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Light of Day | Photo: Colin, 2019 | Flickr cc

Editorial

In this issue, you, our readers, may want to reflect on the adjective "collective", for it runs like a conceptual thread through many of our articles, starting with our Science of Seeing feature writer, Heidi Fischer in "I Am Because We Are". Fischer tells us about the research work of ecologist Suzanne Simard in demonstrating the collective cooperation that appears vital to healthier forests, and reveals new wonders of the nurturing of neighbors going on beneath the forest floor. This mutual assistance as the need arises further demonstrates that Nature is not all "red in tooth and claw".

Bionics professor Dr. William Megill, explains in an interview how his collective experience as a boat captain, physics student, marine biologist, and engineer brought him to his current and unlikely German locale, working at the pioneering nexus of robotics and underwater propulsion.

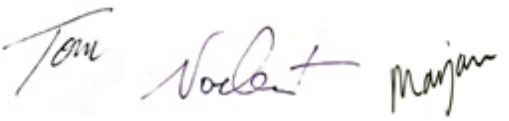
Manuel Quirós' "Life in Two Worlds" depicts the collective conditions that have yielded the fascinating adaptations and natural selection found in the rocky intertidal zone. Here "real estate" is expensive, but the rewards (such as twice daily free removal and delivery services offered by the tides) are great and opportunities and dangers abound in a very dense and demanding space.

Supernature artist Andrea du Plessis has used collective techniques to yield provocative and emotive content. She has combined traditional fine art skills with animation, artificial intelligence, and augmented reality platforms to produce emergent images that are both oddly familiar and otherworldly.

Noah Pentelovitch leads research and advanced development for OXO and Hydro Flask, and is engaged in collective tool-making with Dr. Jacquelyn Nagel (Department of Engineering, James Madison University). They seek to combine the tenets of human-centered design promoted by OXO and bio-inspired design principles to the practical application of product design at the company and hope that this will also yield a model for more effective collaboration among biologists, engineers, and designers.

Erika Cezarini of OKA in Brazil manufactures edible, recyclable, and compostable packaging from cassava, so her business, in an entirely different sense, is "collective" as well. This type of venture is a result of new paradigms about how we might view our consumer products and their relationship to our natural environment.

Richard James MacCowan reviews *Guiding Patterns of Naturally Occurring Design* by Jessie Lydia Henshaw, a new book that combines the architectural design principles of Christopher Alexander of *A Pattern Language* fame, and natural patterns she has observed and analyzed. We hope that all of these features collectively please you and wish you, as always, Happy Reading! ×



Contents

Body of Water in Forest (British Columbia)
Photo: Jonathan Meyer, 2017 | Pexels cc

The Science of Seeing

I Am Because We Are

Adelheid Fischer

I Am Because We Are
Adelheid Fischer

This past January I came across a headline in the *New York Times* that posed the tantalizing question: "How Selfish Are Plants?" The article reported on a recent study that graced the cover of the prestigious journal *Science*. In the study, a team of researchers led by Ciro Cabal, a doctoral student in ecology and evolutionary biology at Princeton University, developed a mathematical model designed to predict the spatial pattern and amount of root growth in plants.

In order to ground-truth the hypothetical outcomes of the model, the team followed up with an experimental planting of sweet peppers. It went something like this. In a greenhouse laboratory, the plants were given equal amounts of sunlight, water and nutrients, but some of them were planted one to a pot while others were closely paired with a roommate about four inches away. After a time, the peppers were removed from the soil and their roots examined. The single plants not only produced vigorous growth directly below the plant stem, but because they had unfettered access to outlying resources, they also sent out long horizontal runners into the surrounding soil. Like the single plants, the paired peppers too sprouted robust roots close to their stems. Sensing other plants nearby, however, they limited the production of horizontal roots that might overlap with their neighbors, thereby avoiding the diminishing returns of competition. But did it mean that the paired plants would behave "unselfishly," dividing resources between them rather than each maximizing its share of nutrients? The answer is no. "For now, it's every pepper for itself," declared the article's author Cara Giaimo.

Now, it may be the case that it's every pepper for itself within the simplified, tightly controlled confines of a laboratory. But once you step outside and walk into the desert or a prairie or a forest or the tundra, is it really every plant for itself? Ironically, just 12 days earlier, the *Times* published a profile of the feisty, paradigm-busting forest ecologist Suzanne Simard whose answer to this question would likely be a definite and defiant "no" (with a few expletives thrown in for emphasis).

Simard should know. She has spent a career of nearly three decades in the old growth forests of the Pacific Northwest and British Columbia. Her first inkling that there might be something amiss with the paradigm of "every plant for itself" came when she worked for a timber company as a newly minted graduate of the University of British Columbia's forestry school. While out in the field, she observed how loggers moved into a stand of forest and stripped out the valuable timber. Then they cleared

Mycorrhizal Fungi
Photo: Camille Defrenne | The Simard Lab

Douglas-Fir Roots and Mycorrhizal Fungi | Photo: Camille Defrenne | The Simard Lab

I Am Because We Are
Adelheid Fischer

the land of undesirable species such as aspen and birch as well as material such as rotting or diseased trees, branches, and tree roots before strafing the site with herbicides to kill sun-loving grasses and shrubs. The goal was to remove anything that might "compete" for light, water and nutrients with the new monocrop of commercially valuable pine and fir seedlings.

Driving this management protocol was the perception of the forest as a collection of solitary individuals that were duking it out for finite resources, i.e., every plant for itself. "I was taught that you have a tree, and it's out there to find its own way," observed Simard in the *New York Times* article. It didn't take long for Simard to recognize, however, that there was something wrongheaded about this approach. Research showed that the eradication of neighboring aspen, birch and cottonwood trees, for example, decreased the survival of Douglas fir saplings by ten percent. She concluded that land shorn of its biodiversity impaired, rather than improved, forest health and productivity.

Mycorrhizal Fungi
Photo: Camille Defrenne | The Simard Lab

To better understand the dynamic complexities of the forest, Simard headed back to college for her Ph.D. As a student in the early 1990s, she came across an experiment demonstrating that one pine seedling could transmit some of its carbon stores to another. She was intrigued. Sure, the exchange worked in a science lab, but could it be replicated in the Wild West of nature's complicated variables? she wondered.

So Simard set up an experiment deep in the forests of British Columbia, planting 80 plots with a trio of seedlings: paper birch, Douglas fir and western red cedar. She injected carbon dioxide gas labeled with the radioactive isotope carbon-14 into the bag of birch. Into the plastic sheaths of the fir seedlings she released carbon dioxide gas containing the stable isotope carbon-13. Then she waited for an hour while the plants carried out the process of photosynthesis. When she returned, she ran a Geiger counter alongside the cedar seedling. Silence. As she approached the birch seedling, though, the instrument crackled to life, indicating that the birch had taken up the radioactively tagged gas. The moment of truth, however, came when she repeated

the procedure with a fir seedling. Much to Simard's joy, it too tripped the Geiger counter, indicating that carbon had flowed from the birch to the fir via an underground network of mycorrhizal fungi that linked the two plants.

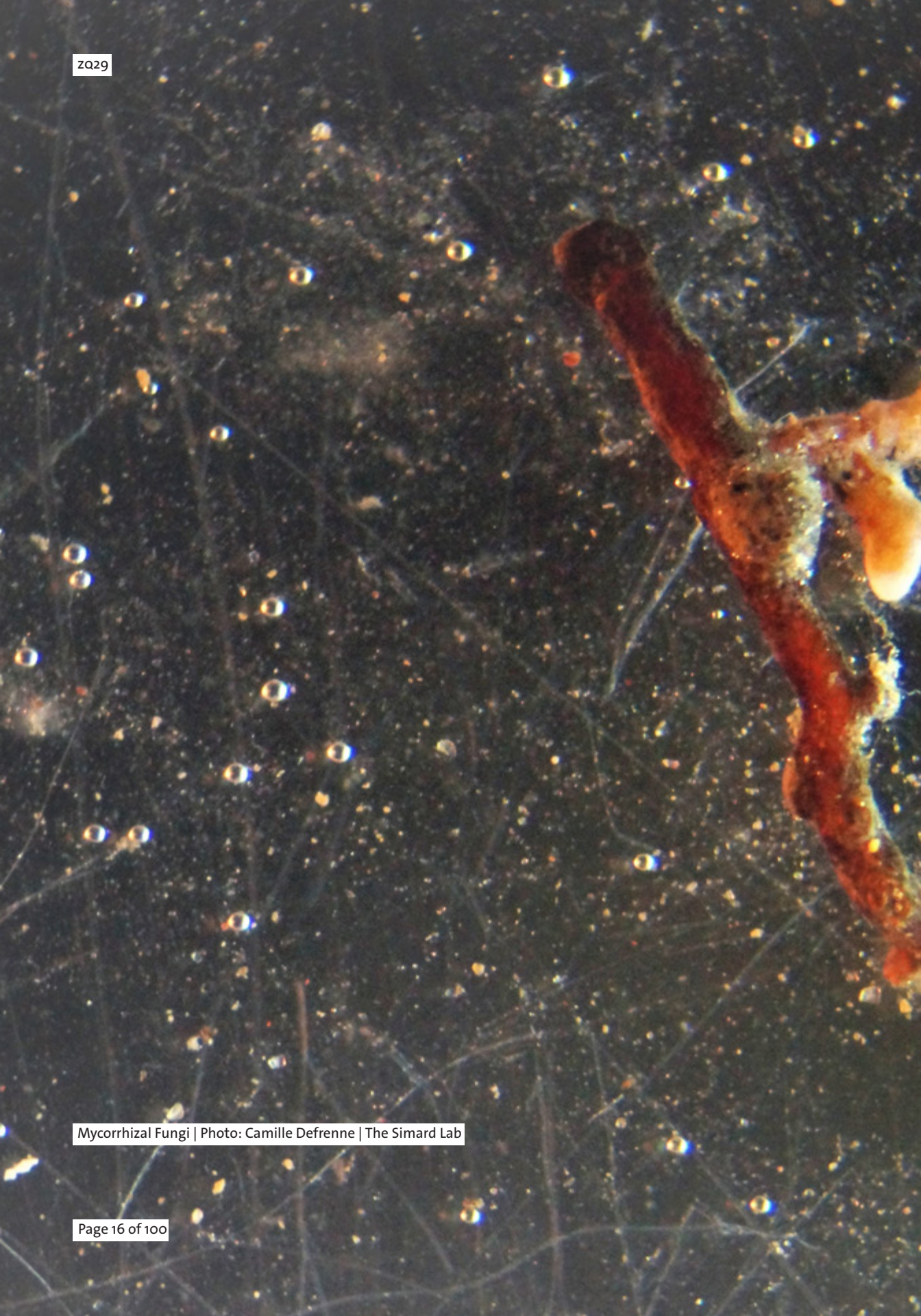
Even more startling was the revelation that the gas exchange was a two-way street: the birches had also taken up some of the carbon-13 from the firs. "I was so excited," Simard recalls on the TED stage in 2016. "I ran from plot to plot, and I checked all 80 replicates. The evidence was clear. The C-13 and C-14 was showing me that paper birch and Douglas fir were in a lively two-way conversation."

And depending on the season, one species did more of the talking than the other. "In the summer, that [leafed-out] birch was sending more carbon to fir than fir was sending back to birch, especially when the fir was shaded. And then in later experiments, we found the opposite, that fir was sending more carbon to birch than birch was sending to fir, and this was because the fir was still growing while the birch was leafless. So it turns out the two species were interdependent, like yin and yang.

