies requires that we recognize similarities between analogs. Surface similarities allow the easiest retrieval, but the value is often limited since finding the analogy is unlikely to lead to unexpected insights. Analogies based on structural similarity or higher-order causal relationships are more difficult to recognize. Once identified, they are more likely to yield unexpected insights (Gentner, 2003). Similarly, analogies between different knowledge domains are more difficult to find but encourage designers "... to map relational patterns such as functional similarities from a source to a target". Ambiguities in the mapping can also encourage creativity (Cheong et al., 2011).

Once the analogies have been identified, making effective use of them involves a complex set of steps (Gentner, 2003) including aligning the two analogs, projecting inferences from the known to the unknown domain, evaluating the inferences relative to the tar-get, re-representation of the analogs to improve the match, and ab-straction of the underlying structure.

logical agents or functions (Mak & Shu, 2004). BIDLab has done a wide range of experiments where university students were given technical problems along with selected biological extracts and asked to develop relevant analogies. Various factors and methods have been identified that facilitate the development of accurate and meaningful analogies which in turn can lead to novel, useful and cohesive design solutions (Cheong, Chiu, & Shu, 2010).

How Could the Tools be Used?

The BIDLab biomimetic search tool support analogical reasoning by:

- mapping engineering functions to biologically relevant keywords
- searching existing sources of biological information for appropriate content
- developing insightful analogies that map the biological content to strategies relevant to the engineering design

What is the Conceptual Approach?

Although we often attribute creativity to the 'eureka moment', creativity and innovation can also be stimulated by new information that leads to novel connections or analogies between problem/solution sets, one known and the other at least partly unknown. These analogies can be especially valuable if outside of the designer's area of expertise. Within a domain, easily perceived similarities such as form can lead to superficial analogies. Between domains, designers often need to explore deeper functional relationships, leading to richer, strategic analogies (Mak & Shu, 2008).

One of the strengths of biomimicry (Benyus, 2002) is the broad set of solutions found in the natural world that are often quite different from those familiar to designers. Biomimicry not only suggests specific and novel solutions (nature as model), it also promotes new frames of reference on our relationship with the world (nature as mentor) and encourages us to evaluate our designs based on different success criteria (nature as measure).

How Does One Use the Tools?

Table 1 from "Biologically Meaningful Keywords for Functional Terms of the Functional Basis" (Cheong et al., 2011) matches engineering terms from the functional basis to biological keywords. Biological terms that have a high degree of collocation with the associated engineering terms are more likely to be useful in searches. Biological terms with a high number of total matches and a low degree of collocation can also yield relevant results when the original engineering function is included in the search.

Biological descriptions can be characterized as describing form, behavior or principles. Based on research involving students who lacked prior in-depth biological knowledge, biological descriptions with higher levels of abstraction tended to result in more strategic analogies. Form-based descriptions tended to result in biological transfer or literal implementation. Principle-based

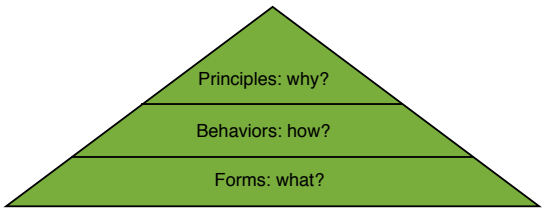
Table 1 Biologically meaningful keywords for functional terms of the functional basis

Functional basis keyword groups	Biologically meaningful keywords	% of colloc.[a]	# of matches[b]
BRANCH + SEPARATE + DIVIDE			
Correspondents: Sort, diverge, split, detach, isolate, cut	Speciate	68	66
	Diverge	44	39
	Segregate	35	34
	Furrow	33	9
	Evolve	18	424
	Denature	17	36
	Grow	16	786
	Reproduce	14	537
	Cleave	14	80
	Surround	11	209
	Stimulate	9	289
	Contract	3	226
	Activate	2	256
(Detach)	Retract	14	7
	Bend	12	33
	Fold	8	74
DISTRIBUTE			
Correspondents: Disperse, dissipate, diffuse, release	Hydrolyze	41	75
	Burst	32	31
	Discharge	29	14
	Stimulate	26	289
	Circulate	26	164
	Fuse	23	120
	Secrete	21	232
	Concentrate	21	58
	Pass through	20	139
	Break down	20	125
	Diffuse	15	238
	Stretch	15	89
	Bind	14	483
	Segregate	12	34
	Change shape	9	71
(Release)	Lyse	26	23
	Decompose	13	31
	Condensate	6	16
	Fold	5	74
	Catalyze	5	125
(Dissipate)	Evaporate	6	47
TRANSFER (cont'd)			
	Break	8	196
	Pollinate	7	74
	Bind	6	483
	Attract	3	96
(Move)	Change shape	52	71
	Organize	10	134
	Shift	7	67
TRANSPORT			
Correspondents: Convey, conduct, carry	Transport	19	283
	Transduce	10	99
	Communicate	6	109
	Bind	6	483
	Extend	3	95
	Collect	3	72
	Stimulate	2	289
	Contract	1	226
(Carry)	Pollinate	9	74
	Disperse	4	123
IMPORT			
Correspondents: (Enter)	Osmose	16	31
	Pass through	15	139
	Squeeze	14	21
	Diffuse	7	238
	Insert	5	132
	Release	4	508
	Secrete	3	232
	Transport	3	283
	Fold	1	74
EXPORT			
Correspondents: Dispose, destroy, empty, eject	Contract	1	266
(Destroy)	Inactivate	6	52
	Denature	6	36
	Attach	3	200
	Break down	2	125
	Bind	1	483

Table 1: Biologically Meaningful Keywords for Functional Terms of the Functional Basis

Photo: ASME, 2011 | retrieved from http://www1.mengr.tamu.edu/pd/publications/biologically_meaningful.pdf

descriptions tended to lead to more strategic analogies. Behavior-based descriptions fell in between (Mak & Shu, 2004).



