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Cover art
Cover: Karen Atta, "Crown of Creation" (detail), cast resin | Photo: Timothy Schenck, 2021 / pp. 2-3: “Unearthly Delights” (detail), cast resin / pp. 104-105: “I Am the Keeper of Our Conversations" (detail), cast resin | Photo: Axel Jensen, 2020

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Crimson dropwing (male) | Photo: Troup Dresser, 2012 | Flickr cc

Editorial

Most biomimetic endeavors, whether in science or art or design, start typically with a question. Moreover, most questions lead on to more questions, and often to unexpected answers. Layers of questions suffuse a society of the curious, engaged in search and re-search, and it is our pleasure to share some stories of these interrogators of Life.

Can a slime mold teach us how to teach our children? Shoshanah Jacobs queries Aaron Senitt about the lessons he has learned as an early childhood educator from this puzzling organism.

What blessings have we gleaned from the nature in our pandemic era backyards? Our Heidi Fischer relates the golden moments in several people's lives when they "slowed down to the speed of Nature". She also writes about the rigorous and driven research being done on the bat by Sharon Swartz and her colleagues. Like planted dragon's teeth, each question answered has yielded ten more.

What are the best tools for professionals to employ bioinspired design? Trans-discipline collaborators Jacquelyn Nagel and Noah Pentelovitch tell us about their recent user experience research.

How have the seemingly madcap obsessions with manned flapping flight, seen in faded photographs and old newsreels, led to advancements in aeronautics? We celebrate humans' relatively crude attempts to emulate this gravity-defying miracle of the natural world.

What guidance do Nature and my art process give me? Karen Atta, our featured portfolio artist, honors this query continually and shares some of her renown work.

Finally, can we change the way we see the world and ourselves if we expand the tenets of biomimicry? Questions of an existential nature are discussed by architect Randy Anway in his review of Henry Dicks' recent book *The Biomimicry Revolution*.

Happy reading! ×

Tom Norbert Marjan

Tom, Norbert, and Marjan

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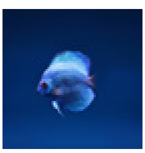
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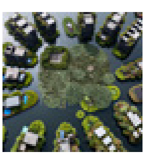
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Codex on the Flight of Birds
Text and sketch: Leonardo da Vinci, 1505-1506

Article

Flapping Flight: the human quest to fly like a bird

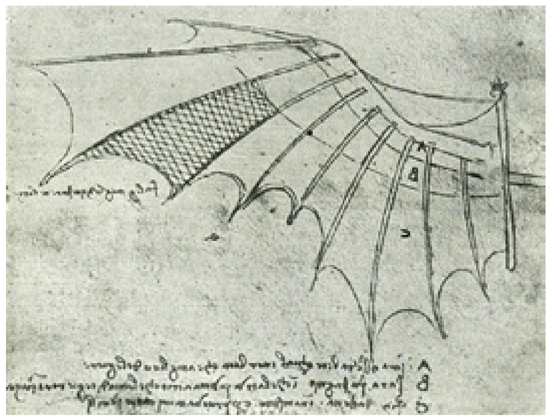
Tom McKeag

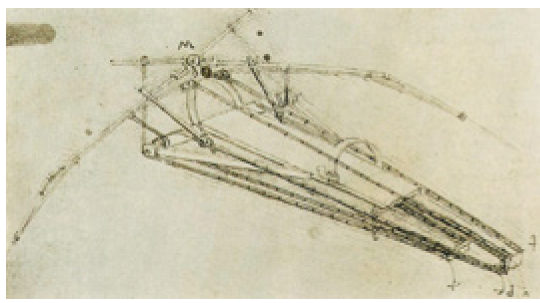
Flapping Flight: the human quest to fly like a bird