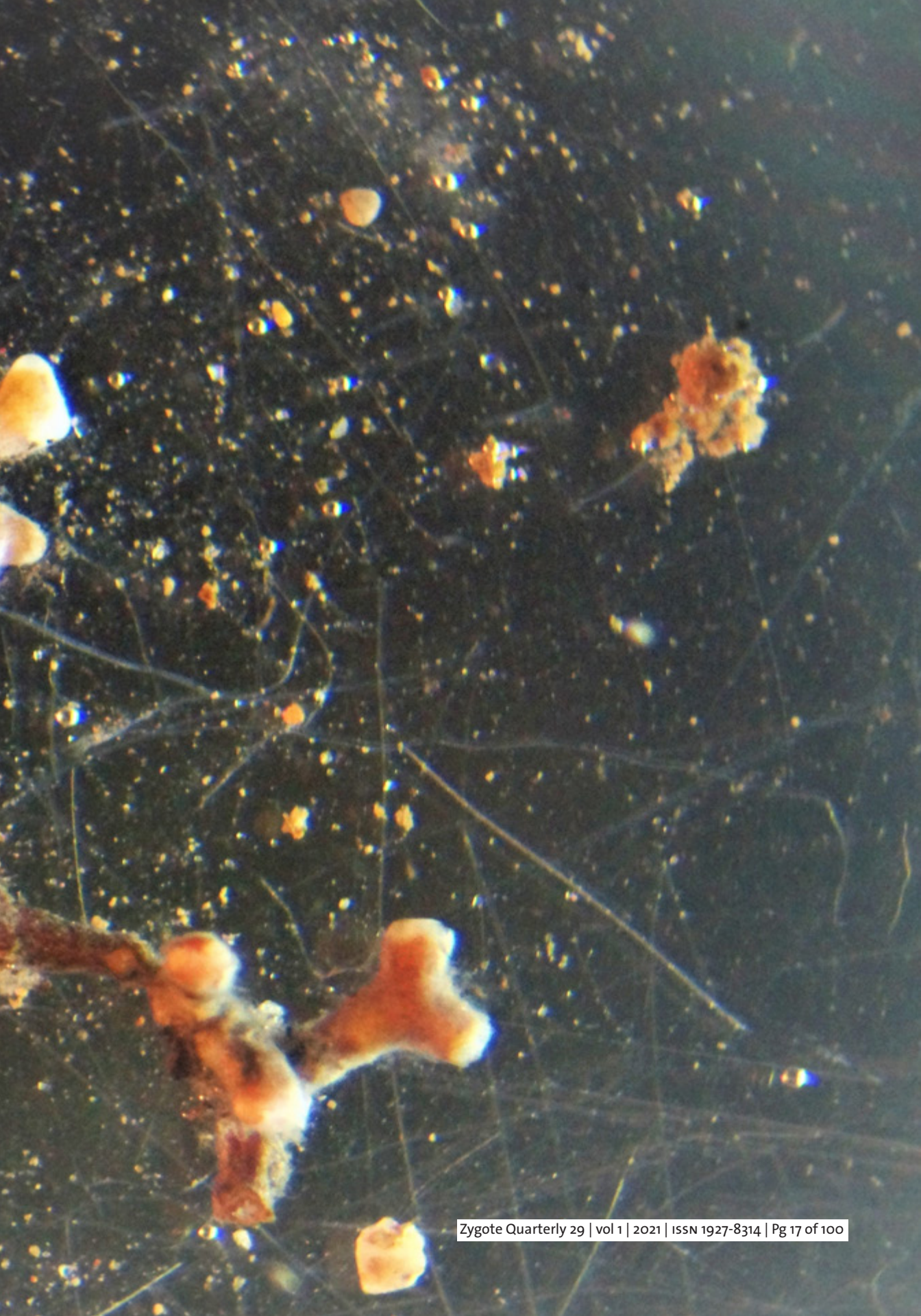
I knew I had found something big, something that would change the way we look at how trees interact in forests, from not just competitors but to cooperators."

In 1997 some of this dissertation research landed top billing on the cover of the prestigious journal *Nature*. Still, it would take more than a decade for her revolutionary findings to filter into the popular imagination. During that time, Simard continued to issue reports from the field that were staggering in their implications. Using genetic testing tools, she revealed that the underground world of a forest is a place "of infinite biological pathways that connect trees and allow them to communicate and allow the forest to behave as though it's a single organism," making it, she points out, a kind of superorganism.

This underground infrastructure is created by mycorrhizal fungi. Scientists have long known that these fungi enter into a beneficial partnership with plants by colonizing their roots. They use fine, branching threads, known as mycelia, to scavenge water, nitrogen and phosphorus from the soil. The fungi deliver these resources to plants in exchange for the carbon-rich sugars that that the plants produce through photosynthesis. But the mycorrhizal associations are not limited to individual trees. Simard points out that hundreds of kilometers of mycelia can be found under a single footstep. These dense networks wind throughout the whole forest community, knitting other individuals into a complex



Mycorrhizal Fungi | Photo: Camille Defrenne | The Simard Lab



I Am Because We Are
Adelheid Fischer

whole. It's what made the carbon exchange possible between Douglas fir and birch in Simard's early experiment.

But she demonstrated that this mycorrhizal network does more than deliver goods. The network also facilitates the flow of information. Warnings about an insect infestation in one part of the forest, for example, can travel via the mycorrhizal network to trees in other quadrants, enabling them to shore up chemical defenses before the pests arrive in their neck of the woods.

Not all linkages in this vast network, however, are created equal. Some trees, often the biggest and oldest in the forest, are more connected than others. Simard dubbed them hub or "mother" trees. These hub trees, which can be connected to upwards of hundreds of other trees, funnel their excess carbon to seedlings in the understory, resulting in a fourfold increase in seedling survival. And when some of these hub trees begin to die, they use the mycorrhizal network to flush a portion of their own carbon back into the larger forest community. Simard acknowledges that competition does exist among trees. But the forest isn't "just a bunch of trees competing with each other," she declared in her TED talk. "They're supercooperators" engaged in countless interactions that are essential to maintaining the integrity, diversity and stability of the whole.

Despite her early publishing triumph in the journal *Nature*, Simard's work was slow to win the acclaim it deserved among her fellow scientists. Today, as the *Times* article points out, she is regarded as "one of the most rigorous and innovative scientists studying plant communication and behavior."

And it wasn't until about 2015 that Simard's work began to attract the attention of the general public after articles appeared in influential publications such as *Scientific American* and the *Atlantic Monthly*. WNYC, a popular public radio station in New York City, featured her work in a 2016 broadcast. Her appearance that year on the TED stage is approaching five million views.

Big ideas have a way of timing their own births. After watching the TED audience leap to its feet to give Simard a standing ovation, it was clear that she didn't deliver just another clever "gee-whizz, that's-cool" talk. She struck a nerve. I would argue that her communitarian challenge to the "every plant for itself" view of the forest surfaced in our popular consciousness at a time when two wildly divergent social paradigms have been engaged in a titanic clash on the national stage: the struggle between what I

would call an era of ubuntu and the ascendancy of a go-it-alone, America First ideology.

Ubuntu—an African word generally translated as "I am because we are"—was defined by President Barack Obama in the address he gave at Nelson Mandela's memorial service in 2013. The word, he says, "captures Mandela's greatest gift: his recognition that we are all bound together in ways that are invisible to the eye; that there is a oneness to humanity; that we achieve ourselves by sharing ourselves with others, and caring for those around us." Ubuntu in human society resonates with ubuntu in forest society: that individual thrival, not merely survival, depends upon engaging in interactions that maintain the integrity, diversity and stability of the whole.

In 2013, when she was diagnosed with breast cancer, Simard herself drew the connection between the operational dynamics of forest and human societies and put into practice the principles of "I am because we are" that she observed during her 30 years in the field. "The thing that really got me through," she said in a 2014 radio interview, "was my connections, the friends I made. It was this incredible magical network where you could just feel the love going from person to person, and we're all doing great. For me it was like I was living the very thing I was seeing in the forests. And I just feel so much comfort. I know I'm going to be OK, just like that tree is going to be okay as long as it stays within its community." ×

For more, check out Suzanne Simard's new book, *Finding the Mother Tree: Discovering the Wisdom of the Forest* (Alfred A. Knopf).

Mycorrhizal Fungi
Photo: Camille Defrenne | The Simard Lab

Douglas-Fir Roots and Mycorrhizal Fungi | Photo: Camille Defrenne | The Simard Lab

Flying Fish Take off Baja
Photo: jacksnipe1990, 2018 | Flickr cc

Interview

William Megill

Interview
William Megill

I'm a Canadian sea captain and PhD marine biologist with a physics degree who teaches engineering design in a landlocked little town in Germany. I've studied whales, jellyfish, sea turtles, and everything they eat. I'm a sea kayaking instructor and was once the "mayor" of the biggest summertime settlement on the north shore of Queen Charlotte Strait, British Columbia. I've seen flying fish race ahead of my boat in Baja, Mexico, and avoided a brush with a stone fish while diving in the Red Sea. I teach physics, biology, engineering, and science communication, oftentimes all in one lecture. My first real job was designing women's underwear, my first scientific publication was a poem, and along the way somewhere I was briefly a professor of geography, but despite graduating 11 PhDs, really I'm best known for running a submarine race. I've been a CEO, a dean, and a director of studies, landed a million euros in research grants, published 28 papers and a patent. I've burned out twice and had a stroke, but they still fear me on the football field. I was an Eagle Scout, a refugee and a short order cook. Now I'm just over fifty and enjoying the living in life.

William Megill at work on the Rhine

And my more traditional bio:

William Megill is Professor of Bionics, Robotics and Sensing at the Rhine Waal University of Applied Sciences, in Cleves, Germany, on the River Rhine near the Dutch border. He started his academic career with a BSc in Physics at McGill University in Montreal, Canada. On graduation, he apprenticed as a coastal sea-captain, operating whale-watching vessels, and conducting ecological research for the Mingan Island Cetacean Study in eastern Quebec. After the apprenticeship he undertook graduate studies in marine biology at the University of British Columbia, in Vancouver. Specifically, his thesis was about the biomechanics of jellyfish swimming. Alongside his graduate studies, he founded and ran a research station – the Coastal

Ecosystems Research Foundation - on the central coast of British Columbia, where he and his teams studied the ecology of grey whales and their primary prey, mysid shrimp. As he was completing his PhD, he landed a postdoctoral fellowship in sports biomechanics and smart clothing at the University of Wollongong, Australia. The postdoc led to a lectureship in biomimetics in the Mechanical Engineering Department at the University of Bath, in England. He lectured in engineering design and biomimetics, and continued the marine biology research begun during his graduate studies, this time focusing on the development of novel sensor systems and underwater robots for use in the coastal environment. His students took the underwater robots one step further and started entering international competitions with both autonomous and human-powered submarines. He now runs the biennial European International Submarine Races every other year in the UK, in which teams of university students from around the world gather to race the boats they've designed and built. When a new university in Germany called asking for someone to design a new graduate programme in biomimetics, he jumped at the chance and took up the professorship

The Trichitala – a biomimetic human-powered submarine with undulatory propulsion
Photo courtesy of William Megill

Interview
William Megill

he now holds. He is now directing the Rhine-Waal University's Centre for Biomimetic and Natural Technologies and is Director of Studies for it's Bionics MSc program.

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

We're winning. The proof is in the pudding, as it were. Ever increasingly, we're finding elements of biomimetics throughout engineering design. Lightweight structures are often optimized with variations on the soft-kill option, and new algorithms come along regularly. Aerospace regularly makes use of new biomimetic inventions, whether it's as obvious as the winglets, as experimental as the sharkskin-inspired dimpling on the hull, or hidden away as lightweight, 3D printed bulkheads. Automotive, civil, robotics, materials, keep going – there are very few fields of engineering now where we haven't got a tendril making its way into the most conventional brainstorm or CAD model.

What do you see as the biggest challenges?

Communication, and in particular, the sharing of knowledge, is the biggest issue. Biomimetics has been so successful so far because we've been able to draw inspiration from open or at least semi-open scientific research on natural archetypes. Now that we're getting more successful, the tendency is for the designers to hide away their concepts or lock them up in broad-brush patents. And then the slow death of organismal biology and natural history is robbing us of the scientific explanations and sometimes quirky observations which make up the basis of our solution set. Eventually we'll stifle the development of the field if we don't keep the bioinspiration accessible to push the creativity.