Designers are more likely to correctly interpret and map the causal relationships to the technical domain if the biological information contains a limited number of verbs and the verbs are written in an active voice (Cheong & Shu, 2009). The former reduces the complexity of the description, making it easier to extract the key relationships. Passive verbs in the description can distract designers from the more important active verbs.

Causal relations have two parts where the first action causes or enables the second action. For example, in "X chases Y and Y flees", the two verbs 'chases' and 'flees' have a causal relationship. Research has shown that students often have difficulty recognizing and properly interpreting these causal relations, inhibiting their ability to develop useful analogies. BIDLab has developed a 'causal template' and 'instructional mapping rules' to increase the accuracy and quality of the analogy (Cheong et al., 2010).

Completing the causal template is a multi-step process:

- What is the *desired function* associated with the problem? What is the corresponding biological function?
- What does the biological function act on (*object A*)?
- What is the *precedent function* that allows or enables the *desired function*?
- What initiates the *precedent function* (the *subject*) and what does the function act on (*object B*)?

For example, the description:

"Bivalves (shellfish) feed by bringing water in through an opening and removing food from the water using their large gills, which are also the main sites of gas exchange. Water exits through another opening."

can lead to two causal relations:

- (Bivalves) **bring in** (water) **to remove** (food)
- (Bivalves) **bring in** (water) **to exchange** (gas)

(Cheong & Shu, 2009)

The 'instructional mapping rules' (Cheong et al., 2010) take the process one step further to develop an appropriate causal relation relevant to the original problem:

- Transfer the biological desired solution to the engineering causal template.
- Identify the engineering object A and object B that relate to the biological objects.
- Develop multiple solution functions that might cause or enable the desired function.
- Develop solution subjects that could be associated with the solution functions.

Causal Relation Template				
In Biology				
Subject	Precedent Function	Object B	Desired Function	Object A
i) ...	i) destroys	i) bacteria	i) protects	i) animal
Your Solution				
Solution Subject	Solution (Enabling) Function	Object B	Desired Function	Object A
iv 2) ...	iv 1) destroys	iii) ...	ii) protect	iii) ...

Causal relations

Adapted from Cheong et al., 2010

Bivalve

Photo: robanhk, 2009 | Flickr cc

Where is the BIDLab Going from Here?

Work is ongoing to automate the biomimetic search tool and improve the relevance of search results. The methods also need to be tested against a wider range of biological information sources.

References

Benyus, J. M. (2002). *Biomimicry: Innovation Inspired by Nature*. William Morrow Paperbacks.

Cheong, H., Chiu, I., & Shu, L. H. (2010). Extraction and transfer of biological analogies for creative concept generation. *Proc. ASME 2010 Int. Design En-gineering Technical Conf. Computers and Information in Engineering Conf* (pp. 15–18). Retrieved from http://www.mie.utoronto.ca/labs/bidlab/pubs/Cheong_etal_DTM_10.pdf

Cheong, H., Chiu, I., Shu, L. H., Stone, R. B., & McAdams, D. A. (2011). Biologi-cally Meaningful Keywords for Functional Terms of the Functional Basis. *Journal of Mechanical Design, 133(2),* 021007. doi:10.1115/1.4003249

Cheong, H., & Shu, L. H. (2009). Effective analogical transfer using biological descriptions retrieved with functional and biologically meaningful keywords. *Proc. ASME 2009 Int. Design Engineering Technical Conf. Com-puters and Information in Engineering Conf.* Retrieved from http://www.mie.utoronto.ca/labs/bidlab/pubs/Cheong_Shu_DTM_09.pdf

Gentner, D. (2003). Analogical reasoning, psychology of. *Encyclopedia of Cognitive Science* (Vol. 1, pp. 106–112). London: Nature Publishing Group.

Gorman, M. E. (1998). *Transforming Nature: Ethics, Invention and Discovery*. Springer.

Mak, T. W., & Shu, L. H. (2004). Abstraction of biological analogies for de-sign. *CIRP Annals-Manufacturing Technology, 53(1)*, 117–120.

Mak, T. W., & Shu, L. H. (2008). Using descriptions of biological phenomena for idea generation. *Research in Engineering Design, 19(1)*, 21–28. doi:10.1007/s00163-007-0041-y

Purves. (2000). *Life, The Science of Biology, 6th Edition*. W. H. Freeman & Company.

Shu, L. H. (2010). A natural-language approach to biomimetic design. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 24(04)*, 507–519. doi:10.1017/S0890060410000363

Stone, R. B., & Wood, K. L. (2000). Development of a functional basis for design. *Journal of Mechanical Design, 122*, 359.

Untitled

Photo: Magda's Cauldron, 2008 | Flickr cc

Untitled

Photo: tiltti, 2008 | Flickr cc

ISSN 1927-8314