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About Zygote Quarterly

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Cover art
Cover: Juan Nicolás Elizalde | Mexican funnel-eared bat (*Natalus stramineus*) from the series "Amiguitos de la Oscuridad" (Little Friends of the Darkness) | pp. 2-3/pp. 116-117: Cabeza de Libelula, Anisoptera | Photo: Fedaro, 2022 | Wikimedia Commons

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Coral Fungi, Jessup Path | Photo courtesy of Mallory Zondag

Editorial

Science writer Margie Patlak shares a peek of her upcoming book in *Autumn Meadowhawk Dragonfly* and her wonderment at the often-overlooked miracles happening in her backyard garden. We follow her story with *How to Build a Dragonfly*, a look at how one manufacturing engineering company, Festo, has successfully mimicked the dragonfly's remarkable flying mechanics.

Mallory Zondag, a mixed media fiber artist, and our regular naturalist writer, Heidi Fischer, recently returned from Artist in Residencies at Acadia National Park in the state of Maine, USA. In her ongoing series, *the Science of Seeing*, Heidi invites us to view more closely the tiny world of mosses, particularly those found in the forests of New England. In our first portfolio, Mallory explains her inspirations for her organic and tactile creations.

Manuel Quiros, in *Don't Blame Bats*, extolls the ecological services of this ancient and successful order. He dispels myths about this misunderstood creature, lists current conservation efforts, and details efforts to harness echolocation for personal, consumer use. In our second portfolio, we revisit Juan Nicolás Elizalde, a papercraft artist and animal portraitist at Guardabosques who we featured in 2015. His latest project is a homage to the bat that takes the form of 100 lovingly detailed paper busts.

Ray Lucchesi and Michael Ogden turn us west in *Water in the Southwest, USA*. Their tandem interview takes a wide-ranging look at water use in the southwestern U.S., including policies, innovative projects and the differences among standard engineering, traditional society practices and regenerative design.

Randall Anway and Marc Weissburg review *Revisiting Nature's 'Unifying Patterns': a Biological Appraisal*, a recent paper by Lecointre et al. critical of the Nature's Unifying Principles list promoted by the Biomimicry Institute. Randall in *Mind the Gap* highlights the need for interdisciplinary communication and reaching a broader audience. Marc in *Language vs. Knowledge* emphasizes the importance of design patterns as well as the value and limitations of metaphors. Both contributors argue for a balance between scientific rigor and humanistic perspectives in developing a common design language and practice in the transdisciplinary field of bio-inspired design. Happy reading!

Tom, Norbert, and Marjan

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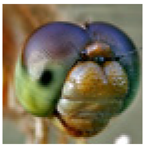

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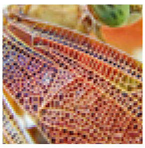

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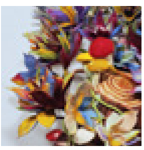

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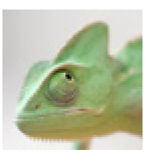

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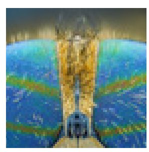

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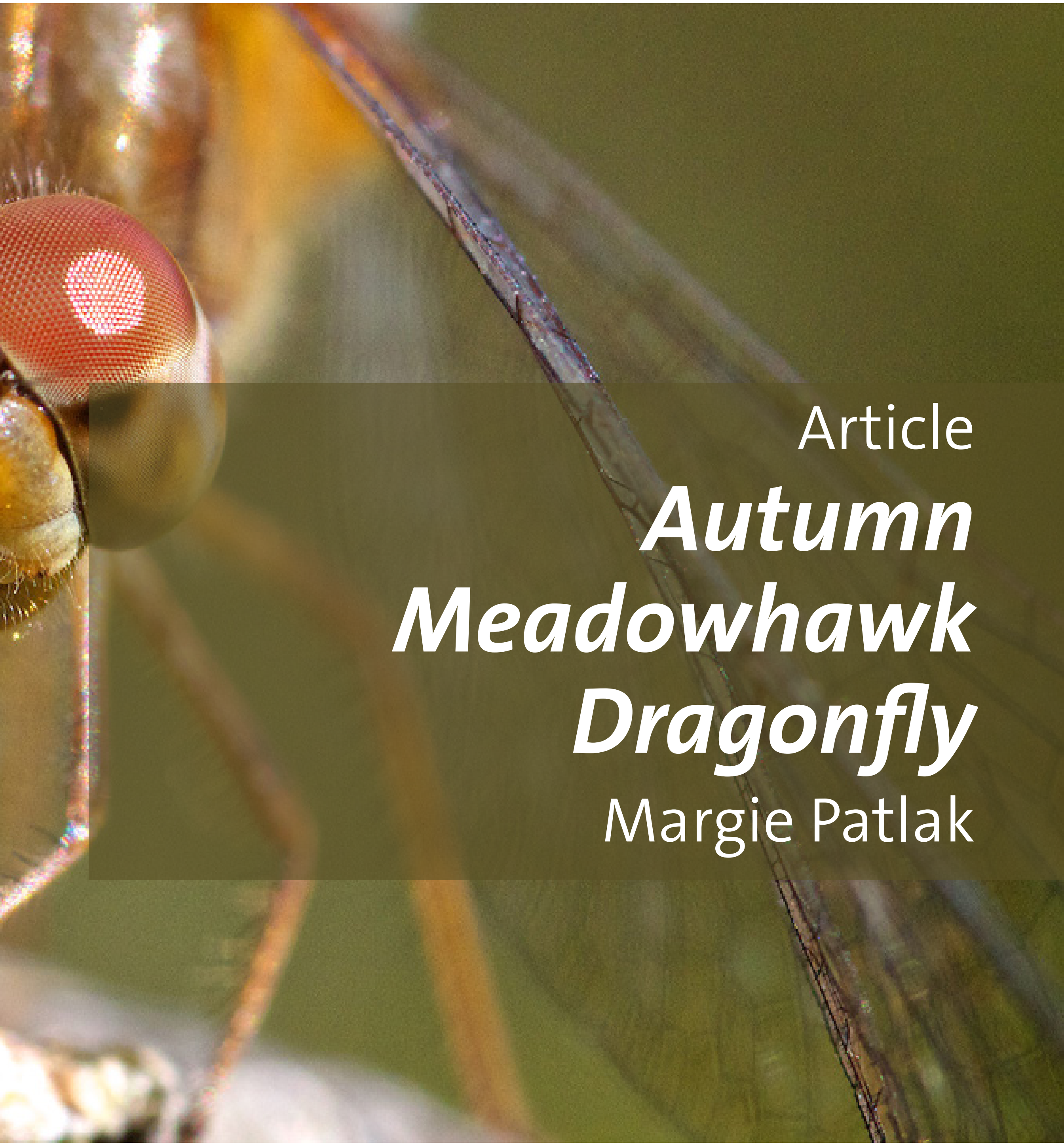
Autumn Meadowhawk (*Sympetrum vicinum*) Dragonfly - Female
Photo: David Marvin, 2015 | Flickr cc



Article

Autumn Meadowhawk Dragonfly

Margie Patlak

Autumn Meadowhawk Dragonfly
Margie Patlak

It's early November and there's a golden glow in the bay, the low light illuminating the tawny grasses and amber seaweed, and silvering the puffs of marsh goldenrod seed heads. Without any flowers to feed on, there are no bumblebees and few other insects flying around my backyard despite unusually warm temperatures in the sixties.

But there's one striking exception—the Autumn Meadowhawk.

Many of these small carmine-colored dragonflies are zipping around, sunlight shimmering their translucent wings. I follow one until it stops to rest and am surprised to discover it's not one Autumn Meadowhawk, but two attached! One is lined up behind the other, and both pairs of large chestnut-colored-eyes stare at me, hexagonal glints in each. I knew mating dragonflies often fly together, the tip of one abdomen attached to that of the other. I've seen the wheel or, more appropriate, heart shapes these dragonflies form while sperm transfers into the female's sperm storage sac she uses to fertilize her eggs. But these two Autumn Meadowhawks are lined up in tandem. Why?

I discover that after mating, the male Autumn Meadowhawk dragonfly continues to use his special claspers at the end of his body to grasp the female by the neck. Fitted together in this funny way, they fly to a body of water where the male dips the female in repeatedly to lay her eggs. Although it sounds like doting co-parenting, this male companionship while the female lays her eggs is actually a competitive act to ensure no other males come along to mate with the female and deposit their sperm in her sperm pouch. Many male dragonflies have some behavior or specialized features to outcompete the sperm of others, given that often the female mates more than once before laying her eggs. In some dragonfly species, the male's penis sports lobes that expand during mating to first pack down any sperm that preceded it into the sperm pouch before depositing theirs on top. Or they are shaped like a bristle brush that they use to scrape out other male's sperm. Both remarkable designs boost the likelihood that the last one in will score a fertilization.

The males of Autumn Meadowhawks instead use the strategy of guarding their sperm by holding onto the females they mated long after copulation, sometimes until nightfall, creating what the entomologist Gilbert Waldbauer called "living chastity belts." He noted in his book *Insects Through the Seasons* that the walking stick holds the insect record for such prolonged intercourse. "The small male—as little as one-quarter

Meadowhawks mating | Photo: Gary Yankech, 2014 | Flickr cc

Autumn Meadowhawk Dragonfly
Margie Patlak

the length of the female—may perch on the back of his gigantic mate's abdomen and remain in copula with her for as long as seventy-nine days," he wrote. That's nearly three months--almost an entire season! Talk about being proprietary.

Some species of fruit flies have another surprising strategy to outcompete males in the fertilization game—supersized sperm. Although men can obsess on the size of their penises, for these fruit flies it's the size of their sperm that seems to matter more. One species has sperm as long as 7 cm, which considering its tiny size, is the equivalent of human sperm measuring the length of a tennis court, Jonathan Balcombe pointed out in his book *Superfly*. Much of its length is in its tail, which forms tangles that block subsequent male sperm from fertilizing an egg. The diminutive fruit fly actually holds the record of having the largest sperm cells of any known organism. Who would have known?

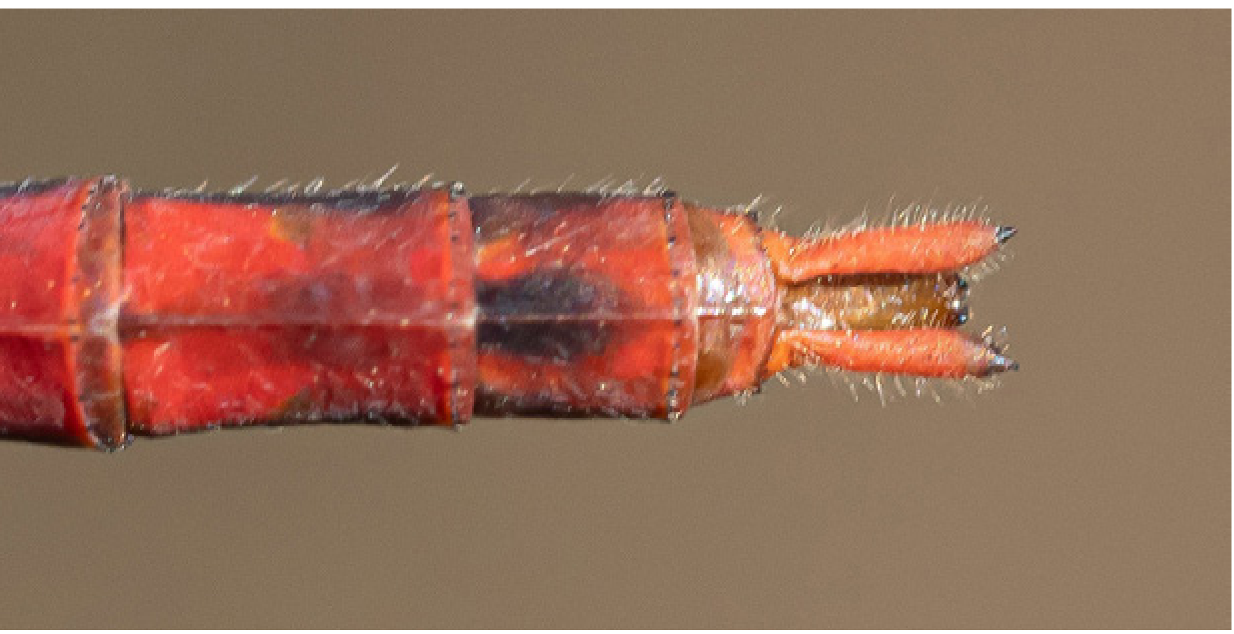
We don't see dragonflies for most of their lives because they reside for as long as 5 years as nymphs underwater in ponds and other water bodies. Still recognizably dragonfly-like with its big bowl eyes, a nymph lacks wings and a long tail but darts around using jet propulsion created by

Autumn Meadowhawk (*Sympetrum vicinum*) Dragonfly
Photo: David Marvin, 2022 | Flickr cc

sucking up water and then rapidly squirting it out through its anus. The dragonfly nymph's rear end has another important purpose—breathing--as its gills are located in its rectum. The nymph can quickly nab its aquatic prey with an amazing toothed retractable jaw like the shovel of a front loader tractor. In a mere millisecond, this appendage jabs out and then retracts to scoop up tadpoles and other prey. Bam!

Overnight the dragonfly nymph transitions from water to air, swimming to flight. While clutching a reed, stick or something else to keep it out of water, its back skin (which is really its skeleton) splits open and out comes a compressed dragonfly, gulping its first breaths of air while it waits for its wings and torso to expand and its new skin to harden. Imagine undergoing such a transformation, swimming one day and flying the next!

I marvel at the dramatic life cycle of dragonflies—a life cycle so unlike ours. But I first came to appreciate dragonflies years ago when I was a young damsel in distress and they came to my rescue. Immersed in the middle of a pothole marsh, my upper body was marinated in sweat while muck painted the lower. Cicadas rattled above, heat and humidity warped the distant view.