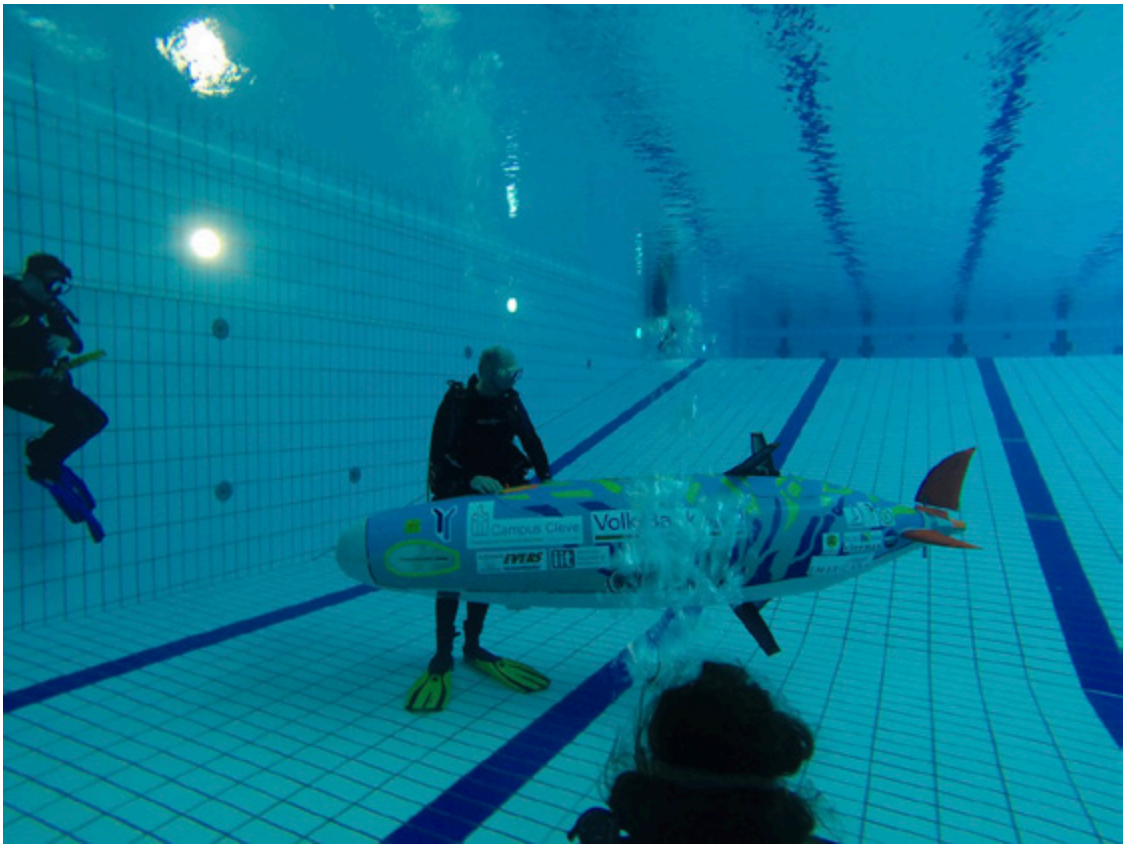
What areas should we be focusing on to advance the field of biomimicry?

I'm a teacher, so I'm going to say, "communication" again. We need to get the message out to a wider audience of engineers who don't yet realise that there's a whole set of problem-solving tools out there with a completely novel approach based on a totally different set of base properties. We're finding success by "sneaking" our innovation into industrial design. We make connections with individual engineers or maybe we get lucky and we dislodge an "in" with a whole design team or even a company. Our ideas make it into a product or part of one, and we celebrate, but we don't make enough noise about the process. Part of that is because of the IP and patents

I mentioned earlier, but the other part is that we're not doing a really good job of selling biomimetics as a design tool to a wide audience. Our goal should be to place a biomimetics course in every engineering degree worldwide. Then the next generation of engineers, who are predisposed to the (mostly) eco-friendly and sustainable solutions that naturally come out of biomimetics, will be able to take the field forward into industry in a big way.

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

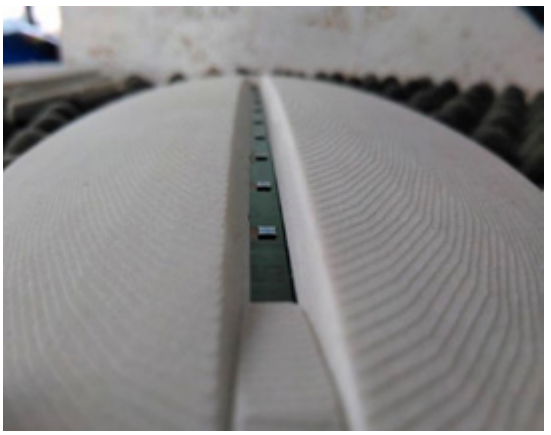
I'm not sure where the original interest came from. Physics and biology have just always been there. Studying physics was always most interesting when the example



The Rivershark – a biomimetic human-powered submarine with flapping pitching foil propulsion
Photo courtesy of William Megill

Interview
William Megill

was about something biological. Even during my physics degree, the biology was never far away, and the underwater acoustics brought them both together in my senior year. In grad school, I was using the mix to understand comparative biomechanics. It was really at the postdoc level, when I started integrating artificial muscles and conducting polymer sensors into smart clothing, that I really started developing an interest in biomimetics. By the time I took up the lectureship in Bath, I had figured out how to mix the engineering into my mental model, and I began building biomimetic concepts into my teaching and research. I think though it was the success of the biomimetic propulsion on our human-powered submarine that really cemented it for me. Now I'm a professor who's designed his own masters degree and who runs a research centre dedicated to the topic. It's hard not to be excited about the topic!



The Fluctomation Lateral Line – a biomimetic fluid flow sensor based on the lateral line sense of fish
Photo courtesy of Claudio Abels

What is your best definition of what we do?

I think of biomimetics as a branch of engineering design, which looks to the basis vectors of nature's solution space and maps those onto the basis vectors of the technical requirement space. We are the transformation matrix between those two sets of basis vectors. The first part of our job is to abstract the biological solutions and describe them in a logical order along those basis vectors, so that when we apply the transformation matrix to the problem, we land at a solution. The second part of our job is to invert the matrix and transform the solution we've described with biological basis vectors into one which can be described with technical ones. Or maybe I'm just being too mathematical here.

By what criteria should we judge the work?

We can use the same tools we would use to judge engineering in general. Does the biomimetic solution improve the situation? Does it solve the problem? By how much? What does improvement even mean? We could define it as better efficiency, lower toxicity, improved social acceptance, or, well,

whatever is useful at the time. I think in the end, we will have been successful at our job when biomimetics is "just another tool" in every engineer's toolbox.

What are you working on right now?

I have a new submarine waiting for the students to return. This one will be propelled with four pairs of flapping, pitching foils. The challenge is both a fluid dynamics one of getting the flap frequency and cord-compliance right, and a mechanical one of transmitting the continuous rotational power from the pilot to an oscillating intermittent rotation at the fins. We'll also be using a lot of new materials and manufacturing techniques to make the hull and frame, so I'm excited to put our new digital manufacturing capability to work.

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

I've got interested recently in insect walking and how to apply that to the design of a legged rover. There was a short video clip of a diesel-powered logging machine prototype developed by an Austrian company that walked more or less exactly as I'd envisaged my rover to do it. I'm thinking electric motors and plastic harvesting under the sea, but that the machine I want to build is demonstrably feasible was pretty motivating.

What is your favorite biomimetic work of all time?

I think that has to be the Twiddlefish-to-Nektor story. It starts with a paper in the *Journal of Experimental Biology* about a 99¢ toy fish on a wire, which when alternately twisted (twiddled), swims in a bathtub like a real fish, and ends with the multimillion dollar sale of a company making a novel propulsion system for small robot submersibles. The fluid-structure interaction studies that came out of that have led to a long string of flexible foil propulsors including divers' fins and the kayak propulsors we use on our submarines.

What is the last book you enjoyed?

First Man, it was called. A biography of Neil Armstrong. The story of the physics and engineering that went into the moon missions was just spellbinding. The book that got me into my career as a marine biologist was called *There's a seal in my sleeping bag*, by Lynn Hancock. The story of discovery of the biology of the British

Interview
William Megill

Columbia coast was as spellbinding as Dr. Armstrong's physics.

Whom do you admire? Why...

I'm probably not being particularly creative when I say the person I most admire is (well, was) my PhD supervisor, John Gosline. He was an absolutely amazing teacher – comfortable with groups of any size and of any ability. He could explain super complex topics in an immediately organized way that just made sense. In his research, he'd be speculating in the pages of *Nature* or *Science* on the role of a gene in controlling the mechanics of spider silk one day, and the next, he'd have his sleeves rolled up helping me to take an electromagnetic shaker apart so we could instrument it. I've strived throughout my career to follow in those footsteps.

What's your favorite motto or quotation?

Right now, it's "You can achieve great things if you don't care who gets the credit." I've heard it only recently for the first time, but it sums things up nicely for how I've lived my career. In my lab, the students, postdocs and staff come first, and in the greater community, I'm happy to see the "things" happen, regardless of whether I get the credit for my ideas or not.

What is your idea of perfect happiness?

A well-stocked workshop (a creativity outlet), a canoe (to travel quietly and efficiently), some wilderness (to explore), and the knowledge that my kids and my students are themselves healthy and happy.

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

That's easy. I'd be at sea somewhere, at the helm of a three-masted sailing ship. That nearly happened, too, but that's a different interview. ×

pink jelly fish | Photo: Paulo Gamba, 2020 | Flickr cc

Intertidal life
Manuel Quirós

Article

Life in Two Worlds: The Intertidal Zone

Manuel Quirós

Life in Two Worlds: The Intertidal Zone

Manuel Quirós

Figure 1. Rotation of the Iberian Peninsula. | M. Quirós

Between 80 and a 100 million years ago during the Upper Cretaceous period, the Iberian Peninsula rotated towards the rest of the European Continent (Figure 1), creating the Cantabrian Sea (Photo 1). This particular sea washes the northern coast of Spain and part of the southwest side of the Atlantic coast of France with about 800 km (500 miles) of steep rocky areas and cliffs as well as more protected beaches and estuaries. The area chosen for this article is located in a rocky part of the Beaches of Oyambre in the little town of Trasvia (Santander, Cantabria) where I have a family house and spent several weeks each year over the last three decades (Photo 2).

Although the sea evokes fantastic creatures such as cetaceans, sharks, marlin, and other colossi, more than 90% of marine life forms are invertebrates. The ocean is a vast, varied ecosystem dominated by boneless, flexible, watery organisms with astonishing life cycles often involving metamorphosis. The intersection of physical conditions (temperature, salinity, dissolved oxygen, wave exposure, suspended food, sunlight) and interactions between organisms define specific zones, where life and death are separated by a few centimeters or inches (Figure 2).