Autumn Meadowhawk Dragonfly

Margie Patlak

I struggled to ignore all bodily discomforts and focus on my master's thesis research, which required me to identify the plants brushing my legs. Pothole marshes serve as vital food depots for cranes and other migratory birds and stand out in all the squared off fields of grain and grasses in the Midwest. Unfortunately, I stood out and served as a food depot for the mosquitoes swarming around me, feasting on my blood!

Outnumbered, I couldn't stave off their itchy, annoying, and highly distracting bites with my futile swatting. But then I heard the dim clatter of dozens of fluttering wings, so unlike the whining drone of mosquitoes. I looked up and saw not a bird or a plane, but a full-fledged squadron of dragonflies! Zipping in with large fractal iridescent wings and cartoonish bulging eyes, they snatched one mosquito after another out of the air—bam!--like superheroes in comic books. With their astonishing 95 percent kill rate, in the blink of an eye the dragonflies rid the marsh of all the mosquitoes that had been plaguing me for the past hour; saving the day, as they say, and from then on became my heroes for life, my best friends forever. Obsessing over them, I collected anything with their images, from shirts to mugs to earrings. Now I collect dragonfly facts

Autumn Meadowhawk (*Sympetrum vicinum*) Dragonfly - Female
Photo: David Marvin, 2022 | Flickr cc

while trying to understand how they had so quickly cleared the marsh of mosquitoes.

The more I learn about dragonflies, the more they astonish me. One of the first winged insects to evolve, they were around before dinosaurs, back before the continents split up and started to drift apart, taking the dragonflies with them. Dragonflies watched the dinosaurs sink into the ground, destined to become fossils, while they kept going. Like many animals when the world was young, they were bigger... much bigger. Back then, dragonflies had wingspans of more than two feet!

Because evolution has perfected dragonflies' eyesight over more than 300,000 years, it matches their fast-flying prey. Their bloated eyes, comprising most of their head, have 24,000 facets, enabling them to see in every direction except behind. These eyes capture 200 images a second. (Our eyes capture a paltry 60.) This fast-snapping-camera vision lets dragonflies experience time differently than we. They see life in slower motion so they can react more quickly -in 30 milliseconds--to things we never notice.

Dragonflies also see a more colorful world. We only see color combinations of

Autumn Meadowhawk Dragonfly
Margie Patlak

red, blue and green, due to having only three different types of light-sensing proteins called opsins in our eyes. But dragonflies can have ten times as many opsins.

With their four independent wings, dragonflies can move in any direction in space--sideways, forwards, backwards, upwards and downwards. And, like a helicopter, they can hover in a single spot in the air for a minute or more.

With all these feats of movement, dragonflies can ambush unsuspecting flying insects from any direction. Their legs gather and point upward to create a death basket that scoops up prey in flight They are not only agile, but fast—they can zip about at more than 35 miles per hour. That speed is due in part to the intricate and prominent veining of their wings that not only underscores their iridescent beauty, but makes the wings incredibly stiff and strong, enabling them to pull more distance with each wingbeat. Those veins are also equipped with more than 3,000 sensors for airflow and strain on the wing that help dragonflies fine-tune their flight. Engineers have modeled these flight dynamics in making a working robot, as you can read about

Dragonfly sitting on green plant
Photo: Skyler Ewing, 2020 | Pexels cc

in the companion article “How to Build a Dragonfly”.

Dragonflies need strong wings because some migrate south over a thousand miles each fall. In between India and East Africa, the Globe Skimmer dragonfly has clocked more than 10,000 miles each year. Here in the northeastern United States where I live, green darner dragonflies and various species of skimmer dragonflies fly all the way down to the tropics each year. Mass movements of Autumn Meadowhawk dragonflies also occur in the Northeast in the fall, although scientists have yet to document any major southward migration of them.

Dragonflies’ migratory journeys are terribly tiring. They often have to rest motionless during brief stopovers or stay in one spot until their muscles warm up for flying. Many don’t survive. They litter the ground with their chitinous carcasses when days start to grow cold. One fall day while out walking with a friend, I spotted an Autumn Meadowhawk dragonfly on the road. Wanting to bring it back to adorn my desk, I picked it up and carefully cupped it in my hand during our walk, but ten minutes later it jolted me with its movement. The dragonfly wasn’t dead, but merely resting or warming up! I opened my palm and let it flutter away, wishing it a safe journey. ×

Margie Patlak is a science and nature writer whose memoir *More Than Meets the Eye: Exploring Nature* and *Loss on the Coast of Maine* was given an "Outstanding Book" award by the American Society of Journalists and Authors in 2022. She is currently writing a book about insects, from which this article is adapted.

We would appreciate your feedback on this article:

Dragonfly close up.
Photo: Ravi Kant, 2020 | Pexels cc

Article

How to Build a Dragonfly

Tom McKeag

How to Build a Dragonfly

Tom McKeag

Today I saw the dragonfly
Come from the wells where he did lie.
An inner impulse rent the veil
Of his old husk: from head to tail
Came out clear plates of sapphire mail.
He dried his wings: like gauze they grew;
Thro' crofts and pastures wet with dew
A living flash of light he flew.

- Alfred, Lord Tennyson

Suppose you worked for the Creation, Insect Division, and your managing angel came up to your desk one day with a gnarly problem. It seems your colleagues in the Drosophila and other departments had gotten a little overly enthusiastic with their work and now there was a disproportionate surfeit of small flying insects on planet Earth. It was too late for a recall, as the orders had already gone out and God, being God, had instantaneously willed it to be so. They needed a solution.

Your bosses had ruled out introducing a new disease (over quota as it was); debilitating mutations were always messy, and, as always, there was pressure from public relations for a racy new predator. So, unto your desk, landed the following design brief.

Fast flying insect within the macro scale:

- 100 body lengths per second speed.
- Captures and recycles a wide range of other insects in the air; capture success rate of 95%
- Can hover, glide, fly backwards for both capture and evasion. Six directions in propulsion: forward, backward, up, down, left, and right.
- Best in class optics: 360-degree visibility; 200 images per second recognition.
- All weather, durable construction
- High evolutionary survivability

You wept for at least a million years, but eventually your final design prototype was approved and field-tested in the Carboniferous Period. A bit clunky at over two feet long with a thirty-inch wingspan, but the age being what it was, bulk was needed for short-term survivability, and hey, it was trendy. You even got a division award one century for the world's largest insect. Since that time, you have looked on with pride as what became known as the dragonfly, Anisoptera, has flourished with over 3,000 species on every continent but Antarctica. Now, it seems, the Homo sapiens species has even mimicked your design with an abiotic replica. Imitation is, indeed, the best form of flattery, so, with department approval, you have decided to look in on the design process of these mortals.

If you wanted to be snarky, you might mention that the human engineers did not have to resolve a host of design issues that you had had. Reproduction, for instance;

Cabeza de Libelula, Anisoptera| Photo: Fedaro, 2022 | Wikimedia Commons

How to Build a Dragonfly
Tom McKeag

where real designers tread. And how about life cycle stages? Most of the dragonfly's life is spent, not in the air, but in the water, after all, and it still had to be a top-drawer predator, right out of the egg. You'd like to see them figure out the hydraulics of the emerging nymph, or switching from breathing water to air. And optics! Let's not even discuss it. OK, let's discuss it: it took several million years to design those ommatidia, and, frankly, it was the achievement you were most proud of. Each of these thousands of facets registers a separate image within the 360-degree vision of the compound eye, and sorting out those opsins, or color sensitive proteins, within them, wasn't easy. You have laid your petty professional pride aside, however, and must admit that these engineers have done a remarkable job of mimicking the flight dynamics of your design baby.

Festo is where these engineers work. It is a global manufacturer of pneumatic and electric automation technology based in Esslingen am Neckar, Germany. The company has been designing nature-based robots that exhibit complex technical functions since 2006, and swimming and flying are specialties. Their dragonfly inspired robot is called the BionicOpter and was developed in 2013 as part of their Bionic Learning Network, a collaboration with universities and private development companies.

The BionicOpter mimics one of the premier flyers of the animal kingdom, uniquely able to glide, as well as hover and fly in six directions, including up and down and backwards. The dragonfly does so with an array of integrated characteristics including a high power- to-weight ratio, a double pair of independently moveable wings, articulated flexibility in those wings and a highly sensitive feedback and control system. The Festo robot has a 44 centimeter body length and 63 centimeter wingspan, so has the scale of the large prehistoric ancestor of existing dragonflies. Nonetheless, miniaturization and "lightweighting" were critical pursuits for the design team.

Most of the animal's weight is devoted to its large wing muscles and its chitinous exoskeleton and veined wings are models for lightweight strength. The team at Festo used carbon fiber rod and a polyester membrane for the wings and polyamide, ABS, and aluminum for the housing and mechanical system. Nine servo motors, a microcontroller, rotor, two batteries, and transmitter had to be included in the weight and space budget within the synthetic thorax.

The unique flying capabilities of Anisoptera can be attributed to its wing array, flexibility and precise articulation. Dragonfly flight is highly dynamic, with each of its four wings flexing and twisting continually during beats. The animal is able to control the curve of each wing, the angle of attack, the length and speed of wingbeat, and whether each pair is in or out of phase of stroke with the other. It is able to adjust its wing strokes for the maneuver needed. For maximum thrust needed for turns, it will beat its wing pairs together; for hovering it will oppose each pair, with one pair up while the other pair is down; for fast flight, it will offset the pair strokes by 90 degrees; for gliding, it will simply hold the pairs flat together at the proper angle of attack.

The Festo team needed to recreate some of these mechanisms in order to achieve the same performance. First, they calibrated the onboard motor to be adjustable between 15 and 20 Hz for the beat frequency of the wings. Each wing of the model can be turned from horizontal to vertical, and the amplitudes of the wings can also be varied from 80 to 130 degrees by adjusting the crank mechanism. Each wing is based in the synthetic thorax with a swivel in order to change the direction of thrust. This, used in combination with the amplitude control

Festo - BionicOpter
https://www.youtube.com/watch?v=nj1yhz5io20

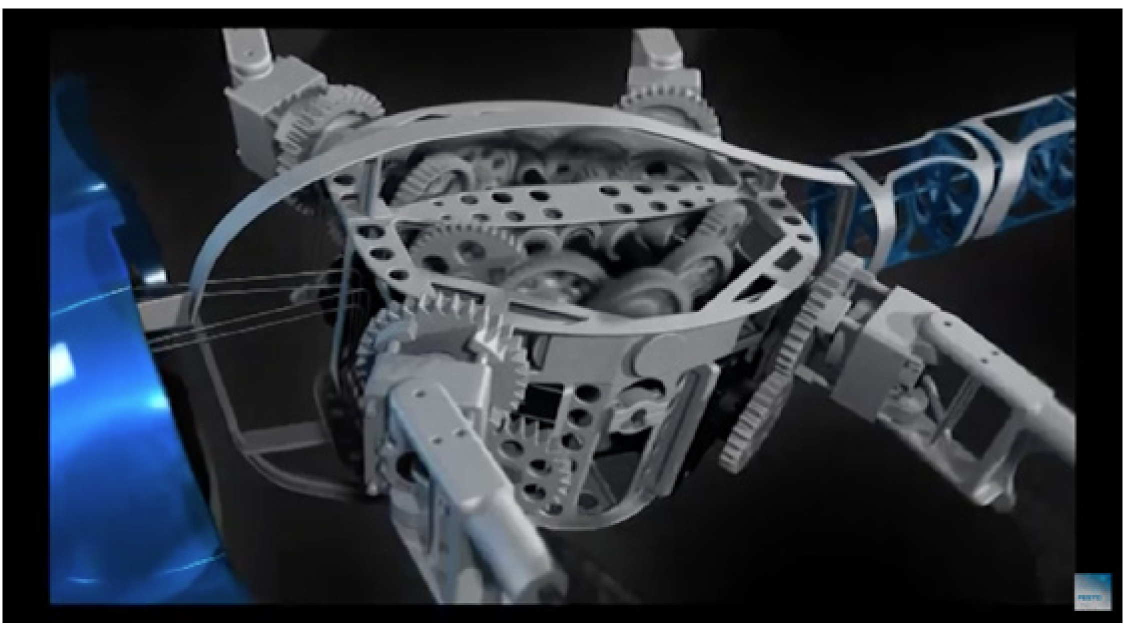
Macro Photography of Dragonfly | Egor Kamelev, 2017 | Pexels cc

How to Build a Dragonfly
Tom McKeag

enables the robot to hover, fly backwards, and switch from hovering to forward flight without a loss of momentum. Finally, the head and tail of the model can be turned, the head horizontally and the tail vertically, for additional directional control. This has been achieved through the use of flexible "muscles" (actuators) made from the shape memory alloy (SMA) Nitinol (nickel titanium, NiTi). The Nitinol contracts with the heat of an electric current passed through it.

While these mechanisms are key to this functional robot, it is the sensors and feedback control that take the BionicOpter further into the realm of the bioinspired. An integrated system combines inertia sensors to indicate acceleration and tilting angle, and acceleration and position sensors detect speed and direction in space. A remote control system transfers signals from the operator to the onboard microcontroller which calculates the mechanical actions required based on the flight record and the operator's commands. The nine servo motors then move the robot to the correct combination of beat frequency and amplitude and angle of attack.