One of the most extraordinary areas of these coastlines are the rocky shores, a very productive and well-studied zone where many of the first discoveries about marine ecology were made by scientists who studied their complex marine communities. This area is rich in plants (algae) and invertebrate life showing an extraordinary variability across space and time. Tides and strong waves create incredibly demanding

Photo 1. A general view of the Cantabrian Sea on a calm wave day. | M. Quirós

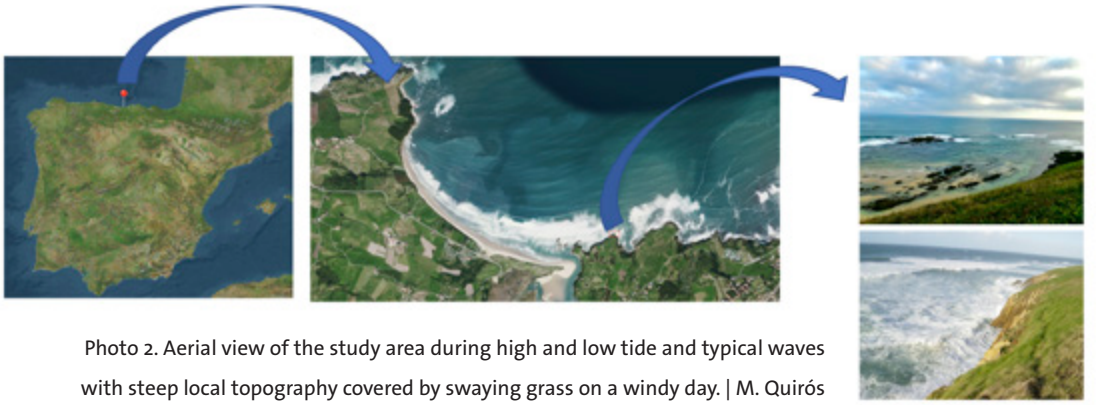


Photo 2. Aerial view of the study area during high and low tide and typical waves with steep local topography covered by swaying grass on a windy day. | M. Quirós

conditions for the organisms that inhabit this zone. The alternation between complete submergence in seawater and dry semi-terrestrial conditions can be fatal. Tides influence the immersion or exposure to water and also the effects of waves in a predictable endless cycle. Extreme exposure to wind and sun during low tide, sudden and extreme changes in temperature and concentration of salts in water, pH variation, oxygen levels variation (day/night), reduced times for feeding and reproduction, exposure to strong waves, and predation are just some of the factors affecting the organisms inhabiting this zone.

Waves and currents affect organisms living on exposed rocky shores, but at the same time, many organisms require the movement of water to carry away waste and deliver nutrients and oxygen. The crash of waves prevents organisms in the high zones from desiccation. Passive filter feeders, such as barnacles and mussels, rely on water currents to bring food within their grasp.

Life in Two Worlds: The Intertidal Zone

Manuel Quirós

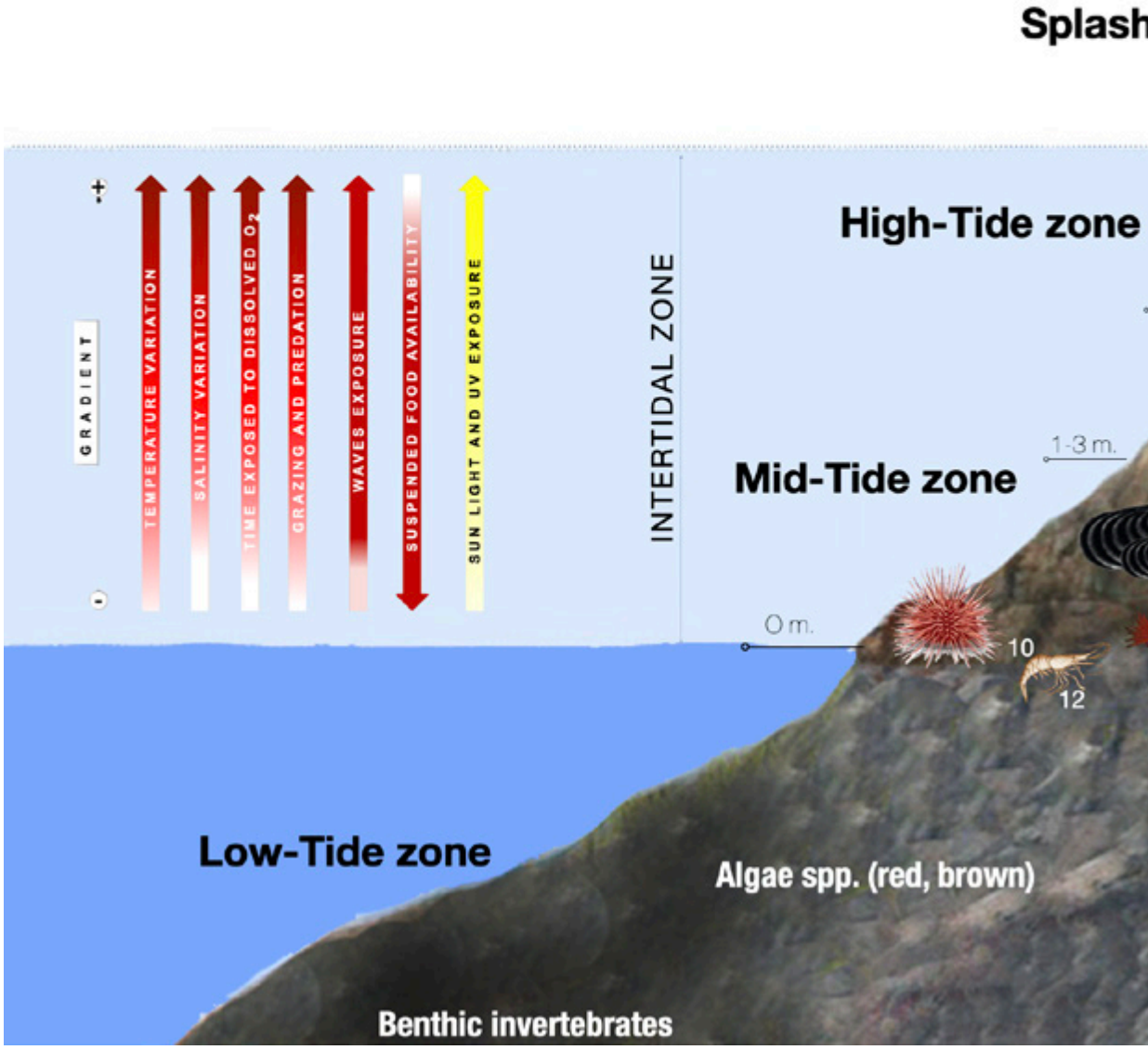


Figure 2. Intertidal cross-section of the highly exposed rocky shore described in this article with the seven key gradients that create vertical zones with their dominant organisms. | 1 Lichen (*Xanthia spp.*); 2 Limpets (*Patella spp*); 3 Rock Crabs (*Pachygrapsus marmoratus*; *Necora puber*); 4 small Acorn barnacles (*Chthamalus spp*); 5 Hermit crabs (*Clibanarius erythropus*); 6 Coralline algae (*Corallina spp*; *Lithopyllum incrustans*; *L.tortuosum*);

Planktonic larvae depend on water flows to disperse them, and later return them to the substratum when they enter their juvenile (fixed) phase.

Periodic emersion of the intertidal zone produces semi-terrestrial conditions, dangerous for these marine creatures. Colonising a lower zone reduces access to oxygen due to the limited surface area for diffusion found in small organisms. Some marine invertebrates opt for anaerobic metabolism, using metabolic pathways that generate end products such as alanine, succinate, or propionate which do not accumulate in the muscles or blood of the animal but are eliminated directly into the water. Some marine invertebrates are capable of surviving for days or even months without oxygen, especially if they live in environments below 10ºC (50ºF) which reduces their metabolic activity by up to 40% [1].

This paradox of diversity amid physical adversity is one of the reasons that wave-swept shores are considered one of the most fascinating and complex marine environments, colonized by a whole series of organisms with fascinating life strategies. The Cantabrian Sea is home to more than 150 species of algae (brown, red, green, or encrusting corallines), 16 gastropods (gut-footed) mollusks, some cephalopods

7 Mussels (*Mytilus galloprovincialis*); 8 Periwinkles (*Melarhaphe neritoides*; *Ocenebra erinaceus*; *Gibbula spp*; *Osilinus lineatus*); 9 Limpets (*Patella spp.*) shorter and wider individuals; 10 Sea-urchins (*Paracentrotus lividus*); 11 Anemones (*Actinia equina*; *Anemonia viridis*); 12 Common prawn (*Palaemon serratus*); Low tide zone: Algae (*Codium tomentosum*; *Fucus spp.*; *Leathesia difformis*; *Bifurcaria bifurcate*; *Cystoseira bacatta*; *Stypocaulon scoparium*) | M. Quirós

Life in Two Worlds: The Intertidal Zone
Manuel Quirós

(head-footed) like the common octopus, ten crustaceans, anemones, echinoderms, to name just some of the numerous invertebrates. Different fish species, including the small-spotted catshark *Scyliornus canicula*, challenging to observe, are also residents.

The intertidal zone described in this article is located on a shoreline of a few hundred meters (about 700 feet) that I have been exploring during the last three decades. During the low tides, a wide range of microhabitats is walkable, such as spiky-boulder flats, semi-vertical walls, and rock-pools, subject to movement by storms and strong waves and even erosion. Rock-pools where water remains in holes and depressions function as friendly refuges. In winter, the water temperature may reach near freezing, while in summer rising solar radiation and sudden downpours may lower salinity considerably. The tidal clock regulates the daily activity pattern for all the organisms living here. Some crabs even show a double timer, emerging to feed only if this occurs during the hours of darkness, avoiding birds and other predators, including humans.

The Moon's gravitational force on the Earth causes two high tides each day (Figure 3). The Sun is more massive than the Moon but much further away, creating a 'solar tide' about half as high. Particularly high tides occur when the solar and lunar tides line up twice in each lunar month. In March and September, the Oyambre region experiences exceptional tidal ranges (locally known as St. Matthew tides) of about 4 meters (13 feet) exposing more than 300 meters (1000 feet) of coastline (Photo 3), increasing the walkable areas for exploration but unfortunately also for poachers. This easy access combined with coastal pollution and other human

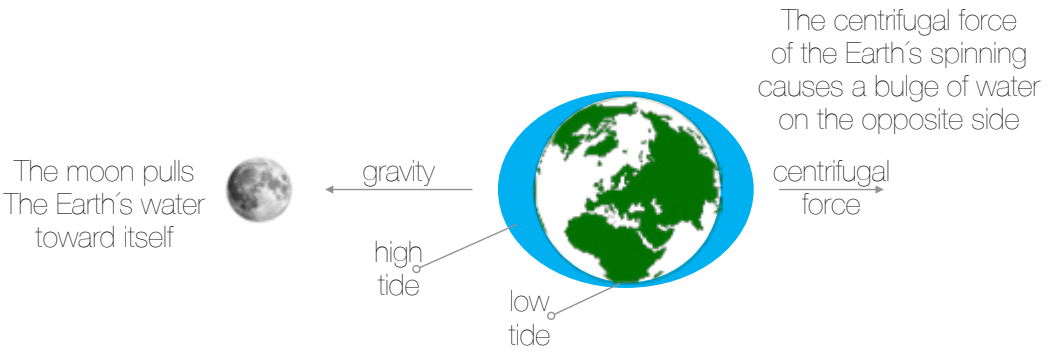


Figure 3. Tidal activity is primarily due to the moon's gravitational pull added by local winds and weather. | M. Quirós

pressures are causing declines in local sea star, sea urchin, limpet, and octopus populations.

For most intertidal life forms, low tide is a time of physiological stress, and these marine organisms have evolved to be semi-terrestrial with a high risk of tissues overheating in summer or freezing during winter months. Changes in conditions occur every six hours, and thanks to this endless cyclical process, organisms have evolved ingenious adaptations. Small patches of rock become a battleground for different species competing for space that matches their specific requirements. The result is a sophisticated three-dimensional structure (Photo 4). Organisms found here respond to the ever-changing conditions with varied and creative solutions. From flexibility to hard armour, from sessile to free-moving, from individualistic to collective behaviour - these survival strategies are described in more detail in a second article.