Begrudgingly, you admit that these engineers have done well with the crude implements at their disposal and you return



Festo - BionicOpter - Animation
https://www.youtube.com/watch?v=JUAD7nhyzhU

to Creation Works, Insect Division, knowing that your job is secure, for at least another thousand years. Still, you make a note in your report that these humans can be pretty clever. ×

Project webpage
https://www.festo.com/us/en/e/about-festo/research-and-development/bionic-learning-network/highlights-from-2013-to-2014/bionicopter-id_33493/

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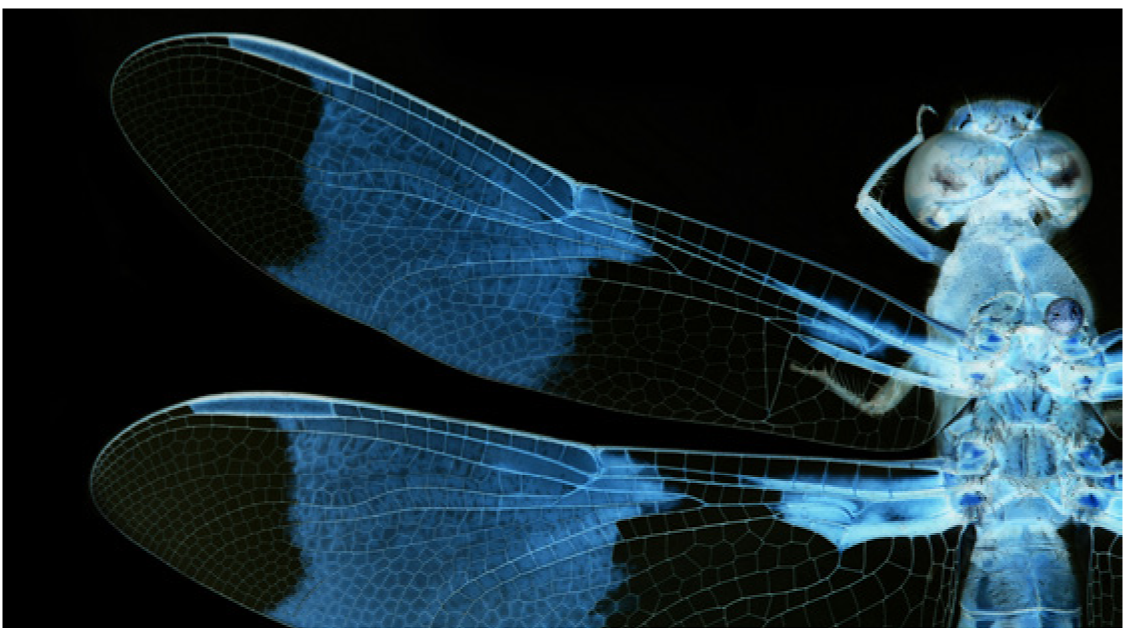

Left Wing of *Plathemis lydia* (Common Whitetail Dragonfly).
Photo: Christopher Johnson, 2015 | Wikimedia Commons

Mossland closeup, 2022


Portfolio
Mallory Zondag

Portfolio
Mallory Zondag

Mallory Zondag is a Mixed Media Fiber artist and artist educator. Her work explores our tenuous relationship with the continuous growth and decay of the natural world and humanity's place within those cycles using hand felted wool, wax, fibers, fabrics and objects both found and recycled. Our collective fascination and repulsion towards natural processes, from blooming flowers to blooming molds, pushes her to sculpt moments of grotesque beauty, investigating this duality through the meditative and hands-on practices of wet felting, weaving, sculpting and stitching.

Her work has been exhibited in both solo and group shows nationally and internationally. She has been an Artist In Residence at Acadia National Park, The Allentown Art Museum, The Wassaic Project and many schools and community organizations. During many of these residencies she has led community art programs where felted wool living walls are collaboratively created with students of all ages and abilities. She was commissioned to create the sensory space for Artsquest's Accessible Arts program and was commissioned to recreate a component of one of Amalia Mesa-Bains's installations for her retrospective at the Berkeley Art Museum and Pacific Film Archive.

Mallory Zondag

Could you tell us about how you are inspired by nature?

It feels like a calling, I am endlessly fascinated by the natural world. The forms and patterns, the process of growth and decay, the way light can paint the same view in endless variations. I always say that nature is the greatest artist and that the pieces I create are ways of replicating and interpreting the visual and tactile motifs of the natural world to tell human narratives. Stories about how we interact with the natural world, about relationships, connections, social systems and any other idea or story I'm compelled to tell.

It feels easy to forget in the time we live in that we are not separate from nature, no matter how much we have tried to make


Biome closeup, 2021

Portfolio
Mallory Zondag

it so. Our bodies themselves are organic, we contain internal ecosystems, we are effected by light and air and our environment same as all other living beings from trees to microbes to whales. To live in a time that seems to be the peak of our separation from nature, our intrinsic and inextricable connection to it is a fact and an idea I feel I will explore through my art, almost as a scientist conducting research, for the rest of my life.

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

There are two things I find always grab my attention and get me excited about creating art. One is physical and one is scientific research. The first is simply texture, of all sorts, the intricacy of pin cushion mosses, the sculptural forms of oyster mushrooms, the undulating smooth surfaces of exposed tree roots on hiking trails, I could go on and on. I am constantly taking photos of textures I see every day from a bit of moss in a sidewalk crack to map lichens on gravestones, hollowed out tree stumps given over to shelf fungi, it is constant inspiration. They lead me to the forms I create through wet felting, the patterns I stitch and the textures I latch hook. My other source of deep inspiration and excitement is natural systems, the ways in which nature is endlessly interconnected and how that extends to human beings whether we like it or not. The research by Suzanne Simard revealing the undeniable connections within forests through mycchorizal fungal networks, shifting our understanding of trees from individual organisms to members of a connected network will never stop inspiring me, for what it says about nature and parallels we can and should be drawing with human nature and survival on this planet. It is through interconnection that we all thrive.

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

I just finished a new body of work called "Connective Fibers". It is a series of large scale sculptures made primarily through wet felting that use both visceral and organic forms to tell a personal narrative about the ending of an emotionally abusive relationship. The sculptures were made possible by a grant received through the Statewide Community Regrants program of New York. Now that those pieces are finished I will be leading a few community art programs that I created called "Fiber Living Wall" where I work in schools, elementary through high school, to teach the students wet felting.


Connective Tissue closeup, 2022

Scar Tissue closeup, 2023

They create felted leaves, flowers, rocks and mushrooms and at the end I take all of their work and stitch it together into a cohesive sculpture, representing a tiny ecosystem that then hangs permanently in the school. I'll also be working on a piece inspired by my time as resident artist at Acadia National Park, felting and latch hooking the many mosses and lichens that carpet the forest floor and rock faces and very literally help build the forest by creating soil and providing beds of moisture to support sapling growth.

What is the last book you enjoyed?

Utopia Avenue by David Mitchell. He is one of my favorite authors because when I read his work I feel like a hand comes out of the book and pulls me directly into the world of the story. This is his newest book and I couldn't bear to put it down.

What is your favourite motto or quotation?

"Hello tiny creature, made of star compost." It is a line from a David Mitchell novel, *Ghostwritten*. I read it last year and it has just stuck with me for illustrating one of the biggest ideas in the simplest of sentences. We are small within the universe, one tiny piece in the infinite organic machine, we are made of star compost. That idea, similar to Carl Sagan's *Pale Blue Dot*, says to me live your life as best you can because existing in itself is miraculous, live with the best intentions, love, explore, create, but don't take yourself too seriously, don't take our planet for granted, check your ego and how you interact with the world because you are a tiny creature made of nothing more than star compost, both miraculous and insignificant.

What is your idea of perfect happiness?

The ideal balance between connection and solitude, contentment and excitement. I don't think it can ever be just one thing, it's all the things I love in balance. Connections with friends and family and community fill me with joy but time in solitude also brings me peace, time to create and to relax. I love to feel cozy and content with coffee and some stitching project or a good book but I also love the feeling of adventure, of travelling, have new experiences and being out in nature. It is finding the ideal balance between all of these things in my life that makes me the happiest.

Portfolio

Mallory Zondag

If not an artist, who/what would you be?

I don't think I could be anything else in this life, I am undeniably pulled to creating and to thinking and communicating through tactile sculpture but if I didn't have that pull to create I think I would like to be a scientist. The way my mind works I don't think I'm cut out for scientific research but if I was, with everything I'm inspired by as an artist, the ideas I'm fascinated with, researching mycelium or mosses, coral reefs or forests or anything about the natural world would be my dream job in this alternate universe. ×

For more of Mallory's work: https://www.mallorymakes.com/art

We would appreciate your feedback on this article:

Moss Rug for Amalia Mesa-Bains, 2022

Parasite, 2023

Primavera, 2022

Order At The Counter closeup, 2023

Parasite closeup, 2023

Mix of *Dicranum* moss and liverwort (*Ptilidium ciliare*) | Homan's Path Trail, Acadia National Park
Photo courtesy of Mallory Zondag

The Science of Seeing

'Tis a Gift to Be Simple

Adelheid Fischer

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In the Islamic tradition of landscape design, gardens are considered earthly manifestations of paradise. To create a heaven on earth, the ancient designers identified three essential ingredients: shade, lush vegetation and the sound of water trickling through them both.

This design recipe, it turns out, can create a paradise just about anywhere on earth, as I discovered this past summer while serving as an artist-in-residence at Acadia National Park. For two weeks, my own piece of heaven was a stretch of maritime spruce-fir forest on Maine’s Schoodic Peninsula.

But I didn’t travel to Acadia expecting to find nirvana in a forest. Nearly every day during my residency in the park, I paced the peninsula’s scenic roadway that ran alongside the shores of the Atlantic Ocean. I was desperate to be near water—and lots of it—having just fled the hottest and driest summer on record in my hometown of Phoenix, Arizona. But the Maine coast didn’t invite pleasurable idling. It was sun-shot, restless with hissing waves and jumbled with slimy rocks so sharp they could have shredded the tires of a John Deere tractor. So more often than not, I would duck up a trail into the adjoining forest, a dimly lit place straight out of the pages of the Brothers Grimm. Almost as soon as I entered the woods, the sound of the sea became so muffled that I could hear the riffles of narrow hop-across streams tinkling like glass. Here, the boughs of the conifer trees wove a loose thatch through which the sun streamed in slant shafts of muted light. Best of all, however, were the mosses. They trailed up trunks and branches, dressing the trees in what looked like fleece pajamas. The whole forest floor was plush with mosses, an emerald carpet that overtopped boulders and downed logs, creating a landscape of hunched, pillowy forms. It was all I could do to keep from stripping to my skivvies and rolling around in it.

Mosses flourish in the moist shade of evergreen forests like these, writes bryologist Robin Wall Kimmerer in her enchanting book *Gathering Moss*. A single boulder might host dozens of species. But the region didn’t always look like this. Some 18,000 years ago, the Laurentide Ice Sheet mounted its final retreat, leaving behind a landscape that was gouged, scraped and bulldozed into bare rock and sediment. The spores of mosses were among the earliest arrivals. These tiny granules, measuring less than the width of a human hair, nestled easily into fractured rock and gravel pores. Coated in layers of a tough material known as sporopollenin, which made them resistant to desiccation and breakdown by chemical weathering and UV radiation, moss spores

Mosses flourish in the moist shade of evergreen forests like this maritime spruce-fir forest on the Schoodic Peninsula in Acadia National Park. | Photo courtesy of Mallory Zondag

Mix of *Hypnum* moss, *Dicranum* moss and *Leucobryum* moss
Anvil Trail, Acadia National Park | Photo courtesy of Mallory Zondag

were well equipped to withstand the challenges of these exposed environments.

The mosses flourished, slowly colonizing such forbidding places as granite balds where the plants followed the paths of rock fissures, running like green basting stitches through the fields of drab gray. Only a few inches tall, they trapped seeds and precious moisture and began the laborious process of building soil. They joined forces with lichens, another pioneer species, to slowly create hospitable conditions for sedges and small shrubs such as three-toothed cinquefoil and lowbush blueberry. In time, enough soil accumulated to support trees like the conifers that made up my paradisiacal forest of spruce and fir.

These diverse assemblages, known as crevice communities, not only grew up but also out until they merged with other crevice communities, writes Maine biologist Tom Wessels in *Granite, Fire and Fog*. On the leading edge of this slow creep across the exposed granite, he observes, were the mosses. In some places, after an estimated 400 years of development, old growth forests became established on the mossy sod. In these mature forests, as in the crevice assemblages they nurtured, mosses sop up rainfall and store it like sponges, a service that benefits the whole community.

The ability of mosses to jumpstart life in inhospitable places is due, in large part, to their design. In the *The Hidden World of Mosses*, bryologist Neil Bell describes them with eloquent succinctness: "Mosses are quite small and simple." Unlike vascular plants, which rely on a more complex plumbing of specialized tissues to transport water, minerals and nutrients from roots to crown, mosses "have leaves that are only a single cell thick—effectively a sheet of cells," Bell writes. Water is transported by capillary action over the surface of their leaves. Since they lack roots, mosses can colonize the weathered surface of rocks, dispensing with the need for soil. For sustenance they mostly look to the sky. In Acadia, frequent onshore fogs can be a special bonanza. Biologist Wessels points out that drops of rain or fog condense around particles of dust containing calcium, potassium or phosphorus. Concentrations of these nutrients can be 1,000 times more enriched in fog compared to rain.

Thin leaves with a large surface area have a downside, however. They can render mosses vulnerable to desiccation during droughty times. But mosses have turned this limitation into a super power, becoming champions at both withstanding and avoiding drying out. The plants, for example, can survive the loss of a whopping 98 percent of

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their water. Indeed, some specimens, shut away for decades in herbaria collections, have revived in a matter of minutes after being wetted. On the flipside, mosses, such as *Sphagnum*, are champions at banking water. Sandwiched between living cells that carry out photosynthesis are dead cells whose sole purpose is to maximize the capture of water. “These non-green cells are reinforced by special ribs so that they don’t collapse when they are empty and have little holes in them to let water in and out,” Bell writes. “They effectively act like hundreds of little water bottles in each leaf allowing the *Sphagnum* plant to store 20 times its own weight in water.” Small wonder then that native people in the north routinely used *Sphagnum* to line the diapers of their infants, a material that was not only absorptive but also antimicrobial.

Hypnum moss | Sundew Trail, Acadia National Park
Photo courtesy of Mallory Zondag

Despite the fact that mosses have been working their magic at Acadia for millennia, little is known about the precise pathways that these plants take from spore to crevice community to old-growth forest. Understanding these pathways has become a priority for park biologists as crevice communities and tourists increasingly vie for the same real estate. In places like Cadillac Mountain, a popular scenic overlook on Mount Desert Island, crevice communities are disappearing under the footfall of tourist traffic. Humans have become the modern equivalent of continental glaciers, resetting the evolutionary clock to bare rock in places that once hosted thriving crevice communities. Enthralled by the long view—a panorama of mountains, islands and ocean—visitors kick up the padding of moss that holds many plants in place. It only takes a little bit of trampling, says Jesse Wheeler, Acadia’s vegetation program manager, to destroy centuries of slow, patient growth. Rain and wind can carry off

Mix of liverwort (*Bazzania trilobata*) and *Dicranum* moss
Sundew Trail, Acadia National Park | Photo courtesy of Mallory Zondag

Mix of *Hypnum* moss, *Dicranum* moss, liverwort (*Bazzania trilobata*) and *Cladonia* lichen | Acadia National Park | Photo courtesy of Mallory Zondag

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Mix of peatmoss (*Sphagnum* sp.) and *Dicranum* moss | Acadia National Park
Photo courtesy of Mallory Zondag

the dislodged clumps and quickly erode the exposed soil down to bedrock. Since 2017 Wheeler and his colleagues and research partners have been monitoring a series of experimental plots to better understand the formation of crevice communities and how humans can lend a helping hand in accelerating their regeneration. In the process, they are drawing visitors' attention to the ancient miracles taking place right under their feet.

"At the scale of a moss," writes Wall Kimmerer, "walking through the woods as a six-foot human being is a lot like flying over the continent at 32,000 feet. So far above the ground, and on our way to somewhere else, we run the risk of missing an entire realm which lies at our feet. Every day we pass over them without seeing. Mosses and other small beings issue an invitation to dwell for a time right at the limits of ordinary perception. All it requires of us is attentiveness. Look in a certain way and a whole new world can be revealed." ×

Moss identification requires extraordinary expertise. Special thanks to Blanka Aguero, Herbarium Data Manager at Duke University, for her knowledgeable guidance in identifying the plants that appear in the essay's photographs.

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Close up of a Chameleon on a Plant
Photo: Brandon Brito, 2023 | Pexels cc

Article review

Revisiting Nature's 'Unifying Patterns'

Randall Anway

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Mind the Gap: A Review of “Revisiting Nature’s 'Unifying Patterns': A Biological Appraisal”

Bio-inspired design, a practice that derives inspiration from nature's designs, has increasingly attracted attention for its potential in addressing complex design issues across various disciplines. As a concept it fosters debates and warrants deeper reflection, as it intersects both scientific and anthropocentric constructs of utility and creative invention.

"Revisiting Nature’s 'Unifying Patterns’: A Biological Appraisal" (Lecointre et al., 2023)[1], a review drawn from a multidisciplinary background that includes biology, cognitive psychology, and design sciences, provides a unique lens into the thinking of some of its most esteemed practitioners, who have dedicated their lives and work to observing and learning from nature in innovative ways.

Highlighting the need to understand nature on its own terms rather than projecting human-centric attributes and biases onto it, this carefully worded review aims to align language used in communicating about the natural world and mounts a critique of anthropocentrism in bio-inspired discourse. The authors note that attributing

[1] Lecointre, G., Aish, A., Améziane, N., Chekchak, T., Goupil, C., Grandcolas, P., Vincent, J. F. V., & Sun, J.-S. (2023). Revisiting Nature’s “Unifying Patterns”: A Biological Appraisal. *Biomimetics, 8*(4), Article 4. https://doi.org/10.3390/biomimetics8040362

human traits to nature can lead to misconceptions and limit our understanding of it.

For example, the authors consider it misleading to speak of 'natural strategies' or 'plans,' asserting these are anthropocentric metaphors which hinder accurate understanding of natural processes. Describing nature as "parsimonious", "frugal", "intelligent", "rational", or "logical" is inaccurate, as these concepts stem more from human cognition than from the relative chaos of evolution. The authors also argue that these metaphors are teleological and impose a sense of order that is inapplicable to the natural world.

The authors cite underlying cognitive biases as a potential contributor to this confusion, referring to the tendencies of humans to attribute intention or agency to nature, rather than consider nature in terms of its inherent properties. The authors critically examine the rhetoric and language often used in bio-inspiration discourse. The authors explain that metaphors used as “Unifying Patterns” to describe ‘nature’s lessons’ (Biomimicry Institute, 2023) tend to be geared towards expected outcomes, involving anticipation and causation. Using such metaphors in this way wrongly suggests purposefulness in nature.

A green chamelon lizard (details)
Photos: Ricardo CL, 2023 | Pexels cc

Revisiting Nature’s 'Unifying Patterns'

Randall Anway

Biomimicry Institute’s Ten “Unifying Patterns of Nature”	Proposed Scientific Reformulation
1. Nature uses only the energy it needs and relies on freely available energy	In terms of reproduction, both internal and external constraints can lead to higher energy expenditure than might be inferred from observation of adult populations. Evolutionary processes require considerable amounts of energy—either from the organism’s point of view (number of gametes produced) or from the population’s (number of deaths). However, natural selection seems to ultimately favour physiological systems that minimise energy expenditure.
2. Nature recycles all materials	The living world has an extraordinary (but not infallible) capacity to recycle organic material. In any given ecosystem, a diversity of organisms reuse, scavenge, or decompose matter into components taken up by other forms of life. However, “recycling” can take millions of years, and some organic materials have never been “recycled” at all.
3. Nature is resilient to disturbances	Ecosystems and biological entities are resilient to disturbances only within certain limits. At the ecosystem level, once certain disturbance thresholds are crossed, the “identity” of the ecosystem may be changed irreversibly.
4. Nature tends to optimise rather than maximise	Living systems are the result of trade-offs, not optimisation. Populations seem to ‘maximise’ reproduction and offspring, which are later filtered by environmental constraints (biotic and abiotic). Apparent optimisations in terms of species’ physical and behavioural traits would be more accurately described as being the ‘best under the circumstances’.
5. Nature provides mutual benefits	Mutually beneficial relationships are found in living systems, yet they are not necessarily more significant than predation and parasitism.
6. Nature runs on information	Living systems sense and respond to their internal/external environments and communicate in a multitude of different ways (physical, chemical, and behavioural).
7. Nature uses chemistry and materials that are safe for living beings	Whether the chemicals and materials synthesised within biological systems are “safe” depends on the species in question, their life history stage, their environmental context, and, last but not least, the quantity of the chemical compound in question. Nevertheless, almost all are ultimately biodegradable, given sufficient time and the right environmental conditions.
8. Nature builds using abundant resources, incorporating rare resources only sparingly	Most biological materials are inevitably composed of abundant, locally available resources.
9. Nature is locally attuned and responsive	Individual organisms are responsive and often able to acclimatise to new environmental conditions. At the population level, organisms continually adapt to their surroundings through natural selection.
10. Nature uses shape to determine functionality	In biological entities, functionality determines form. Structural complexity, rather than chemical composition, is behind the vast array of multi-functional biological materials found in the natural world.

Proposed scientific reformulations of the Biomimicry Institute’s ten “Unifying patterns of nature” for an enlightened bioinspiration.
Lecointre et al., 2023

Highlighting the complex dynamics of biological evolution, the authors further explain that natural occurrences are driven by spontaneous variations which are shaped by local constraints and natural selection. The authors emphasize the uncontrolled randomness and variation occurring in nature that results in unique organisms and environments, pointing out we often tend to notice only the “successful” outcomes and not the vast number of “failures”. Consequently, many of us find it hard to accept that the matching of form and function seen in nature is random and not deliberate.

The article takes particular issue with the term "pattern" as used by the Biomimicry Institute. The main complaint seems to relate to using the term to refer to guiding principles within biological systems, not just regularly repeating structures. Natural patterns are regularities observed not only in biological phenomena but also represented in math and physics. The elucidation of these sometimes complicated structures and behaviors has progressively advanced since the 1917 work of D'Arcy Thompson. The generative rules or algorithms underlying so-called self-organized natural patterns "do not replace biological principles, but rather work alongside them" (Lecointre et al., 2023, p. 5).

This is an important distinction, as these 'regularities' - predictable and repeating arrangements of matter and energy - can be seen in both living and non-living elements of nature. For example, the remarkable resemblance between systems of river tributaries and leaf veins can be represented mathematically, and their generative processes expressed in the language of physics. The physical and chemical constraints entailed in these processes and represented mathematically in scientific theories also apply to evolution.

A second distinct meaning of 'pattern' comes from evolutionary biology. It's used to explain the tendency in biodiversity for certain biological features to regularly occur together across different species over time. Patterns such as these are inter-nested - meaning features repeatedly appear together - based on inheritance or species' genealogy. An example given is the consistent co-presence of vertebrae and feathers in certain animals due to historical evolutionary reasons.

Thus, this concept of 'pattern' has specific meanings to various scientists, as a blend of contributing insights from diverse fields of study working together with care and precision. If designers are to have intelligent conversations with scientists, it's essential to understand and use this

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A green chamelon lizard (detail)
Photos: Ricardo CL, 2023 | Pexels cc

empirical concept clearly and consistently. The Biomimicry Institute's use of the term to refer to 'lessons from the natural world' (Biomimicry Institute, 2023) therefore seems to diverge, albeit understandably, from more precise interdisciplinary communication and collaboration between BID designers and research scientists.

Overall, the paper advances the belief that overcoming cognitive biases and accurate comprehension of how evolution works are foundational for successful bio-inspired design, a cross-disciplinary approach to design which incorporates biological concepts. This emerging discipline straddles fields such as biology, engineering, and design, linking systematic thinking from scientific and artistic disciplines. Acknowledgement that this field can be prone to the projection of intention onto nature can also be viewed as an opportunity to educate a broad audience. This could potentially address barriers to achieving more robust bio-inspired design goals.

Referencing Biomimicry 3.8's "Unifying Patterns of Nature", Lecointre, et al. champion the utility of eighteen eco-biological principles offered 'in the spirit of joining this work in progress'. Citing the potential for "flaws and miscalculations ... in the development of bioinspired processes, products, and systems" they assert that bio-inspired designers must "truly [grasp] how nature operates" in order to effectively adapt biological 'solutions' or ideas into their designs. To support this assertion, they lay a groundwork for this expectation by explaining various biological and ecological processes against the backdrop of evolutionary theory.

To avoid misunderstanding between interpretations of terminology, the suggested revisions of the Biomimicry Institute's ten "Nature's Unifying Patterns" are framed as "Principles of the living world" together with eight additional principles framed as "Eight Biological Principles for Enlightened Bioinspiration". As a caveat, it is explained they concentrate on the organismal level, not "living systems" levels where different principles may apply.

Observations and conclusions

"Everyday social practice, routinized, always involves non-understanding, blurring, and the possibility of the failure at and break with routine communication. ... This incurable indexicality and fuzziness of linguistic utterances and actions is understood ... as a productive characteristic of the local, ongoing accomplishment of society." (Bochmann, 2022).

While maintaining the scientific essence that is integral to bio-inspiration, it's important not to alienate other perspectives. The idea of personification of nature may seem to deviate from scientific thinking but has repeatedly surfaced across cultures as a powerful engine driving innovative solutions (Abram, 2016). It's a small point, but somewhat ironic and perhaps telling, that the authors refer to our ability to understand the living world by way of "its own" processes and properties - as if nature was an individual entity with qualities of possessive self-determination. Could there be understanding otherwise?

To unlock the full potential of bio-inspiration, there is a need for collaboration and integration of the scientific and anthropocentric perspectives, rather than advocating for a narrowly one-sided scientific approach. We should embrace bio-inspired design as an interdisciplinary method where reflexivity lies at its core. The article's underlying assumption is that dialogues between "designer" and "biologist" job categories need to be rooted in a shared scientific understanding of living organisms. However, instead of getting stuck on the dangers of attributing human-centric concepts to organismal and living systems levels, it strikes me that deconstructing our anthropomorphic tendencies has at least an equally essential role in promoting better integrated and effective bio-inspired dialog.

The essential humanness engrained in bio-inspiration involves re-examining the perceived "increased efficiencies gained from division of labor" through specialization (Margulis and Sagan, 2002). Furthermore, exploring the symphony between objective biological principles and subjective human experiences can nurture cross-disciplinary dialogues and innovative perspectives (Allchin, 2004).

Embarking on such intertwined trajectories will likely reveal that substantial, long-run support for foundational work is very likely and arguably compulsory to launch bio-inspiration past its preliminary phase into everyday application. Such an underwriting must mirror an ecosystem outlook - where interdisciplinary, cross-sector, intergenerational investments echo both the multifaceted factors influencing natural processes and specific environmental/social/economic concerns that need to be addressed.

Humans tend to design and build with specific fixed aims (such as economy) and functions (such as self-domestication) in mind. In contrast, persistence of a particular organism, species, or system is largely based on its inscrutably evolving compatibility with dynamic local conditions. Thus, understanding the living world in terms of other-than-human processes and properties is key towards developing a more accurate perspective aligned with contemporary biological theory.

Bio-inspiration has the potential to not merely mimic natural structures, functions, and behaviors, but redefine the many-dimensional human relationship with nature (perhaps even the concept of nature itself). While such a humanistic cast may correspond with bio-inspired design's less tangible aspects, it can also serve as an enabler to identify functional symbioses between science and design - in effect, evolutionary step-change in the organization of our shared knowledge, values, and context.

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Flying Fox
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Article

Don't Blame Bats

Manuel Quirós

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Bats are mammals in the order Chiroptera ("finger wing" from the Greek roots). making up about 20% of all mammal species. Bats dwell in colonies which can reach millions of individuals. They are well-known for their echolocation abilities that help them hunt and move rapidly in the dark. Bats vary greatly in size: the largest species is the giant golden-crowned flying fox, weighing up to 1.6 kg (3.5 pounds) with a wingspan of up to 1.7 meters (5.5 feet). The smallest is the bumblebee bat, measuring up to 3 cm (1.2 inches) in length and weighing two grams (0.07 oz) as a full-grown adult.

Present on Earth for more than 50 million years, bats have been found in all areas of the world except in the Arctic and Antarctica. Bats represent the second oldest group of mammals after the monotremes, which include the platypus and echidnas. Of the bat species, 75% are carnivores that can capture over 3,000 insects in one night. Other species nourish themselves with fruits or flower nectar. Globally, bats provide vital ecosystem services such as insect pest consumption, plant pollination, and seed dispersal, making them essential to the health of global ecosystems. Bats are one of the many organisms that play a key role in our ecosystems - if they disappeared or their populations declined significantly, planet Earth would not remain the same.