Similar to mangrove forests, intertidal areas are an essential refuge for the survival of the young of many coastal species, increasing biodiversity, harbouring organisms that recycle nutrients (and in turn are eaten by others), and resting or reproduction areas for migratory birds. These areas reduce coastal erosion by dissipating waves, capturing carbon in the skeletons of organisms, and supporting scientific research, sports activities, ecotourism, and artisanal fishing. Conservation of these vital areas creates opportunities for citizen participation in the development of management plans, maintenance of protected reserves, organization of educational events, and spaces for recreation, benefiting all inhabitants. A recent study published in October 2020 shows that urban kids in

Photo 3. High and low tide in the study area during the full tide cycle showing up to 5 meters of water depth and more than 300 meters of exposed rocks. | M. Quirós

Photo 4. Black-shelled mussels (*Mytilus galloprovincialis*), acorn barnacles, and oysters, competing for limited space on the exposed rock during the low tide. | M. Quirós

ecologically-enriched playgrounds showed increases in plasma TGF-β1 which is related to immune system regulation. The authors argue that the core reason for this pattern is the biodiversity loss in modern urban environments [2].

We cannot understand a species if we do not understand the context in which it develops and how it responds to temporary or permanent changes in its habitat (Figure 4). The strategies that the species have to overcome will vary depending on many aspects, including their mobility or sessility, external structure (shell/nakedness), mode of feeding (filter feeders/browsers /hunters/ parasites), and parental care.

Exploring the evolutionary adaptations of just a few species of mollusks can suggest new design ideas and potentially disruptive solutions. This type of exploration provides an opportunity to reconnect with nature, increasing our appreciation for natural systems and the organisms that inhabit them.

In "Life in Two Worlds: Organisms of the Intertidal Zone" planned for the next issue of *Zygote Quarterly*, I will describe some fascinating creatures dealing with the challenges of living at the junction of terrestrial and aquatic spaces. ×

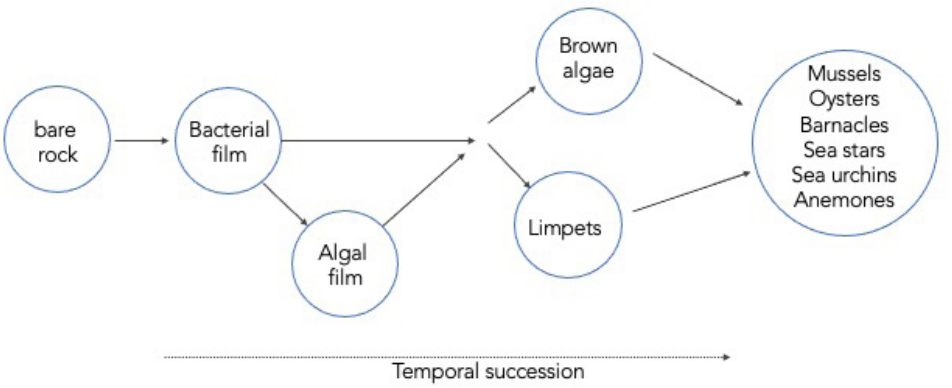


Figure 4. The time scale of the colonization of organisms in an intertidal zone. Limpets play a fundamental role in preventing the invasive development of algae. | M. Quirós

Life in Two Worlds: The Intertidal Zone
Manuel Quirós

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We would appreciate your feedback on this article:

Beaches of Oyambre, Trasvia (Santander, Cantabria) | M. Quirós

Manuel Quirós BSc, MSc, PhD is a passionate nature conservationist. He guides, as an independent teacher in several universities in Spain, inspiring classes through Sustainability and Biomimicry education as a transformational behavior strategy towards regenerative culture. He is the owner of NIU (https://www.natureinspireus.com/), a biomimicry consultancy; cofounder of Red Internacional Biomimesis (RI^3: https://redinternacionalbiomimesis.org/) and Biomimicry Iberia (https://zqjournal.org/editions/zq19.html). He participates as speaker in many international symposia like ONU-Habitat or COP 25. Contributing editor of *Zygote Quarterly* since 2013.

Manuel Quirós

Maliliadae Anirhocera (detail)
Andrea du Plessis

Portfolio

Supernature

Andrea du Plessis

Supernature
Andrea du Plessis

I was born and raised in Pretoria, South Africa, where I spent most of my childhood and early youth. After finishing school I enrolled for a degree in Fine Arts, but was unable to finish due to difficulties within the family. Overwhelmed by the fear of not being able to pay my student loan with a degree in Arts I decided to quit my studies and took up random jobs, essentially giving up on the idea of being an artist.

Andrea du Plessis

For about seven years after dropping out I had very little interest in making art and hit a complete creative block. During this time I decided to travel to the UK, where I ended up living and working for four and a half years. It was there that I enrolled for a diploma in Art Therapy, slowly getting back into art making. Returning to South Africa (Pretoria) in 2010, I found it difficult to get an Art Therapy practice going, and decided to enroll for a degree in Multimedia Digital Visual Arts to pursue my art career. In 2015 I moved to the beautiful city of Cape Town, where I am now living with my two pet rabbits, working from my studio as a freelance Integrated designer, illustrator, and multimedia artist.

What kind of techniques do you use for your work?

I like to describe myself as a multimedia artist because I enjoy working with a very wide range of traditional and new media (painting, sculpture, illustration, animation, augmented reality & A.I. generated art).

The series I am currently working on, called “Supernature”, is an exploration of our complex relationship with nature in an augmented age and how our access to the natural world has changed over the centuries. The work aims to create a link between

art historical representations of nature (eighteenth century, Romantic landscape painting) and contemporary representations of nature (new media such as augmented reality and artificial intelligence).

The process of creating a work such as "*Paloceae Lupantozoa*" (figure 1) for example, involved numerous steps and techniques. After researching several eighteenth century landscapes, I painted my own version with oil on canvas, incorporating techniques used by the old masters such as glazing and the golden ratio. The finished painting was photographed digitally and separated into layers in photo editing software in preparation for animation.

I then used an open-source A.I. (artificial intelligence) neural network platform, called

Figure 1. *Paloceae Lupantozoa,* 2020

Supernature
Andrea du Plessis

Artbreeder.com to generate insect/plant/animal hybrid images of nature (figure 2) and downloaded individual frames needed for a frame by frame animation. I then sequenced these frames into a continuously looping animation of hybrid forms morphing into one another - presenting the digital version of nature as eternal, undying.

Finally, the layered landscape and A.I. animation was combined into one final video artwork (figure 3). For sound I used a combination of samples: my own recordings and A.I. generated sound samples generated on sites such as Melobytes.com in response to an image of my painting. The artworks in this series are also made A.R. (augmented reality) interactive, meaning viewers can

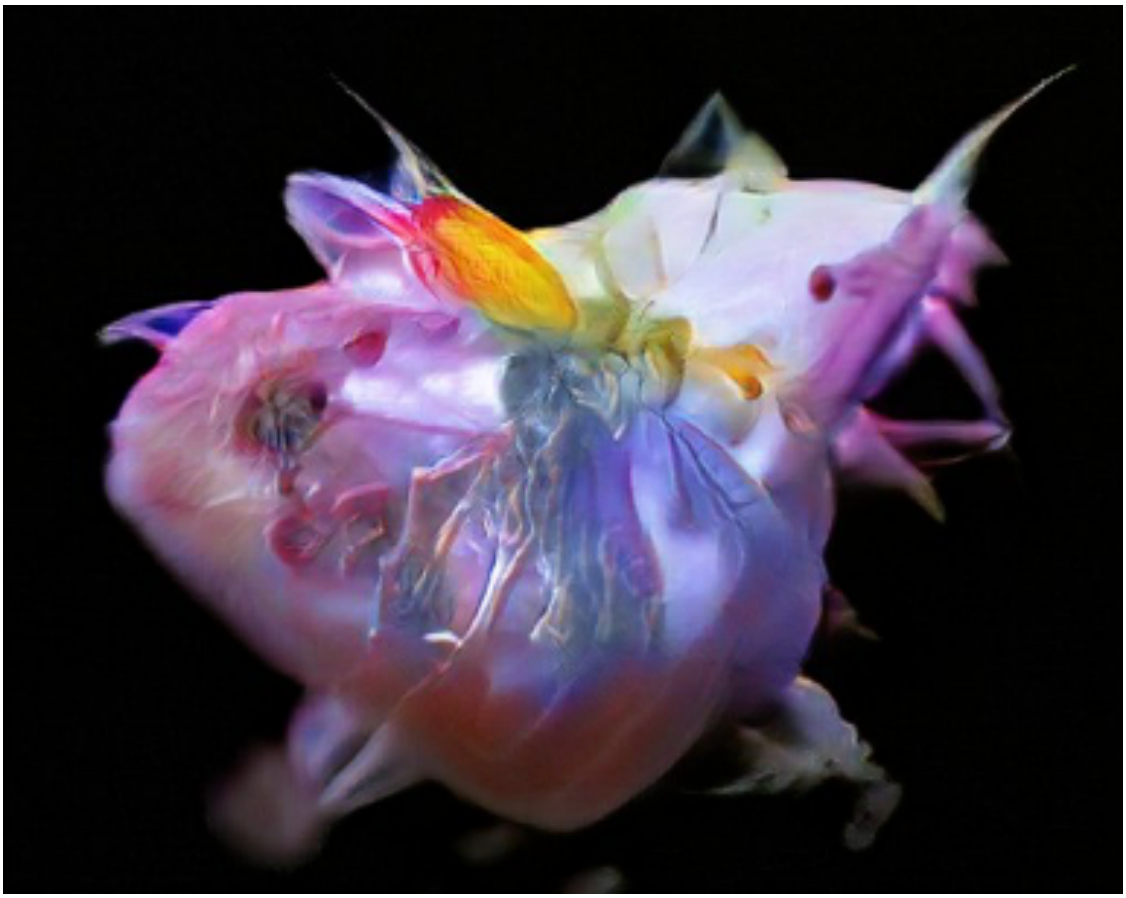


Figure 2. *Screenshot of image generated on Artbreeder*, 2020

watch the painting come to life via an app on their smart phone or tablet (figure 4).

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

Although I have always favoured realism, the style and content of my work has gradually shifted more towards surrealism. I love the idea of momentarily transporting viewers to a familiar yet alien world to contemplate alternate realities. With "Supernature" I specifically worked with the concept of interconnectivity between species, and therefore used images of hybrid organisms metaphorically. My work has become more conceptually focused and I'm really enjoying revisiting antiquity.

Figure 3. *Paloceae Lupantozoa*, 2020 (https://vimeo.com/468166962)

Images generated on Artbreeder, 2020




Supernature
Andrea du Plessis

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

2019 and 2020 have been transformational years for me and this has definitely shaped the way I view the world, and my place within it. My research for the "Supernature" series has included looking into biomimicry. The more I learn about nature's evolutionary wisdom the more I look at the natural world with awe. I am constantly considering my impact on nature and asking "How I can do less harm?", "What I can this creature or plant teach me?"

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

I do quite a lot of artist research and also draw inspiration from music, but at the moment the natural world is an endless source of inspiration for me. There is just so much to discover! The Covid-19 pandemic and being in lockdown has genuinely triggered within me a deep reverence for nature's power and intelligence. I'm privileged to have had a garden to hang out in during lockdown and this really became a sanctuary as I began noticing all the insects and birds going about their day.