Widespread societal ignorance surrounding this animal species affects our ability to understand and appreciate their relevance. Despite delivering many necessary ecological services, they have acquired various myths and false beliefs[1], most famously that they suck human blood, which just three out of the 1,400 species do. Bats are known to directly transmit only five illnesses, and COVID-19 not being one of them - the Bats Conservation Trust UK and the Spanish Association for the Conservation and Research of Bats (SECEMU) launched a campaign called #dontblamebats[2] to counter this myth. While it is possible that the virus traces its ancestral roots to a bat species, it is likely that transmission to humans occurred via an intermediary species, with pangolins being suggested as a potential candidate[3,4]. Although bat researchers get a precautionary rabies vaccine, studies suggest just 5-6% of bats carry rabies – similar percentages found in feral dogs or cats[5]. Thanks to their unique immune system that we are only now beginning to understand, bats can control virus infections without triggering an excessive inflammatory response or "cytokine storm" that can cause serious complications in humans.

Bumble bee bat (*Pipistrellus pipistrellus*) eating a mealworm
Photos: Gilles San Martin, 2010 | Flickr cc

Don't Blame Bats

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Common noctule bat | *Nyctalus noctula*
Paper sculpture: Juan Nicolás Elizalde

Common noctule bat | *Nyctalus noctula*
Photo: Juan Tomas Alcalde

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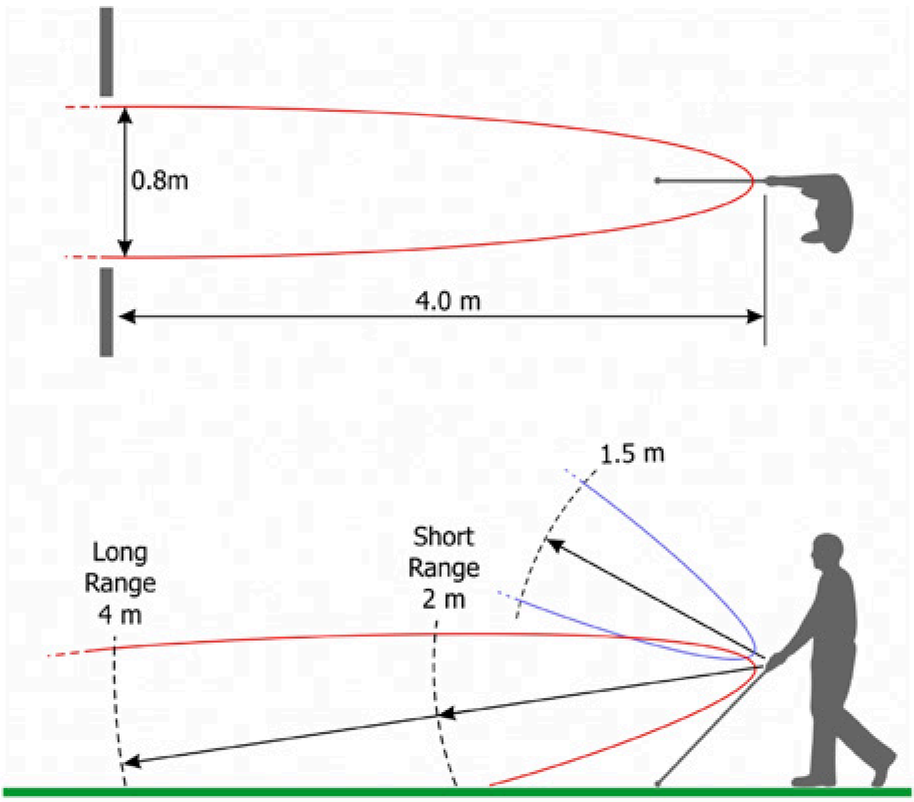
Juán Tomás Alcalde, PhD conservationist and bat expert, is the president of SECEMU (Spanish Association for the Conservation and Study of Bats), an NGO founded 30 years ago to educate both citizens and the government about the importance of bats. Dr. Alcalde discovered that in the Ebro Delta of Spain, an important rice-growing area, *Pipistrellus pygmaeus* (the smallest bat in Europe) controls the *Chilo Suppressalis* moth that feeds on the stems of a plant causing significant losses in rice harvests. Bats also eat *Anopheles* and *Aedes* mosquitoes, which cause numerous illnesses and deaths globally.

According to Dr. Rodrigo Medellín, there are 20 to 30 bats for each human in Mexico. A million of these highly sophisticated animals can eat 10 tons of insects per night[6]. A 2019 study in Africa found that a colony of 150,000 fruit bats can disseminate more than 300,000 small seeds in a single night as they fly between their feeding and their roosts[7]. This could regrow around 800 hectares (about 2000 acres) of forest.

Many consumer products such as cotton, tomatoes, chilis, corn, or even candy, would be in danger without bats. Bats pollinate *Agave*, a key component in Tequila - "no bats no tequila." Another example is durian fruit, *Durio zibethinus*, which in 2019 delivered about U$254M in export value to Southeast Asia. Indonesia produces about half of the region's durian, and wants to expand production significantly. A 2019 study[8] in Batetangnga Village, West Sulawesi, suggested bats were the primary pollinators of durian flowers, supporting calls for stronger efforts by Asian governments to protect bat populations.

According to Dr. Alcalde, bats are in danger globally due to territorial loss, pesticides, industrial agriculture, pollution, and wind farms. Bats have a low reproductive capacity with just one offspring per year. In Spain, 40 meter tall wind turbines with 18 meter blades can reach tip speeds over 200 km/hour. It is suspected the bats confuse the wind turbines with the trees in which the bats roost. Estimated annual bat mortality in Spain is as high as 30 to 40 per wind turbine, suggesting a million bat deaths in Spain alone[9]. This will add up to the already existing biodiversity losses. Several studies suggest that since insects and bats prefer light winds, increasing the night-time cut-in speed of wind turbines from 3m/sec to 6m/sec during the autumn mating season would significantly reduce bat fatalities, at the cost of a 1% decrease in energy production[10].

Bats have also made contributions to innovation. Echolocation inspired a team of students from the University of Leeds, UK, to design a cane for the visually impaired in 2012[11]. This electronic cane utilizes echo-location, mimicking the natural navigation system of bats and dolphins. It emits an ultrasonic wave, and the returning waves indicate the presence of large objects nearby, causing the cane to vibrate as a warning signal for the user. This technology has been adapted for cycling[12] and even mountain biking[13].



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Researchers at Brown University discovered that the muscles in bat wings can tolerate cold much better than the muscles of other mammals[14]. This knowledge may eventually help people cope with harsh outdoor environments. Drawing insights from the remarkable adaptations of bats and other species, we can forge pathways toward sustainable and resilient technologies that yield benefits for both our environment and our species.

Advances in DNA sequencing technology, expansion of DNA sequence databases, and metagenomic analysis of bat guano samples enables researchers to study the diet of specific bat populations as well as detect novel viruses. Our growing understanding of biodiversity and how it affects human lives helps us grasp the intricacies of how our planet operates and the need to preserve it.

Public opinion is changing. The global rise of the conservation movement is driving projects like Tequila Ocho, which has achieved the Bat Friendly[15] certification developed by the Tequila Interchange Project and the Universidad Nacional Autónoma de México. This novel certification goes beyond sustainability: it emphasizes regeneration, where the protection and restoration of bat populations are integrated with economic activities. In Spain, the Olivares Vivos certification, supported by the European Commission[16], is centered around olive trees and olive oil and also strives to increase bat populations. Regeneration is the new sustainability. ×

Footnotes

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Brown long-eared bat | *Plecotus auritus*
Photo: Juan Tomas Alcalde

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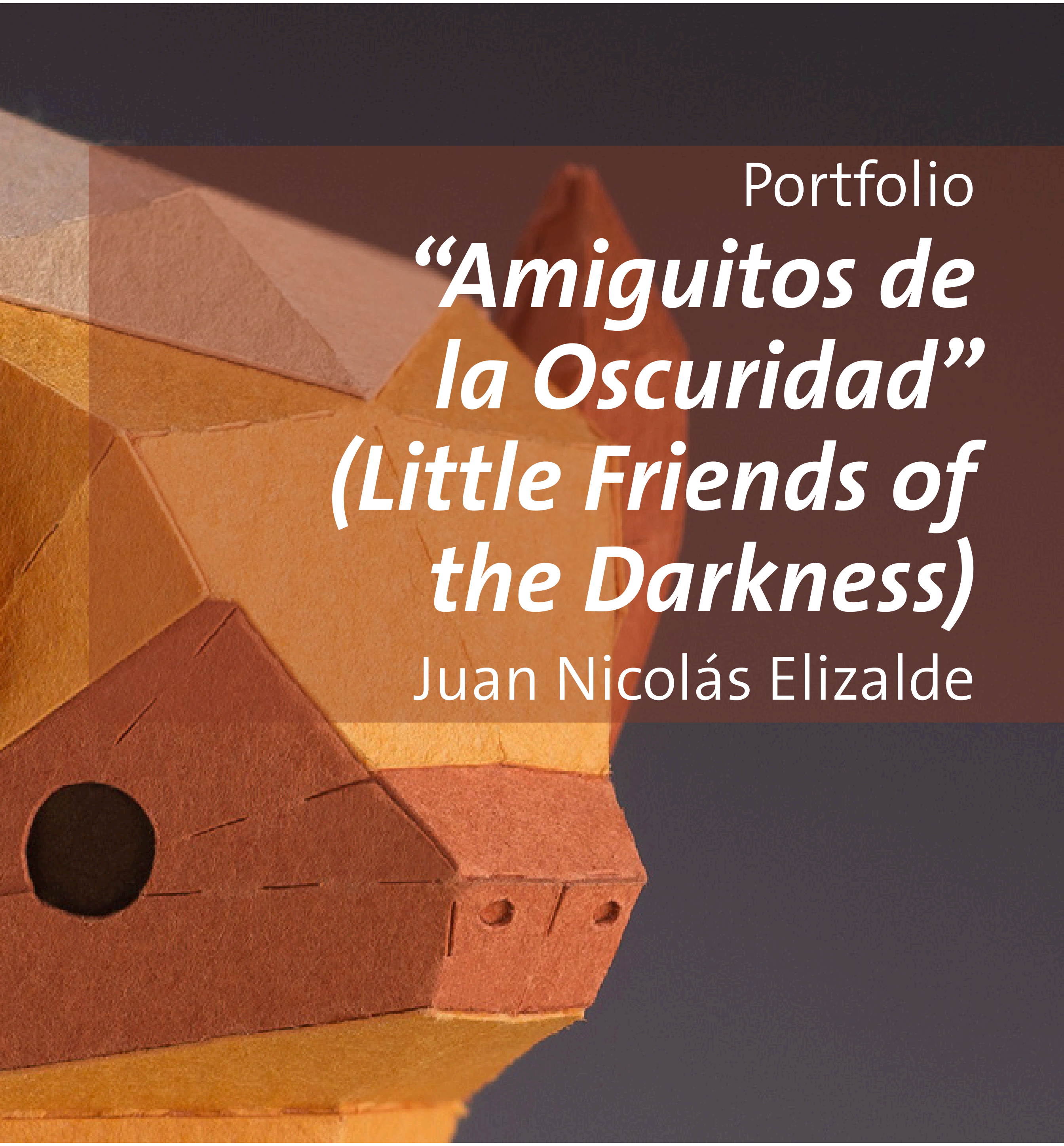
Manuel Quirós, BSc, MSc, PhD is a passionate nature conservationist. He guides, and as an independent teacher in several Spanish universities inspires students to adopt sustainability and biomimicry as a transformational behavior strategy towards regenerative culture. He is the owner of NIU (https://www.natureinspireus.com/), a biomimicry consultancy; cofounder of Red Internacional Biomimesis (RI3: https://redinternacionalbiomimesis.org/) and Biomimicry Iberia (https://zqjournal.org/editions/zq19.html). He participates as a speaker in many international symposia such as ONU-Habitat and COP 25. He has been a contributing editor and author (*ZQ29* & *ZQ30*) for *Zygote Quarterly* since 2013

Thanks to SECEMU (https://secemu.org) for the valuable information provided by its president, Juán T. Alcalde, as well as Juan Nicolás Elizalde, a member of the Guardabosques studio dedicated to sculptures and paper kits based on nature. "Amiguitos de la oscuridad" is a project inspired by a poster of bats by Ernst Haeckel and a later discovery of bats portraits by Merlin Tuttle. Currently sculptures of 88 species have been created with a final goal of 100 (Instagram:@amiguitosdelaoscuridad). A portfolio by Guardabosques can be seen in this issue of ZQ as well as https://zqjournal.org/editions/zq14.html and in the Spanish version https://zqjournal.org/editions/zq14ES.html.

Special gratitude to Nur Younis who completed our biomimicry program and helped with research and translation. Nur is a fourth year undergraduate student working towards a dual degree in Business Administration & International Relations at IE University in Spain.

We would appreciate your feedback on this article:

Eastern red bat | *Lasiurus borealis*



Portfolio

“Amiguitos de la Oscuridad” (Little Friends of the Darkness)

Juan Nicolás Elizalde

"Amiguitos de la Oscuridad" (Little Friends of the Darkness)

Juan Nicolás Elizalde

Could you tell us about your activities since we spoke to you in 2015?

Since 2015 we have been developing more models and sculptures at Guardabosques. Prior to that year our main work was paper birds, but later we diversified into many other animal species and paper kit collections. Our love for nature has remained the same, while we keep exploring this theme in new formats of this papercraft technique such as shop windows, editorials, masks, exhibits, awards, books, etc

What are you working on right now?

After I finished designing my goal of 100 paper bat portraits, I started working on how to turn this project into a book and an exhibition, I hope that I achieve that soon!

Wrinkle-faced bat | *Centurio senex*
Eastern tube-nosed bat | *Nyctimene robinsoni*

(Currently some photos of the bats are exhibited at the Bats! exhibition at Peabody Essex Museum in Massachusetts). Also I'm working on different nature related books that I've been planning for the last few years.

Any recent exciting projects you want to tell us about?