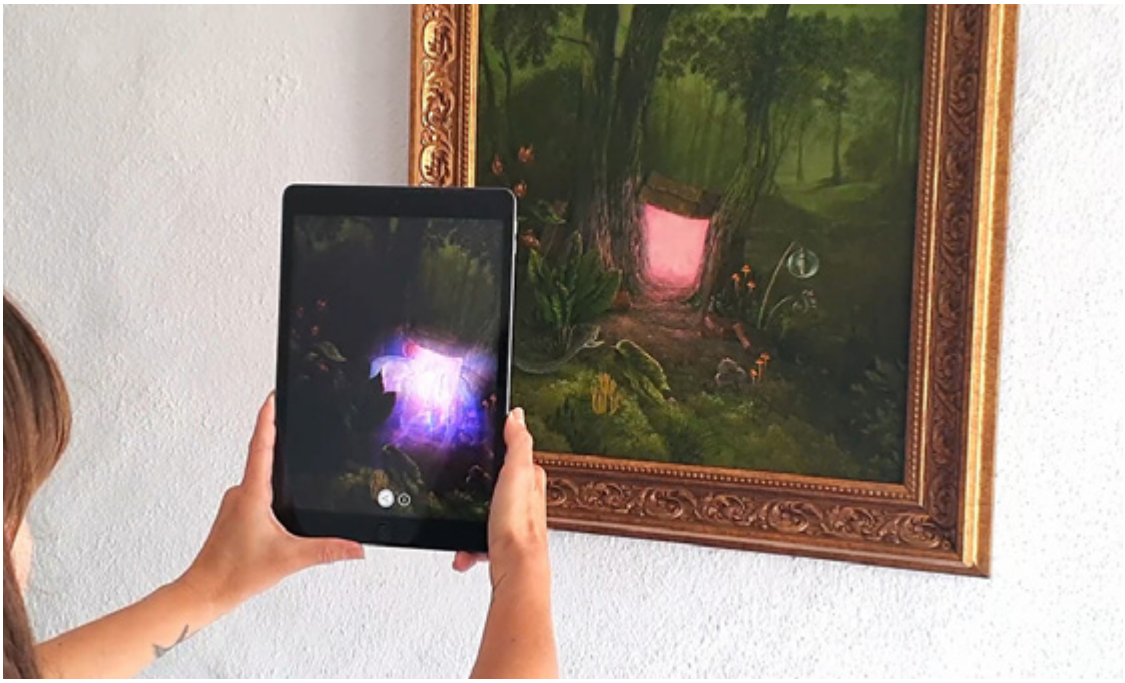


Figure 4. *AR interaction*, 2020

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

At the moment I am working on new artworks to flesh out my "Supernature" series. I am also looking into creating an immersive experience, possibly in the form of an installation. I would like to incorporate some sculpture, so I'm working on concepts for hybrid sculptures.

Can you also tell us about your work as a designer and illustrator?

Graphic design is most certainly a completely different approach to visual communication, so I have to wear a different "thinking cap" when I switch to working on visual art. I find both creatively stimulating and fortunately the technical skills needed for design and illustration can also be used for art making. Having design and animation skills certainly comes in handy as a visual artist, and likewise, having the formalist understanding of principles such as colour theory and perspective. as an artist certainly benefits my design practice. I really enjoy illustration and have worked on some really fun projects such as an augmented reality children's book prototype and concept art for Hasbro's *My Little Pony vs. Transformers* augmented reality game.

What is the last book you enjoyed?

I recently rediscovered *The Little Prince* by Saint-Exupéry again. It's just such a magical, nostalgic story that seems so simple but to me it spoke about growing up and the loss of one's childlike sense of wonder. It also reveals so much about human nature – our obsession with time and numbers, and our ability to turn nature into a commodity. I love the Prince's gentle, innocent interactions with the fox, his rose, and the animals he meets on his travels. A sense of wonder is something I want to evoke with my work, so this book has been an inspiration.

Pythozoa Aporia (https://vimeo.com/471941301)

Supernature
Andrea du Plessis

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

I have really enjoyed experimenting with creating A.I. generated art this year on www.Artbreeder.com. I love interactive platforms like these where I can engage in a kind of collaboration with a machine and explore its creative potential. It really has got me questioning the creative act as well as creative authorship.

Memo Akten's artist website, www.memo.tv, has been a mind-blowing source of inspiration. Akten's work with A.I. and machine learning was what sparked my interest in computer generated art. Not only does he use new media in a genius way, he is also concerned with the collisions between nature, science, technology and religion.

Thirdly I really enjoy Olafur Eliasson's artist website, www.olafureliasson.net, as a source of inspiration. Eliasson is a Danish-Icelandic artist and works in collaboration with other artists, researchers, and assistants to create large-scale interactive installations. He's interactive website reflects the interactive nature of his artworks. It's fascinating to see what can be achieved when working in such a collaborative environment.

Arbor Pavitae (https://vimeo.com/468246890)

What's your favorite motto or quotation?

In the seven years that I wasn't making art I remember feeling too disconnected to even know how to approach a blank piece of paper and instantly disliking everything I tried to paint or draw, which obviously made me even less interested in making art. It snowballed into a legitimate creative block. The only way I got myself out of it was by persevering. Pablo Picasso once said: "Inspiration exists, but it has to find you working". Time and time again have I found this to be true. Looking back I realized that inspiration is not something that will hit

you like a thunderbolt while you sit waiting. The only way to get out of a creative rut is to start somewhere, no matter how insignificant you think it is. Start with anything, any idea, and see where it takes you, because the more you do the more ideas and inspiration will come to you. ×

For more of Andrea's work please see:

www.andreadp.co.za

We would appreciate your feedback on this article:

Maliliadae Anirhocera (https://vimeo.com/468133244)

Arbor Pavitae | Andrea du Plessis

Pythozoa Aporia | Andrea du Plessis

Paloceae Lupantozoa | Andrea du Plessis

Oecophylla smaragdina Weaver ant
Photo: Rushen, Thai National Parks, 2013 | Flickr cc

Interview

Noah Pentelovitch

Interview
Noah Pentelovitch

Noah Pentelovitch is the Associate Director of Advanced Development for the Housewares segment of Helen of Troy, which includes OXO and Hydro Flask. Noah has nearly a dozen years of experience in product design, development and manufacturing working at Wrigley, Klein Tools and OXO. Noah has worked on everything from butter dishes to coffee makers to food storage containers. His work is now focused on developing the Houseware segment's Research and Advanced Development capabilities and finding and applying new materials, manufacturing processes, technologies, and design approaches. Noah also works on sustainable materials and manufacturing. Noah has recently been working on understanding how BID can be practically applied at OXO and Hydro Flask. Noah received his bachelor's degree in Mechanical Engineering from Northwestern University.

Noah Pentelovitch

What got you interested in bio-inspired design (BID)?

I became interested in BID through Steven Vogel's *Cats Paws and Catapults* and *Comparative Biomechanics 2nd edition* which introduced me to looking at nature through a physics and engineering lens. The design process as a creative process is limited by what you and the people around you know. Although we are good at engineering things, inspiration from nature can help designers and engineers get away from traditional solutions.

How are you trying to apply BID?

I lead Research and Advanced Development for OXO, a consumer products brand that has been around for 30 years and has over two thousand products. OXO's goal is to make everyday tasks and chores better with tools that provide demonstrably better

Weaver ant
Photo: TroopDresser, 2011

Interview
Noah Pentelovitch

experiences. At OXO, industrial designers and mechanical engineers work closely with product managers and a network of contract manufacturers. Projects need to happen quickly and deliver manufacturable and profitable products using existing materials and manufacturing processes.

OXO engineers typically have a set of problem-solving approaches that help them meet tight timelines and deliver commercially viable solutions. The challenge is to help them figure out creative ways to translate novel functions and strategies from biology into innovation compatible with the materials and manufacturing processes available to OXO. This is as much a human problem as a technology/biology problem.

What is OXO's design approach?

OXO was an early adopter of human-centered design, popularized by Don Norman's *The Design of Everyday Things*. Sam Farber, OXO's founder, observed his wife, an architect with mild arthritis, struggling to use a traditional potato peeler made of bent steel. This observation led to the development of a peeler with an ergonomic grip that was not only more comfortable to use by arthritis sufferers, individuals with small motor coordination issues, but also for the general population. Human-centered design is the process of observing people, identifying needs that they may not have identified themselves, and addressing those needs. Human-centered design at OXO started with product design but has now permeated the entire brand. Our entire team is conversant in it and understands the principles.

Design is a huge component of what OXO does, but materials, engineering, and manufacturing are what makes design real. The challenge is being creative in finding and combining materials into a product that looks good, functions well, and can be sold at a price people can afford.

How are you trying to introduce BID at OXO?

BID is not one thing—there are many approaches, tools, and philosophies. Before we can integrate it as a problem-solving tool, we have to try it and find out what works for us, what doesn't and why. I want to explore how BID could be used at OXO, but also be a testing and proving ground for researchers developing BID tools and processes. We have very creative and open-minded engineers and designers - I think if you can show them a new and, most importantly, effective way to solve a problem, they'll adopt it.

In October we did a study with Dr. Jacquelyn Nagel. The idea was to have industry engineers, in this case from OXO and Hydro Flask (our sister brand in Helen of Troy's Housewares segment), try various BID tools using the same problem prompt and compare the results. We focused on building blocks such as functional modeling and 'draw by analogy' to help engineers frame the question correctly and then recontextualize natural systems within the context that they work in. I view this as a start, not an end. We will continue adding tools to our toolbox and testing other approaches to find the ones that fit best with our problems, processes, and skill sets.

Bio-inspired solutions can be highly innovative, but frequently have difficulty making it off the page or out of the lab. An advantage I think we have is that our engineers and designers are there to bring ideas to market. We can't end up with concepts we can't make and scale. We have a limited set of materials and manufacturing processes available to us that we know and understand well. We bring that knowledge with us into the BID process, and for this reason I believe we will be more likely to find innovative solutions that can be brought to market.

What are you working on now?

Dr. Nagel has been evaluating the data from the study and assessing what conclusions can be drawn from it. We are discussing writing up the results and hope to share them soon. One of the key takeaways from

Draw by analogy
Courtesy of Violet Lim

Myrmecocystus Honeypot Ant | Photo: Smithsonian National Museum of Natural History, 2005 | Flickr cc

the workshop is that BID is not going to be an everyday problem-solving tool for us. Most of our day-to-day problems are better addressed through standard solutions and engineering practices. BID requires deeper and longer periods of work and the benefit is a wider array of creative solutions. This is especially valuable in early-stage concepts and when we want to explore new approaches to solving old problems. BID will be a valuable tool provided we are intentional when deciding when and how we use it. We need to plan ahead, set the framework for everyone involved, define the problem in the most advantageous way, and allow time for research and iteration.

Next, we are going to look for the hard problems we face that would be good candidates for BID. After we do that, we will use the BID tools we have learned to see what kinds of solutions we can come up with. Additionally, we are going to start exploring other tools and approaches.

I want to help designers and engineers at OXO become conversant in BID and understand how and when it can be utilized to develop novel solutions to hard problems. Although BID has a technical side in terms of identifying and understanding relevant natural systems, the softer side of understanding how BID relates to what we know and how we operate is just as important. Implementation is a huge challenge and requires connecting the natural system to materials, manufacturing, and other business constraints. BID needs to be comprehensible and relatable to the problems we have every day.

As BID proponents, what questions should we be asking ourselves?

We should be asking why BID is not being adopted widely by industry and whether the tools and processes that exist meet the needs that engineers and designers have. There won't be a one-size-fits all solution for every industry. Different industries and businesses have very different constraints: longer or shorter timelines, cheaper or more expensive goods, low vs high volume production, exotic vs common materials.

We should ask who is engaged in the community. Is the intended end user represented in the literature, the conversations, and the interest groups? The interest is there, but is the follow through? Professional engineers and designers are steeped in the materials, manufacturing processes, and problems of their industry. BID tools and processes need to be adapted to existing company process and structure. It's hard to change how a company operates, but there are many people who, if they can

be shown how BID can work for them, will champion its usage.