Very scattered things at the moment, but I'm excited working on these books right now! Also, now that I finished the paper bats I want to start working on a paper monkey project. ×

We would appreciate your feedback on this article:

Cuban flower bat | *Phyllonycteris poeyi*

"Amiguitos de la Oscuridad" (Little Friends of the Darkness)

Juan Nicolás Elizalde

Visored bat | *Sphaeronycteris toxophyllum*

Long-eared free-tailed bat | *Otomops martiensseni*

“Amiguitos de la Oscuridad” (Little Friends of the Darkness)
Juan Nicolás Elizalde

Common vampire bat | *Desmodus rotundus*

Ghost-faced bat | *Mormoops magalophylla*

“Amiguitos de la Oscuridad” (Little Friends of the Darkness)

Juan Nicolás Elizalde

Gray bat | *Myotis grisescens*

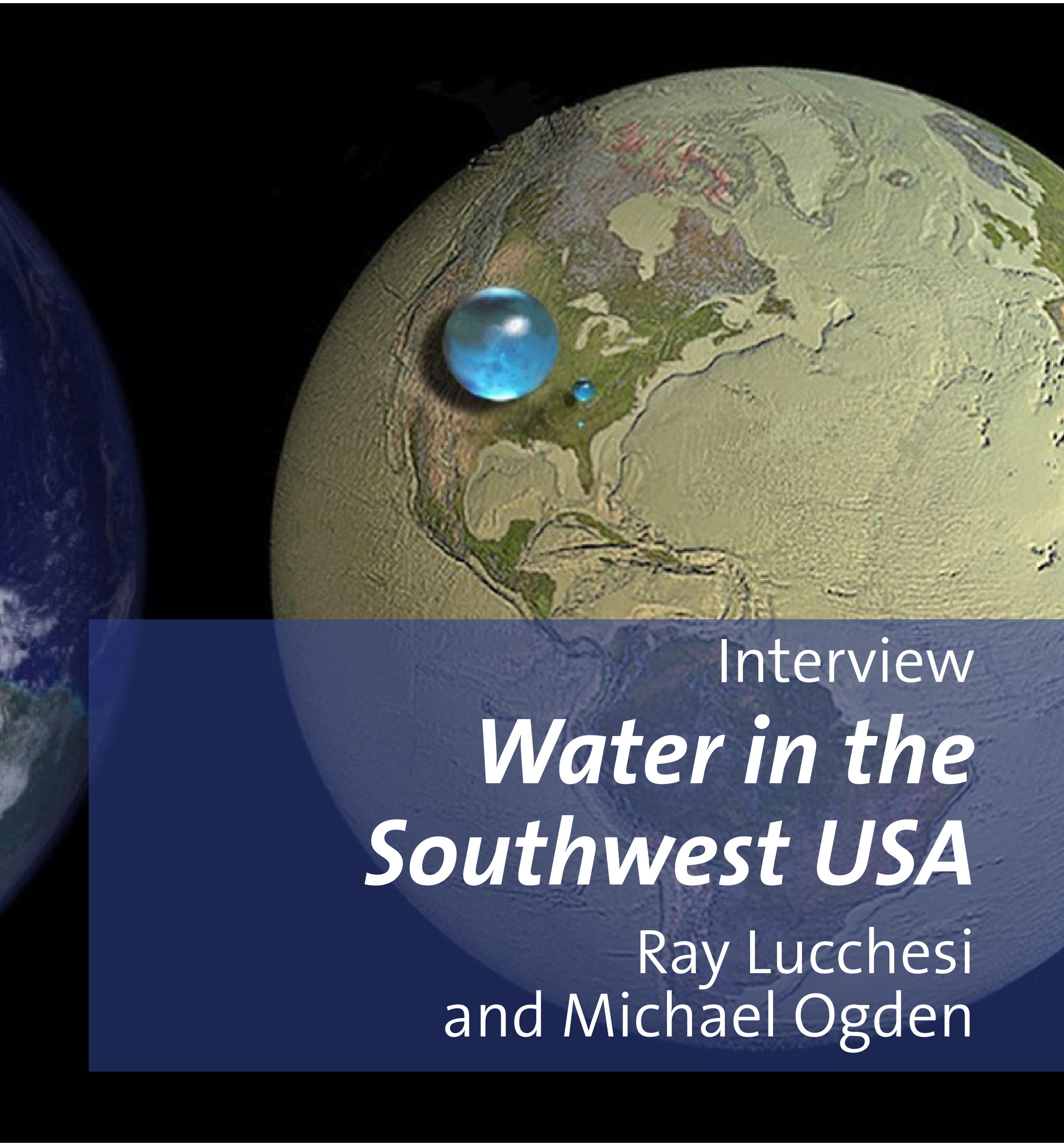
Commerson's roundleaf bat | *Hipposideros commersoni*

"Amiguitos de la Oscuridad" (Little Friends of the Darkness)
Juan Nicolás Elizalde

Pied butterfly bat | *Niumbaha superba*

Spectral bat | *Vampyrum spectrum*

Illustration showing all of Earth's water, liquid fresh water, and water in lakes and rivers.
Photo: Howard Perlman, USGS/illustration: Jack Cook, WHOI



Interview

Water in the Southwest USA

Ray Lucchesi
and Michael Ogden

Water in the Southwest USA

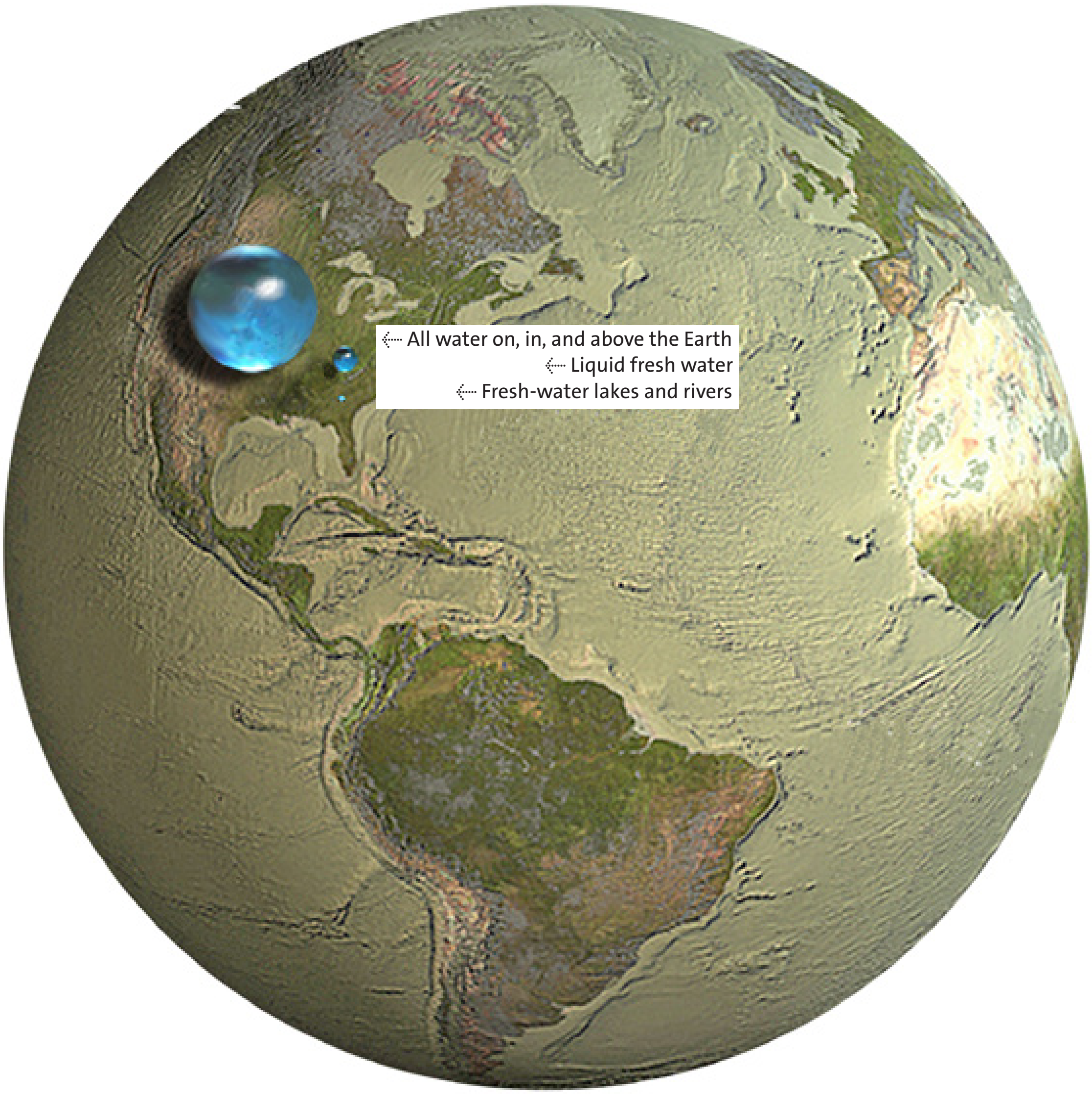
Ray Lucchesi and Michael Ogden

How did you get interested in the impact of water on design?

Ray Lucchesi: I have always been interested in water. I was born and grew up in Las Vegas when the population was about 50,000, now 2.2 million. It was hot and there was little water - I had to interact with the environment because its impacts were unavoidable. It was a place of contrasts - I liked the mountains especially when it snowed. Initially artesian wells on the Springs Preserve met local needs, but as Las Vegas grew, it drew water from Lake Mead, diverted water from the Colorado River and even further afield, losing its connection to the place.

Michael Ogden: Engineers are good at rectangles and circles and all of the technical aspects: we know the numbers. My undergraduate education at Berkeley was largely in mathematics, physics, and chemistry - I had about 20 pages of biology as an undergraduate. Graduate school at Chicago introduced me to mathematical systems concepts. McHarg's classic book *Design with Nature* (1969) introduced landscape architects to the concept of using natural systems or applied ecology: ponds,

Lake Mead in October 2021, as seen from the Hoover Dam with the white band showing the high water level.
Photo: APK, 2021 | Wikimedia Commons


All water on, in, and above the Earth
Liquid fresh water
Fresh-water lakes and rivers

Water in the Southwest USA
Ray Lucchesi and Michael Ogden

wetlands, wetlands, and forests, all strongly connected.

McHarg's group of graduate students hosted the first conference in the US in 1976, bringing Dr. Kathe Seidel (Max Planck Institute for Biology) to tell her very remarkable story on using wetlands for wastewater treatment. From this conference the Universities of Michigan, California, the Tennessee Valley Authority, and the EPA began additional research and developed design manuals.

Indeed, it was the landscape architects that got so excited when Craig Campbell (ASLA Fellow) and I presented at an ASLA national convention in the late 1990s. I focused on the engineering and mathematical concepts of the design showing how limitations on water flow and water treatment requirements might accommodate aesthetic considerations. My subsequent work, research, and publications relied on the concept of natural systems – self regulating, self organizing, and self maintaining ecologies, such as wetlands, meadows, woodlands, and ponds.

Water treatment systems relying on gravity and treatment wetlands got a big start in Europe following the work of Seidel, with France taking the lead. The platinum standard, relying only on gravity to move wastewater, is increasingly common in France. For the worldwide community of engineers and landscape architects, the goal of producing clean water, attractive landscapes, and habitat using only minimal or no energy inputs, has produced some remarkable systems in almost every country.

I have been fortunate to be able to pursue the concept of "Right Livelihood" (https://rightlivelihood.org/) through water projects with the help of mentors like John Todd (https://www.toddecological.com/), Sherwood Reed, P.E., editor of the first EPA design manual and author of *Natural Systems for Waste Management and Treatment*, and George Tchobanoglous, Ph.D., P.E., Professor Emeritus, U.C. Davis, co-author of *Wastewater Engineering: Treatment and Reuse*. To make wastewater systems work, we need gardeners rather than mechanics who want to turn on a switch or move a lever. Although natural water treatment systems are common in countries that cannot afford the machinery, their adoption remains an uphill battle in the USA.

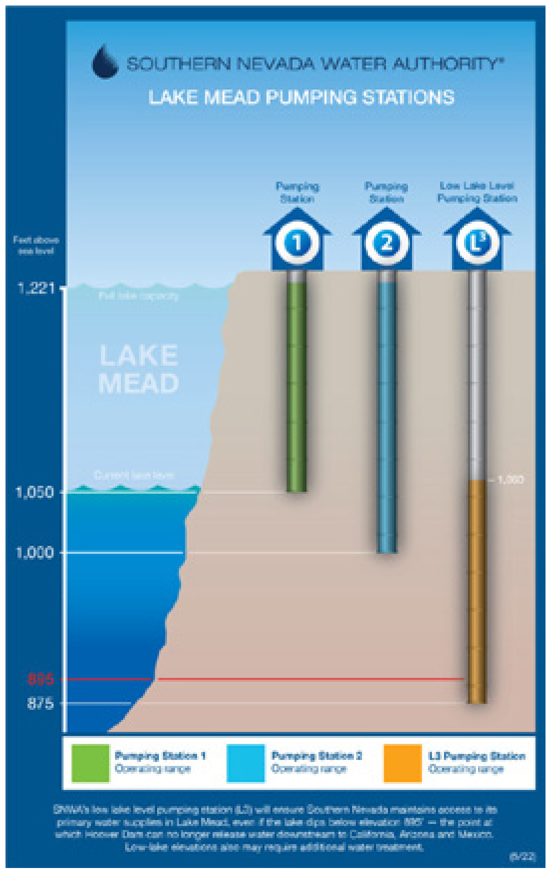
Why has water become a major issue in the Southwest USA?

Michael: Our water quality laws are largely written by people from the Eastern USA where there is an abundance of water - "the solution to pollution is dilution" was the mantra of Eastern engineers. If we had let Native Americans of the Southwest write the laws for the EPA, just imagine how different they would be. If you have ever lived in the Southwest, the first thing you would recognize is that there isn't any water. It is mostly desert with only two river systems, the Rio Grande and the Colorado, both over-allocated and in crisis.