Lastly, we should ask how can biologists and engineers and designers be connected to one another? How can it become as natural to have a biologist in the design process as a manufacturing engineer or a UX researcher? It will be a while until companies are hiring biologists as part of their design or engineering teams. Until then, what can we do? ×

We would appreciate your feedback on this article:

Ant
Photo: pha10019, 2010 | Flickr cc

Bowl, OKA
Photography Lara Chang

Interview

Erika Cezarini from OKA

In conversation with NOUS Cultura Creativa

Erika Cezarini from OKA
In conversation with NOUS Cultura Creativa

I grew up in a very special region, in the Cuesta de Botucatu, a beautiful region of rock formation that has the main recharge of the Guarani aquifer that was once called the Botucatu aquifer, forming the transition from savannah to Atlantic forest. I grew up going to the waterfalls and camping by the rivers with my family since I was little. I spent holidays in an incredible place that I had the opportunity to visit recently in the Paranapanema River basin. The moments in nature have always been the best and where I could marvel at the diversity and beauty of the plants, the geometric patterns and colors that she presents us with. Becoming a designer has everything to do with this interest in geometry, and for wanting to rethink products and the way we do things. I remember the first time I heard the term biodynamics and thought “That's it !!”. Of course it was related to engineering and concepts a little far from my reach of knowledge, but the idea was clear and obvious and made sense for other applications. During the course I became interested in permaculture, bioconstruction and, consequently, in ecodesign. I graduated in 1998 and founded Designio ecodesign where I invested my free time to create projects and ended up turning to the waste issue. I studied composites and created a systemic project to mobilize companies, governments, and citizens. Seeking materials for collectors I came across the use of cassava for packaging, through a study by Marney Cereda, from CERAT at Unesp in Botucatu SP. I was also interested in live food and that was the first time I heard about biomimetics from professor Ana Branco from PUC do RJ, with his concept of biochip. That's how I met Fred Geli (Tatil design), who took the concept to his design agency. I’m into the new, the different, but always looking at the relationship with nature.

Erika Cezarini from OKA

Cacto Mandacaru na Cuesta de Botucatu | Photo: Rosan, 2010 | Flickr cc

Bowl, OKA | Photography Lara Chang

Erika Cezarini from OKA
In conversation with NOUS Cultura Creativa

What do you see as the biggest challenges?

Meet all the technical requirements of the different products to be packaged, without losing purity or biocompatibility. Diversify our materials in terms of process and composition to generate desired results, such as transparency (for lids or windows), flexibility to allow specific movements, and greater resistance to moisture for applications such as cups or lunch boxes.

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

Firstly in education, bringing schools closer to nature and promoting experiences to educate people to look in this direction, to generate ecological literacy. But in all areas of life it makes sense to return to the source to inspire thinking about synergistic and circular processes, aligned with the natural cycle of life.

Cup bites
Photography Tatil Design

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

I have grown up looking at the micro, the natural patterns of plants, animals, and minerals, asking questions such as what relationship exists between geometric shape and light and how does it affect the color we see; or what does shape (geometric structure of the particles) have to do with the hardness of a material? These questions were part of my childhood from a very early age. I was trying to see relationships between form and function, harmony and beauty.

What is your best definition of what we do?

We extract knowledge of what formed us and it is constantly evolving and adapting to our daily lives, whether in processes, in forms, in flows, in harmonization, or interdependence.

By what criteria should we judge the work?

Closed cycle, that is, fully integrated into the natural process of life. Our industrial production is clean and uses little water in the manufacturing process, does not generate waste nor does it generate pollution and the disposal of the material after use is always positive, whether as human food, as animal feed, or even as food for the Earth. Another relevant aspect is the possibility of adding fibers to the composition, allowing a wide variety of aspects, colors and considerable improvement in increasing the material's resistance. The local use of waste is also a relevant aspect not only in economic terms, but also in cultural, social, and environmental terms. Our basic raw material is cassava. We wanted a vegetable base that could be scaled up, had an affordable price and easy cultivation, and that had physical-chemical properties that would allow the formation of products with quality and repeatability. The process of forming the parts is thermal expansion of the biomass inside a closed mold of heated aluminum. The product generated, when made only from pure cassava starch, is similar to extruded polystyrene, with a lot of mechanical resistance, but less flexibility. The fundamental difference is that it is completely biodegradable and can be ingested. Another advantage is that it can go from the freezer to the oven. With the addition of fibers or other components such as flour, seeds, and dyes, the visual aspect can vary a lot, but the properties are maintained. It can be discarded in domestic compost and its biodegradation takes place in less than 30 days, depending on the local

Copo branco | Photography Tatil Design

Erika Cezarini from OKA
In conversation with NOUS Cultura Creativa

humidity. In water, (river or sea) it takes less than 24 hours. It can be used as animal feed, both for domestic and livestock animals, as well as for fish or other marine animals. It is not enough to have a regenerative product if the system that maintains it is not regenerative, so we are building a shared model for the production and distribution of bio packages. We have several structural partners, such as Technology and Automation, IT, R&D, and Design that seek solutions for different contexts, such as taking a production unit to extractive communities, or within different industries and at different production scales. For that we seek to develop a modular system that can be accessible, profitable, and local.

What initiatives are you working on?

We are in the process of increasing the water resistance of the material based on cassava starch and a new 100% vegetable based material that is also more durable. In addition, we are launching a take away line that incorporates safety seals by leveraging the natural adhesive quality of starch to avoid chemical adhesives.

Courtesy of OKA | Photography Lara Chang

What success stories can you share?

So far I have had success stories regarding the development of technology although we have had some small scale commercial successes. Some relevant ones: we achieved resistance and crispness to generate the experience of an edible spoon and are using our material as baking forms - also edible. Adding fibers from agro-industrial residues achieved good results supported by technical reports from the Institute of Technological Research and allows for stacking egg boxes.

What are your plans for the future?

To have units in several countries producing biopackages, using local fibers or residues in the composition, both on a large scale, and in extractive, rural or traditional communities.

What is your geographical "reach", where are your members, meeting places, project locations?

We are based in Botucatu, in the interior of the state of São Paulo, in Brazil, but we sell to the whole country and we are starting exports and licensing of the technology in other countries.

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

We are producing capsules for reforestation. Packing the seeds, soil, nutrients, and hydrogel to ensure the ideal humidity conditions to create a micro environment suitable for the seeds to germinate. With a recent partnership with the Istituto Europeo di Design we have identified opportunities for environmental regeneration of biomes, through the introduction of microorganisms via our biocapsules.

What is your favorite biopackaging work of all time?

The natural ones. Some fruits have an incredible packaging like the pomegranate and its geometry, the banana and its ‘blades’ that come off on each face when peeling, the loquat with its thin skin that comes loose, the poncan with its buds in mini portions, and of course, the first package that we know is the maternal uterus (the holy grail). I really like Ybirá's work with natural leaves that have potential in 100% natural products.

Erika Cezarini from OKA

In conversation with NOUS Cultura Creativa

What is the last book you enjoyed?

Active Hope, by Joanna Macy and Chris Johnstone. It is a book of love for life and relationships.

What is your idea of perfect happiness?

The moments of fullness for me are always associated with an experience in nature, in an environment of beauty and harmony.

Who do you admire? Why...

Vandana Shiva is undoubtedly one of the people who inspires me the most; Fritjof Kapra, his books and teachings have been a gift in my life and way of reading the world; Michael Braungart and William MacDonough, the creators of the C2C or Cradle to Cradle concept; and the beloved John Croft, creator of Dragon Dreaming, who brought me the courage, tools and inspiration to materialize and transform the biopacking project into a real enterprise,

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

A dancer, dancing is my greatest passion, even though I have practiced very little. I would also like to be a sculptor, although I don't think I have the talent for that, but perhaps the desire to have my hands on the ground together with the desire to create art. ×

For more about OKA see: https://www.okabioembalagens.com.br/?lang=en

What's your favorite motto or quotation?

"Simple is the ultimate degree of wisdom" (Khalil Gibran) and "Simple is the ultimate degree of sophistication" (Da Vinci). For me it symbolizes removing the veils, seeing with the eyes of nature, simplifying until reaching the essence.

We would appreciate your feedback on this article:

Nous Cultura Creativa

Julio Glatt is a Master of Science in Biomimicry from Arizona State University and a graphic design graduate from FAAP, Brazil. Passionate about nature, has practical experience in botany, zoology, ecology, documentary photography. Julio translates biological and design principles into graphic representations for easy-to-read nature-inspired solution reports. He explores scientific communication, biophilia, and art as ways to provoke nature re-connection and reflections about humanity's relationship with it.

Daniel Mira is an artist and researcher. Graduated from Universidade de Brasília (Brazil), has a specialization in Visual Poetry, a Masters in Design, and a current doctoral candidate in arts in the same Universidade de Brasília. Develops research, in theory and practice, about how Alexander Van Humbolt's idea of unity in nature expressed in its "Naturgemälde" concept and Goethe's methodology "phenomenology of nature" contributes to the deployment of biophilic perspective for the artist-researcher. In charge of engaging in Humanitarian, Environmental and Cultural initiatives at NOUS institute. Co-founder

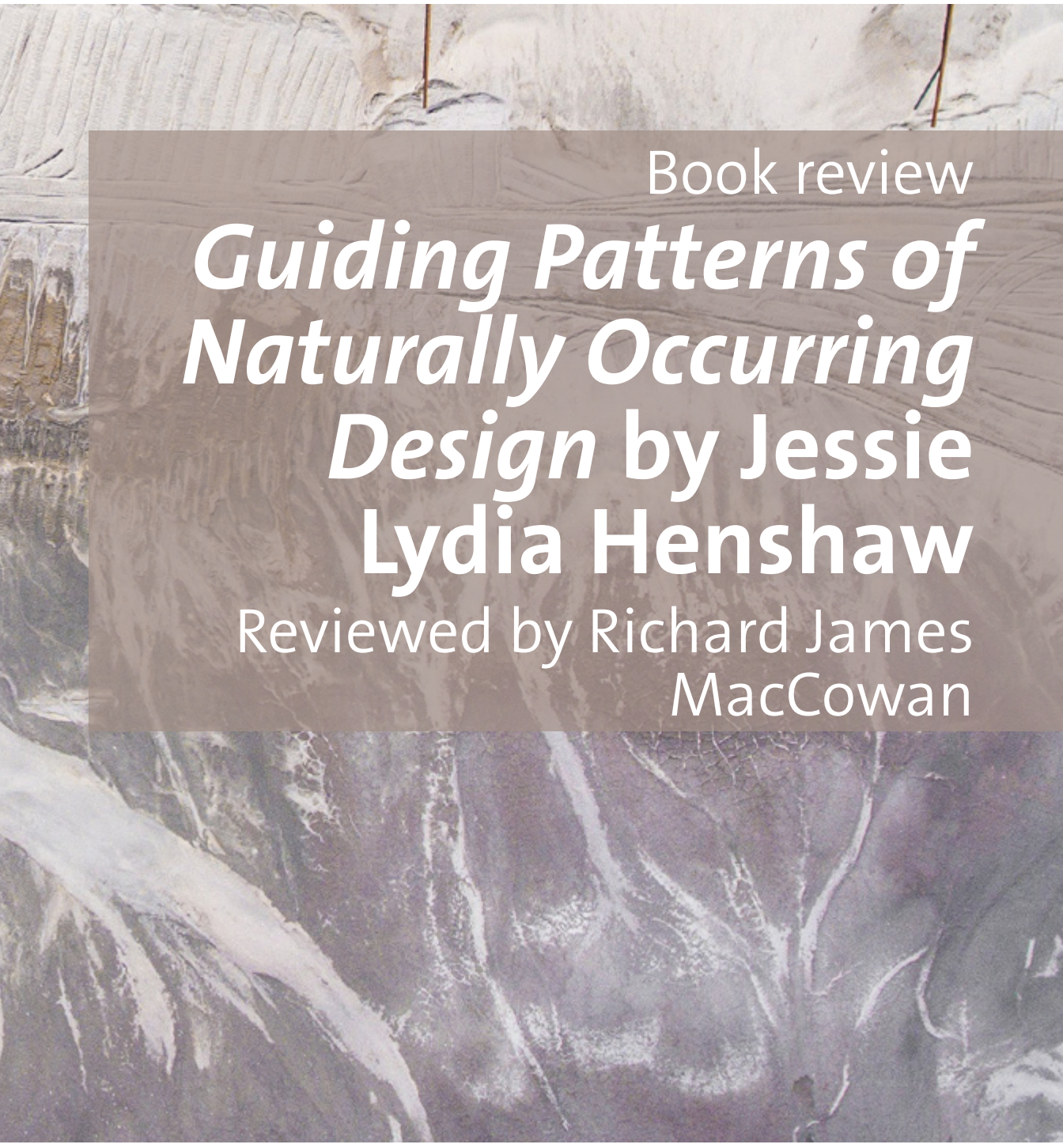
Erika Cezarini from OKA
In conversation with NOUS Cultura Creativa

of NOUS Conscious Communication, a communication consultancy focused on the brand essence, developing models and methods that bring awareness to brand value and market positioning. Has an academic teaching career of more than 10 years. Coordinator at Núcleo de Extensão Humanizante and mid-west region coordinator at Rede de Produtores Culturais de Fotografia no Brasil.