Water is sacred and essential to all life - quickly learned if you don't have any. How do you change the consciousness where we recognize that water is life? Any changes in consciousness are going to affect all the established players, from farmers growing alfalfa to cattle feedlot operators and newcomers from wetter regions who want lawns in a place like Las Vegas that gets four inches of rain a year. Only a small percentage of the inhabitants have been born in the Southwest. The Native Americans respected water resources because it kept them alive for over 10,000 years. Our technology allows us to build huge dams that support water-hungry agriculture, lawns, and golf courses. A major challenge is the idea that the water under my land is mine, even though extracting it with ever-deeper wells depletes the aquifer affecting everyone around me. There has to be a change in consciousness of the general public's relationship to water.

Are you seeing any encouraging signs of change?

Michael: The Isleta Pueblo south of Albuquerque has been around long before Albuquerque showed up. The Albuquerque wastewater treatment plant upstream from the pueblo was discharging 250 million gallons a day, equivalent to the fourth largest river in New Mexico. The Isleta Pueblo,



A graphic showing the configurations of the three pump stations in relation to Lake Mead depth.
Southern Nevada Water Authority

Owens River in Payahüünadü:“place where the water flows”. | Photo by Elizabeth Hoover | cc supported by the EPA, took Albuquerque to court demanding the same water quality as people upstream of the wastewater treatment plant. Isleta eventually won in Federal Court. It cost Albuquerque $250 million to meet that standard. Surprisingly, the precedent was not picked up by other US communities downstream from slightly treated wastewater. Another example is the city of Curitiba in Brazil which requires water discharge from sewage treatment plants to be upstream from the municipal water intake – now you pay attention to water quality!

California gives landowners rights to all the water they can pump out of the ground. In New Mexico, water in natural streams belongs to the public for beneficial use. However, without Federal rules, this can cause large water consumers to move to another state.

Ray: Native Americans in the Northwest, but also through California, Nevada, and Utah, are working together to establish a new relationship with water instead of one imported from parts of the USA where excess water is often the problem. Part of their strategy is working the legal and political systems, but the Pomo and the Paiute are notable for also looking at the broader system - they take care of their springs for the benefit of the local area.

Michael: The Chumash Nation, with the support of Deb Haaland (U.S. Secretary of the Interior), are trying to set up a marine sanctuary to protect the San Luis Obispo coastline as well as their culture. There are hopeful signs in a few locations, but the political power in the West remains resistant to change.

Ray: Something mechanical cannot regenerate, but rivers and lakes can bounce back quickly if we give them a chance. There are initiatives in California, New Mexico, Colorado, and other states to reintroduce beavers to help restore rivers and streams. In some areas, beavers are still considered a nuisance, but they are also part of the complex water stories that incorporate an understanding of how things work now and a remembrance of how things worked in the past, helping bridge the gulf between cultures.

Michael: The Southern California Water District of Los Angeles actually did something sensible with water. Based on the home size, they allocated households a fixed amount of water at a base rate. The cost of anything more than that went up significantly and they posted the rates for everybody. This encouraged homeowners to have water efficient fixtures and convert to low water landscapes.

What Southwest water initiatives have you been involved in?

Ray: As General Manager of the Las Vegas Valley Water District the Southern Nevada Water Authority, Pat Mulroy (https://law.unlv.edu/faculty/pat-mulroy) managed all the water in Nevada and especially Las Vegas. She wanted to shift the milieu of what Las Vegas is, from being "in the desert" to being "of the desert." Those two little words shifted everything, and they spent $200 million to make it happen. Her 2017 book[1] explores "why we face a crisis caused by climate change and what we can do to alleviate it."

Pat wasn't going to build a building - it was about how we get in relationship with a place to shift the consciousness of a million people. She saw that our firm, Lucchesi Galati Architects, had evolved from being just architects to adopting a systems approach. Pat heard about Michael Ogden, so we flew to New Mexico and met up at the Georgia O'Keeffe house in Santa Fe with Ben Haggard and Charles Miller. Charles

Springs Preserve
Photo: Ray Lucchesi, 2014

and his wife Beth had bought the O'Keeffe house and made it a showcase for sustainability. Charles was the former head of the Texas State Pension Review Board and was able to sell the economics of the project.

In the plane on the trip back, Pat was starting to understand the enormousness of the task. She later said we need to move in and take the space and work with the two million people that are here. The $200 million investment was to shift a political human system, not a water system. She reached out to communities, convincing them that Las Vegas could do without lawns. She also demonstrated what was possible: from wetlands to collecting rainwater and buildings that were in relationship with the sun and the water, using rammed earth construction (https://www.rammedearth-works.com/springs-preserve/) that did not require air conditioning. The Springs Preserve Desert Living Center (https://architizer.com/projects/desert-living-center/ and p. 86: https://zqjournal.org/editions/zq10.html) opened to the public in 2007, showing people 'who' the place is, not what it is.

Michael: Pat was remarkable and of all of the people that I have met in all of this work,

Springs Preserve
Photo: Roxanne Ready, 2012 | Flickr cc

she's the only one who had the understanding and the intelligence as well as the ability to communicate so well and get people on board. And this is where Ray and I began our collaboration. Ray wanted to bring architecture, landscape, and water into the desert environment. In a public presentation to the water board (SNWA) and Pat Mulroy, I had said no great city was without a botanical garden. This was taken up enthusiastically and served as a demonstration of what was possible through intelligent design that respected place. Pat had an ecologist on Springs Preserve site that built a wetland to treat stormwater runoff and another that handled sewage from the building on sites. These water treatment facilities were accessible to the public - they even hosted wedding celebrations. These interventions changed the ecology of the site, Increasing the number of bird species from two to 180.

Ray: Lake County is one of the poorest counties in California. Lake County also has the largest lake totally within California. Its economy is largely based on recreation and retirement communities causing increased waste discharge affecting the quality of the lake. Many of the local people commute to work, a three-hour drive, but can only afford cheap cars that last about six months then leave them in the front yard. What if they could stay 'in place' by building local interconnected economies? It starts with water – it comes before food. Unfortunately, we typically focus on the food systems without ensuring the water system is healthy first.

There is a growing awareness in Lake County of the importance of water and how it relates to the food system. Having a water story, a food story, and an economic story can help rebuild these relationships with the watershed. People are doing this in ad hoc ways in a lot of counties in California now. We need more stories that show what is possible in all three areas.

What other projects interest you?

Ray: Neal Spackman launched the startup Regenerative Resources to restore degraded landscapes using living systems such as mangroves and seagrasses. Mangroves are key to two projects in Baja California Sur (https://regenerativeresources.co/current-projects/) - they continue to grow even if their roots are submerged, constantly adapting to changing sea levels, all without technology and outside energy inputs. Regenerative Resources works closely with communities to build social, environment, and economic capabilities, implementing Regenerative Seawater Agriculture to help communities feed themselves, build an

Water in the Southwest USA
Ray Lucchesi and Michael Ogden

economy where there was no economy before, and allow people to stay in place. The goal is to adapt this model along the rest of the Baja Peninsula.

Michael: There is a discipline called restoration. People are doing the same kinds of things with oysters in Jamaica Bay (New York City) and Chesapeake Bay. You bring the seagrass and oysters together to clean up the water of the Chesapeake Bay. Oysters are really good filter feeders while seagrass provides oxygen and habitat for the fish.

Any closing thoughts?

Michael: It is going to take a lot of education to make people understand the ecology of the Southwest deserts. Water is life, and until there isn't any, few people are going to change their relationship with water. Rising temperatures in the Southwest will bring home the realities of supporting massive population growth in places that have little water.

Ray: This notion of regenerative work requires a shift in a community's values - what is our role and how do we move into

Project Melitón: A flagship project in Baja California Sur is an 8,000 hectare RSA.
Neal Spackman (https://regenerativeresources.co/current-projects/)

working with how the place is changing? You cannot freeze a place in time. It is also about remembrance. The tribes understand this when they go into a remembrance - how did it work when it worked well, and why. They get it, they're not necessarily looking for something new to fix it.

What is the 'vocation' of the place that you are in? What is that place contributing? How can those things be kept in place through and with people? We're not doing that. It's not about regeneration - that's easy to understand. But what are you going to regenerate? Regenesis does a 'story of place' before it does anything else because it has to understand not the answers to a place, but who is it? How does it work? We need to transform remembrance of how we thrived to bring hope and move our country's collective hearts, heads, and hands. ×

We would appreciate your feedback on this article:

Mangrove trees to be grown: 45,000,000
Neal Spackman (https://regenerativeresources.co)

Water in the Southwest USA
Ray Lucchesi and Michael Ogden

Footnote:
1. Mulroy, P. (2017). *The Water Problem: Climate Change and Water Policy in the United States*. Rowman & Littlefield. https://rowman.com/ISBN/9780815727842/The-Water-Problem-Climate-Change-and-Water-Policy-in-the-United-States

Ray Lucchesi
Ray is a Principal at Regenesis, and the Founder and Principal of Renovus Collaborative, whose purpose is to collaborate with people, organizations, and communities through integrated planning and design processes resulting in transformative outcomes that increase the value of human and ecological systems.

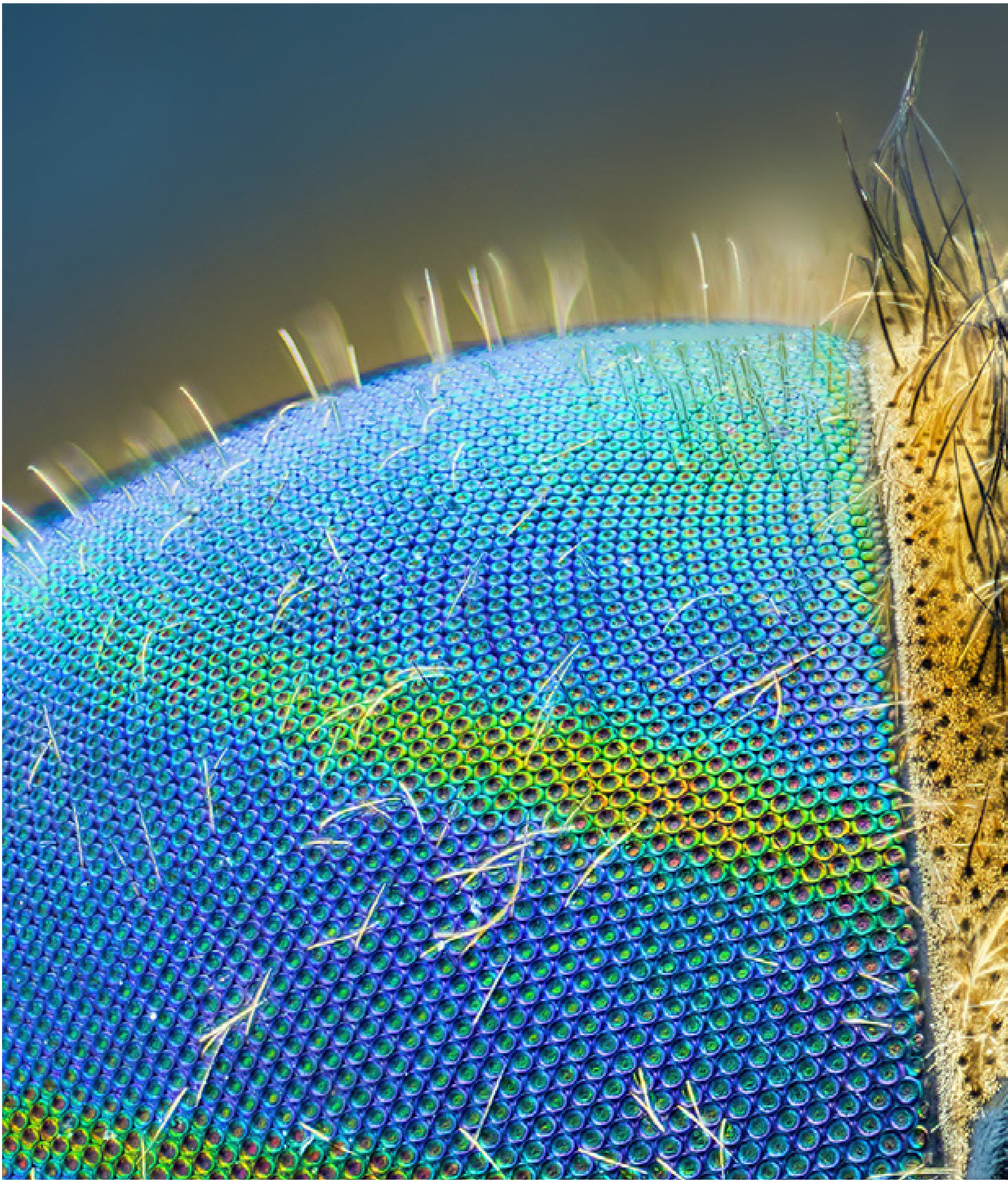
Ray's 35 years of experience in the built environment focuses on regenerative design and development, sustainable and integrated design, and biomimicry. He graduated from Arizona State University, with an emphasis in arid-region ecosystems and passive-design. Ray built upon his education and practice experience by integrating living system and ecological design principles into his work. In addition, Ray has integrated the built, social, and natural environments into a coherent and holistic practice model that delivers value-adding outcomes to the world.

Michael Ogden
I have specialized as an ecological engineer working on more than 600 projects primarily in wastewater, stormwater, and water supply throughout 44 states, as well as Mexico, El Salvador, Panama, Columbia, Peru, Australia, Canada, China, India, Fiji, Afghanistan, and Saudi Arabia. The practice relied primarily on a public domain technology (now worldwide, originally developed at the Max Planck Institute by Kathe Seidel) termed natural systems, which is a term of art used by the US EPA. The technology was particularly appealing to landscape architects since it relied on the ecologies

of wetlands, meadows, woodlands, ponds, and the associated local plant and microbial community. Over the course of 30 years, we designed many LEED platinum projects in a cooperative design process with Award winning Landscape Architecture firms. Some of the projects were total reuse projects and the first of their type.

Making clean water and habitat was good, honest work, but I am no longer working as a practicing engineer. I am mentoring, occasionally teaching, or consulting with former colleagues.

Eucalyptus tree and flower at the Springs Preserve
Photo: Kimberly Reinhart, 2015 | Flickr cc



Tabas eyes
Photo: Pierre Anquet, 2018 | Flickr cc

Article review

Revisiting Nature's 'Unifying Patterns'

Marc Weissburg

Revisiting Nature's 'Unifying Patterns'
Marc Weissburg

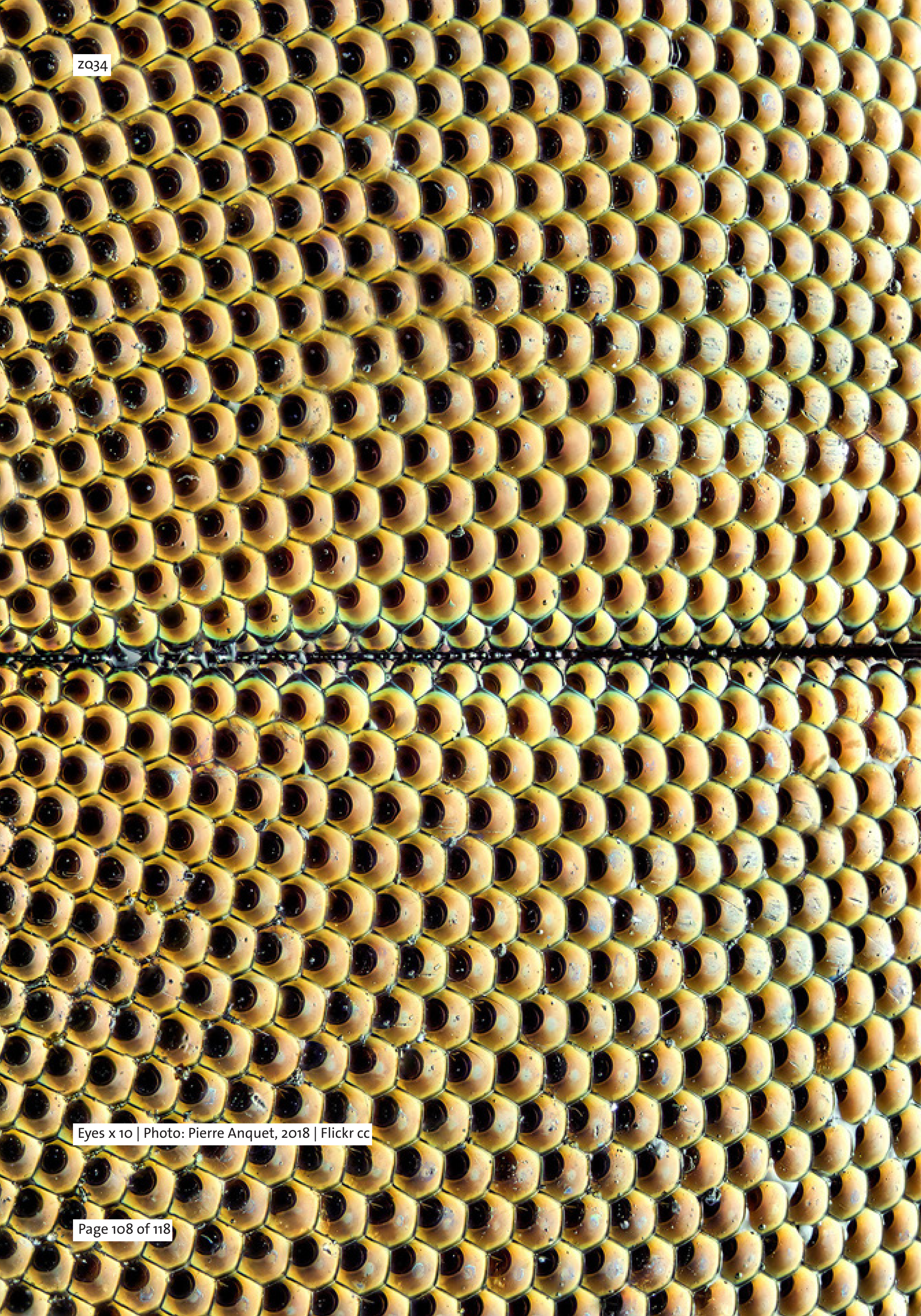
Language vs. knowledge in bio-inspired design: A Review of "Revisiting Nature's 'Unifying Patterns': A Biological Appraisal"

What does it mean to do biologically-inspired design? How do we express principles derived from our understanding of natural systems in a way that supports biologically inspired design? What level and kind of biological knowledge is important? What do we mean by "pattern" anyway?

These are among the questions that Lecointre et al. grapple with, sometimes directly and other times tangentially, in their recent work, "Revisiting Nature's Unifying Patterns" (Lecointre et al., 2023)[1]. Framed as a way to continue to explore the role of biological knowledge in pursuing biologically inspired design (BID), the authors consider the utility and accuracy of Nature's Unifying Patterns (NUPs) published by The Biomimicry Institute. As articulated by The Biomimicry Institute, the importance of these patterns is that they embody essential lessons for biomimicry, that is, "designers " seeking more sustainable solutions derived from the study of biological systems[2]. The question posed by this work is whether NUPs represent a useful articulation of natural principles, and the goal is to advance more scientifically rigorous descriptions that will better support BID and biomimicry. The ensuing discussion is at times fascinating and covers a lot of ground both in terms of essential science concepts and more subtle aspects of how we design or create. It's also occasionally muddy and esoteric. Those who are interested in how we design, and how we design using natural principles will find a lot of food for thought but anyone seeking practical principles that can be the basis for specific designs will be left a little empty.

For those interested in my quick take home, it would be this: the current expression of NUPs has value, but it's limited, and may encourage problematic thinking. Refining how these patterns are expressed and including some additional principles may prevent some of the naivete that leads to problems without necessarily providing effective how-to guidance. My perspective is that some of the perceived inadequacy of NUPs is not because they are scientifically inaccurate (although they are), but because of the diverse ways we think about design, and the difficulty in describing what supports a good design process. The authors' goal here is to advance a shared understanding of biology between biologists and designers, which is absolutely necessary for BID. Of equal importance is a shared perspective and language regarding how we

Urania retouched | Photo: Pierre Anquet, 2018 | Flickr cc



Eyes x 10 | Photo: Pierre Anquet, 2018 | Flickr cc define and solve design problems, and the current lack of such a shared perspective is limiting. This was, to me, the clearest lesson learned.

The authors' deconstruction of the language used in describing patterns found in nature is quite useful. Certainly, the use of "nature" as a subject creates a lot of potential semantic confusion, the most important of which is to conflate human intentional design with "design" via the operation of natural selection. In the evolutionary context, organisms can be said to be "designed" if they achieve a particular function in response to challenges in their environment. Natural selection is the process by which functions are achieved for specific purposes, which captures the similarity to human intentional design as an activity that results in devices or products that also achieve functions in response to specific perceived needs. The problem identified by Lecointre et al. in a variety of places is that natural selection results in "designs" in a much different way than do human designers, and the lack of awareness regarding these differences is problematic. Indeed, one of the first things we do when educating our students or other professionals is to give them a crash course in evolution to disabuse them of a variety of notions that might be unintentionally transferred by the *Nature as Designer* metaphor that is implicitly evoked by the language used in describing NUPs. Assuming biological designs are "optimized", all aspects of biological systems have functional value, not recognizing the role of shared ancestry in determining properties of organisms are identified as among the most pernicious. It would have been even more helpful were the authors to point out the ways that these challenges can be overcome (e.g., Yen & Weissburg, 2011).

Interestingly, the authors are quite clear in their opinion that the NUPs language involves metaphors that create "intellectual obstacles." This observation, which to me is neither wholly correct nor incorrect, exemplifies why BID is both transformative and frustratingly hard. The field is rife with the use of metaphors, analogies, and models with too little attention to either careful articulation of these different constructs or with specifying their role in the design process. Metaphors are terribly useful things when deployed in the right context for the right goals, and it's as important to recognize their strengths as their dis-utility.

Metaphors are expressions in which the exact reading of the phrase is in some sense wrong, but where the phrase conveys meaning, often unexpected, that can have either creative or normative consequences. To use

Revisiting Nature's 'Unifying Patterns'
Marc Weissburg

an example with which I am most familiar, *industrial ecology* is a metaphor that has been used to propel an entire discipline. On the most simplistic level, industries and ecologies are antithetical in a variety of important ways. But the elision of these two a priori conflicting terms stimulates us to think differently about how industries interact (the creative part) and causes us to wonder whether we should, in fact, create systems in which these interactions are more like those that occur in ecological systems (the normative part). *Industrial ecology* has resulted in a field of study that has had quite a positive impact, but like the adjacent BID field, has struggled with articulating how biology relates to human challenges (Ehrenfeld, 2004; Hess, 2010).

What metaphors are not, are detailed models that clearly specify relationships between a system and its referent (Ehrenfeld. 2004). They do not provide how-to advice, are insensitive to context, and cannot be applied directly to solve a particular problem. While all these deficiencies are well noted by Lecointre et al., how metaphors might be beneficially used is not, likely because the descriptions surrounding NUPs is not clear in this regard either. I wonder about the tradeoff in minimizing the metaphorical value of NUPs to achieve greater scientific accuracy. Perhaps it might simply be better to be clear on when one is using a metaphor and on its limitations. The recommendation to adjust "unifying patterns ... to take evolutionary theory into account while retaining their straightforward communicative style" strikes the right note, but without fully addressing the core issue.

The authors also discount the very notion of design patterns in biology, which strikes me as a similar throw-out-the-baby-with-the-bathwater exercise. Design patterns are used in a number of fields (see the journal *Design Science*) but are particularly common in software design and architecture. A consensus definition is that design patterns are general ways to specify relationships between abstract design elements (Goel and Bhatta, 2004). These abstractions furnish high level descriptions of how generic functions are achieved and are the result of repeated instances of functions (problems) being achieved (solved) in a particular way. They represent an approach to a given class of problems. So, "use random diffusion to create a local device network" would constitute a design pattern for (bio-inspired) digital computing (Balaoglu et al. 2006). Because they are meant to be general, a great deal of further specification is required to evaluate the suitability of a given design pattern for a specific circumstance, and on the precise form of the solution. This specificity resides in detailed domain knowledge and will be unique to the area; design patterns in computer science will be different from those in other fields.

Clearly, while some of the NUPs are wrong as noted (organisms are not "optimized", not all materials found in organisms are "safe" at all levels), many can indeed function as design patterns. "Use recycled materials or energy" is a reasonable, if very general, problem solving approach, but its applicability to a specific problem is constrained by time and space scales, materials, or the form in which energy is carried. The reformulation of NUPs, and the additional principles supplied by the authors provides much needed context that can indeed help to "enlighten" BID by pointing out constraints and conditions that affect how, when and where design patterns identified in natural systems can be usefully employed. While Lecointre et al. provide this useful context, they don't really engage the underlying issue, which requires a firm

Lycosidae
Photo: Pierre Anquet, 2018 | Flickr cc

definition of design patterns and a discussion of their utility and limitations. This might limit an appreciation for the importance of the proposed modifications and extensions; they also don't provide more detailed biological knowledge that will help designers solve specific challenges that may use a particular design pattern.

The reticence of Lecointre et al. to use the term "pattern" despite the utility of this construct in design thinking is another illustration of the vexing trans-disciplinary nature of BID. Indeed, when viewed from a biological perspective, *pattern* implies particular conditions that may not be useful in a design context. But, taking design pattern to mean *repeated instances of relationships among components that provides a generalized design solution* (its standard meaning in the design field) could alleviate the potential confusion, particularly in light of the reformulations and caveats supplied by the authors to add context-specific guidance. Renaming "Nature's Unifying Patterns"

Cetonia aurata
Photo: Pierre Anquet, 2018 | Flickr cc

as "Principles of Life" seems less important than clarity in what is meant by a *design pattern*. The Biomimicry Institute's articulation of these patterns lacks such clarity, so it is perhaps unsurprising that critiques of these patterns from a biologist's perspective do not directly engage this issue either.

Lecointre et al. is a perceptive exploration that will no doubt help enlighten and add rigor to BID, and raises important questions about how best to express biological ideas in a useful way to propel design. That some of these issues are implicit, or not articulated in the most direct way is a consequence of the state of BID, which is engaged in defining required knowledge and concepts that currently reside in a rather disparate range of disciplines. It will take some time to best resolve how to organize and communicate the essential ideas, but only efforts such as that represented here can achieve this convergence. Hopefully, future efforts will take up some of the issues here more explicitly and discuss more fully the role of design patterns, metaphor, and analogy when doing biologically inspired design. ×

We would appreciate your feedback on this article:

[1] Lecointre, G., Aish, A., Améziane, N., Chekchak, T., Goupil, C., Grandcolas, P., Vincent, J. F. V., & Sun, J.-S. (2023). Revisiting Nature's "Unifying Patterns": A Biological Appraisal. *Biomimetics, 8*(4), Article 4. https://doi.org/10.3390/biomimetics8040362

[2] The Biomimicry Institute considers biomimicry to be biologically-inspired design for function that is focused on sustainability, and I adhere to this terminology here. This should not be considered an endorsement for this particular definition, however.

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Professor Weissburg is a founding member and co-director of the Center for Biologically Inspired Design at GA Tech (founded 2005), and has been engaged in biologically inspired design pedagogy and research for nearly two decades. He has taught BID for audiences ranging from high school students to industry professionals to career scientists and developed curriculum and best teaching practices at all of those levels. His early research helped understand how animal sensing strategies may be translated into effective methods for chemical plume tracking by autonomous vehicles. His current research examines how the organization of human infrastructure may be informed by ecological systems. Using Ecological Network Analysis, Professor Weissburg and colleagues have examined the organization and performance of human systems at scales ranging from single industries to coupled human natural systems, developed design rules for more resilient and sustainable human systems derived from analysis of ecological systems, and examined how these design rules can improve the efficiency of and fault tolerance of human industrial networks. Professor Weissburg is an executive member of the International Society of Bionic Engineering, and an editor for leading journals in the field of biomimicry, including *Biomimetics*.

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