Carol Freitas is a product design graduate from Universidade de Brasília, innovation consultant, and biomimicry master from Arizona State University. Carol is a certified biomimicry professional from Biomimicry 3.8 and also has a background in Bioempathy and Bioleadership. Founder of the regenerative communication office Nous Comunicaçao Consciente at Brasília, Brazil. Co-founder of Origen Group, an initiative that supports women engaged in sustainability business and practices. Supports international networks such as Biomimicry Institute, Arizona, and is the Bioleadership London innovation cluster representative. Works as speaker and mentor in startup programs: Founder Institute, Startup Weekend Woman, Nasa Space apps, and Biomimicry Global Design Challenge. Carol has visited different biomes in Brazil, United States, Canada, and Africa, learning with nature to help human beings become better species.

The Guarani aquifer
Image: Marko Perendija, Argonne National Laboratory, 2014 | Flickr cc

Scenic view of snowy mountainous terrain
Photo: Curioso, 2016 | Pexels cc



Book review

Guiding Patterns of Naturally Occurring Design by Jessie Lydia Henshaw

Reviewed by Richard James MacCowan

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Consider taking a deeper look into the place where you live. Examine how trees frame the street. Explore how these trees create a better environment for urban cooling and a more walkable and pleasant atmosphere. What you are experiencing are that these trees are part of public space patterns.

Now, suppose you delve deeper into the street. You can observe the details in the street-furnishings and how they bring about a human-ness to the street. Some streets are avenues, others urban greenways. What you are seeing is the creation of pedestrian sanctuaries, another example of a public space pattern.

Unfortunately, many cities are all too often designed for cars, rather than people and nature. As Mehaffy explains, “the major surface arteries of cities can choke the life out of their neighbourhoods.”[1] To avoid these issues, Mehaffy collected and published recurring patterns of good-quality urban design in *A New Pattern Language for Growing Regions* (2018).

Henshaw’s *Guiding Patterns of Naturally Occurring Design* is grounded on the concepts of ‘pattern’ and ‘pattern language’. Popularised by Christopher Alexander in the 1970s, a "pattern describes a problem that occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice."[2] In other words, patterns explicitly focus on problems within a context and guide how, when, and why a designer can apply the solution. Patterns are practical and describe instances of "good" design while embodying high-level principles and strategies. Five sample patterns from *A Pattern Language* (1977) are available at http://www.patternlanguage.com/apl/aplsample/aplsample.htm.

Patterns exist in the context of peer, component, and encompassing patterns. A hierarchy of patterns organised by grammar forms a ‘pattern language’ which provides a way of solving big problems through decomposition while helping designers retain a focus on the big picture. A fully functional version of the interactive Reliable Prosperity pattern language is available at https://web.archive.org/web/20160325201115/http://www.reliableprosperity.net/.

Users can enter a pattern language at a level appropriate to the situation, using encompassing patterns to explore the larger system and component patterns to identify specific solutions.

Think of the distribution of towns in your region. Regional policies protect the land and mark the limits to the urban areas.

Paris, France | Photo: Leonid Yaitskiy, 2018 | Flickr cc

Guiding Patterns of Naturally Occurring Design by Jessie Lydia Henshaw
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City policies define the uniqueness of a city. These larger patterns will lead to the understanding of the different neighbourhoods and how transportation networks connect them. From here, consider how your house sits in this neighbourhood.

According to Henshaw, Christopher Alexander appreciated “that the organization of nature is not in categories, but connecting opportunities." This knowledge leads to the essential question that Henshaw proposes - can we go back to nature for these guiding patterns?

The comparison of human design to naturally occurring designs (or systems) that Henshaw proposes concentrates on how things do things using energy and information flow. Henshaw correctly states that nature does not design, but by looking at the similarities between the early stages of growth of, say a plant, and comparing this to the early stages of design processes, you can see similar patterns of energy and information flows.

The book gives many examples of architectural and natural models that give you insights into what can be transferred. Using the tools laid out in this book, you can begin to explore the natural patterns, including inspecting the meaning and context of words or phrases.

The emphasis is on working with nature, and learning from its underlying principles, instead of the Industrial Revolution focus on controlling it. Pattern language allows you to explore and appreciate systems and organisation, "like how a lobby provides space for 'milling around,' presented in a way to convey welcome to the private or business home, not just the calculated space necessary for accessing minimal corridors." Henshaw and Alexander can help us learn how to retain creativity within deterministic science - a scientific method that previously existing causes entirely determine all events. You can see this in informal settlements where buildings and self-organisation of the community intersect (image 1).

Henshaw's *Guiding Patterns of Naturally Occurring Design* is a collection of the authors' journal and conference papers outlining the development of her work from academia, architectural design, and government. It highlights her opinion on the usefulness of pattern languages, or guiding patterns, for design and design processes in physical space, in this case, architecture and urban planning and business development.

The book has ten chapters split into the themes 'Elements' and 'Mining Living Quality', with the former based on theory

Image 1: Informal Settlement: Lima, Peru | Photo: Bill Hertha, 2009 | Flickr cc

Worms Eyeview of Green Trees | Photo: Felix Mittermeier, 2017 | Pexels cc

and the latter focusing on a case study example.

Chapter Overview

Chapter 1 introduces the reader to the origins of pattern languages and Henshaw's development of her guiding patterns. The chapter moves into natural design patterns and how we should take a dual worldview, our directly sensed and observed impressions, and our mentally composed interpretations of their meaning. As Henshaw describes, "those two views work together so seamlessly we can miss how very different they are, one attached to nature the other a detached construct of what we think."

Chapter 2 focuses on what the author describes as the most common natural design patterns, the natural design typical life cycle. The chapter compares the energy levels of natural design patterns by focusing on 'homes' and 'shelters' and how this process creates the footprints and artefacts left behind.

Chapter 3 proposes a 'Starter Kit' for the reader to the methods Henshaw develops in her work in four groups:

1. Generalising natural design patterns to find working examples,
2. Exploring changes and transformation,
3. Using pattern templates to record and communicate,
4. Identifying existing repositories of nature's patterns.

Chapter 4 summarises the previous chapters and brings the theoretical section to a close, reviewing the value of natural patterns and jumping back into the dual-world view - our directly sensed and observed impressions and our mentally composed interpretations of their meaning. In essence, what we see compared to what we perceive.

Chapter 5 introduces the second theme, 'Mining Living Quality' and focuses on extracting information from various sources and using this practice to investigate deeper into complex research papers.

Chapter 6, 'Mining Connections for Living Quality,' introduces the interconnectedness of the natural world. The subject expands on Chapter 3 with worked examples developing the idea that any design has interdependencies and tradeoffs while also being responsive to its surroundings.

Chapter 7 focuses on two studies Henshaw presented at the Pattern Language of Programs 2014 meeting contrasting pattern descriptions using working words ('how it works') and centre words ('why it matters') - suggestive words found in pattern descriptions. Think of it this way,

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a complementary fit of two people (how it works) can be considered a marriage (why it matters).

Chapter 8 describes why you should use naturally-occurring design and its usefulness with pattern languages. The reader is introduced to Henshaw's background and development of naturally-occurring design through the teachings of Christopher Alexander, Jane Jacobs, and Brian Goodwin. The chapter finishes by summarising the author's methods for assessing a pattern.

In Chapter 9, Henshaw highlights how to search for patterns, both natural and human-made, through the study of human

Image 2: Green Leafed Tree
Photo: Nejc Košir, 2017 | Pexels cc

culture, pattern search, stages of growth, habitations, and natural language.

The book concludes with a summary of the entire volume in a helpful bulleted list of topics acting as a reference point for the work presented throughout the volume.

Analysis

This book brings together academic papers into one tome, requiring the general reader to jump from paper to paper. Although Henshaw has brought life to this topic, greater attention to the graphic style and layout would have opened this fascinating topic to the broader world.

Nevertheless, this book is a must-read for those interested in complexity, systems-thinking, and design, including the field of biom* (an umbrella term for biomimicry, biomimetics, bio-inspired design, and related fields). It has opened my eyes to a fresh way of thinking (and designing), allowing me to crystallise my thoughts to design/develop/create better solutions.

One of the critical elements of any biom* design process is understanding the problem and how it fits into the world, moving across scales of hierarchy. The book gives readers the experience of being on a journey with Henshaw as they develop their thinking about patterns, understand problems, explore relevant analogies in nature, and translate them into valuable methods and solutions. When dealing with complex systems that may not be functioning well, our focus is often on inventions to improve systems health. These interventions are not 'solutions' in general terms. Still, they can enhance the overall resilience of the system.

Biom* practitioners search for natural patterns that reveal new ideas. Henshaw discusses how this can be harmful if they are too abstract and ignore the context of both biology and the target design. The danger is seeing patterns as ready-made solutions. They are not - they are guides to understanding, exploring, and developing solutions. Henshaw argues that we should focus on tangible patterns rather than metaphors.

If you consider a tree as a pattern (image 2), you may see a system with branches and roots reaching out. To Henshaw, this is useful, although this type of abstract thinking can also be detrimental. Henshaw states that the “abstract model omits the all-important forest floor, fields, and fauna that fill out the highly complex local ecology where the tree lays its roots. The search for the magical organisational principles that make the designs of the world work is not helped by abstract models that distract you from the working context of the designs of interest.”

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Henshaw points out that these abstract patterns can be found when discussing the 'circular economy of nature'. Through conceptual models, we believe that both the circular economy and nature do not waste. But nature is not circular in its resource management. Nature accumulates layer upon layer of by-products that will never be used again, and streams of energy radiate to space, eventually as much as comes in. As soils build up, they ultimately become stone, and decayed vegetation gets buried with the accumulating soils to become perhaps fossil oils and gas trapped in the rock.

Conclusion

Henshaw's book provides a methodology to understand where and how to find and identify natural patterns, explore how they can be used, and record these insights in pattern languages for other practitioners. It helped me focus on flows of information and energy by studying functions and looking at growth and self-organisation through the exploration of biological processes.

Henshaw reinforces the need to consider the bigger picture when undertaking any design brief. Her approach of exploring the systems around the problem and relevant natural phenomena will allow for a greater understanding of the many functions, processes, and systems in both domains.

I would wholeheartedly recommend this book to those working on or interested in biom*. The field we work in is complex, as are the means to explore the living world through biology and ecology, the basis of our design principles. It is crucial to consider Henshaw's points throughout the book around considering the patterns' context, be it architectural or natural. We search for the 'silver bullet' but ignore the bigger picture.

Henshaw informs us about how, like nature, design is a wicked beast. As such, we should embrace this complexity to help us make better design decisions and identify the relevant patterns in our design environment.

This book is an excellent example of how we can take patterns, look for further detailed concepts, and develop fresh ways of coming up with new ideas. It will make an excellent reference book for exploring the methods as guides or picking areas of interest. ×

Richard is an award-winning designer with a background in international real estate finance and development, urbanism, and industrial design. He is the founder and biofuturist of Biomimicry Innovation Lab specialising in manufacturing, agriculture, and cities. This has culminated in work across North America, Europe, Africa, and Asia. Richard is also the founder of the non-profit Biomimicry UK, and the CEO of an equine technology startup, Smart Stable Limited. He combines this with extensive research development with international collaborators via the Design Society and the ISO Standards in Biomimetics.

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Additional Readings

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