Tom McKeag

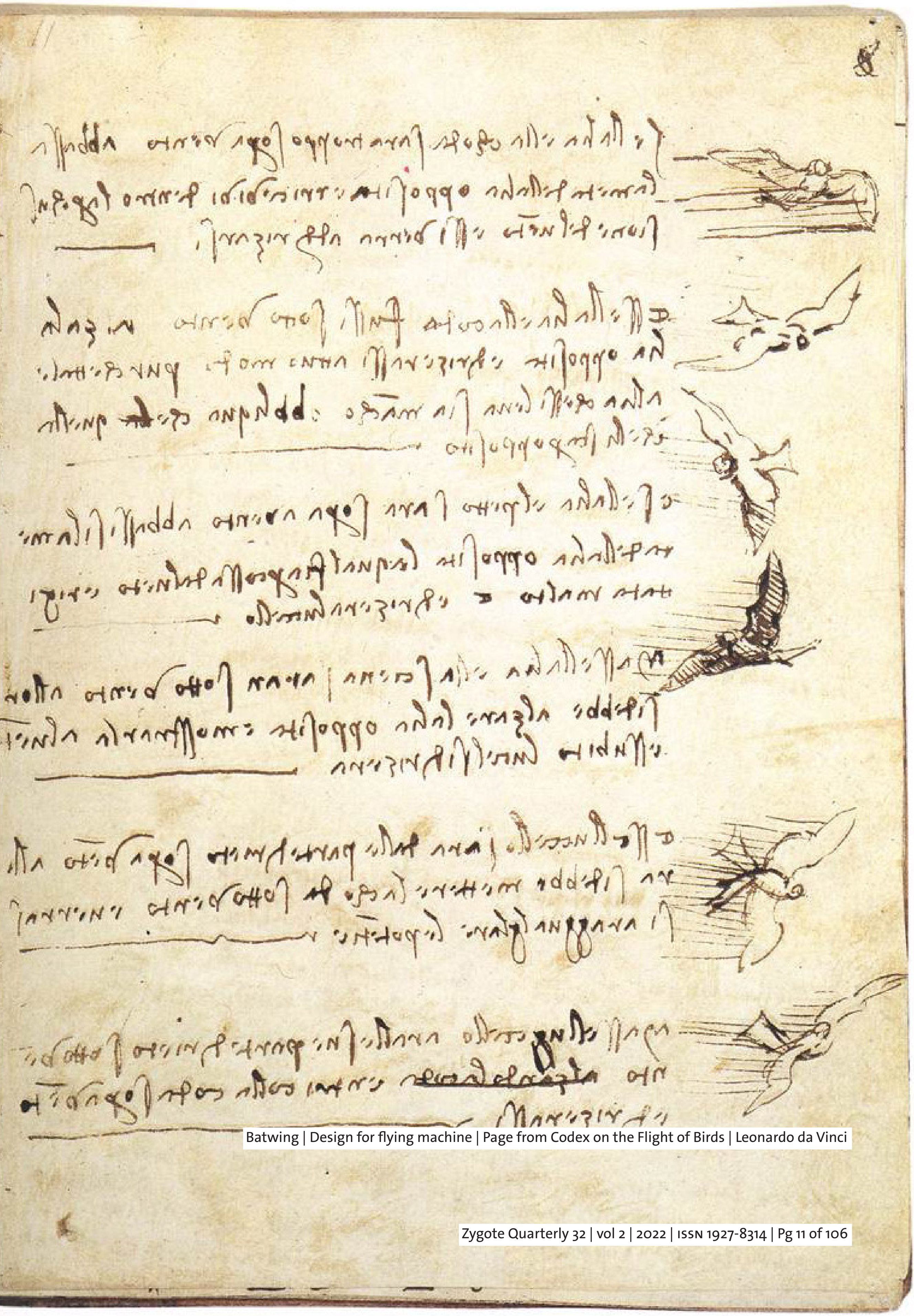
Around the year 1490 a 38-year-old artist from Anchiano, near Vinci, Italy, had just recommenced work on an equestrian statue for the Duke of Milan, Ludivico the Moor, while researching anatomy and the content for one of history's most remarkable notebooks. The *Codice sul volo degli uccelli* "Codex on the Flight of Birds", produced circa 1505-1506, was among the most complete records Leonardo ever wrote, but was just one repository of his over 35,000 words and 500 sketches on the subject of natural flight. In less than 20 pages and 100 drawings, he considered the mechanics of flapping and soaring, air pressure, centers of gravity and what the modern world now calls "aerodynamics". Da Vinci believed firmly that Nature would always yield solutions if studied enough, and he was intensely interested in flight. Throughout his codices were detailed drawings of the natural objects of his interest, and, most wonderfully, how he would translate his observations into the making of a machine to put Man into the sky.

His most favored biological model was the bat, writing, "Dissect the bat and concentrate on this and on this model arrange the machine". Seemingly, he chose the bat because of its perceivable structure, noting "...the bat because membranes form a framework...which binds the whole and is not pierced". His study focused on the form of wings and on the pulley-like actions used to raise them. Most of his testing was, understandably, of a mechanical nature, focused on the force needed to move wings large enough for a man.





This was, after all, the fifteenth century, two years before Columbus would sail to the New World, and Leonardo, despite his genius, was constrained by the limits of his society. The concepts of gravity, thrust,



Batwing | Design for flying machine | Page from Codex on the Flight of Birds | Leonardo da Vinci

Flapping Flight: the human quest to fly like a bird

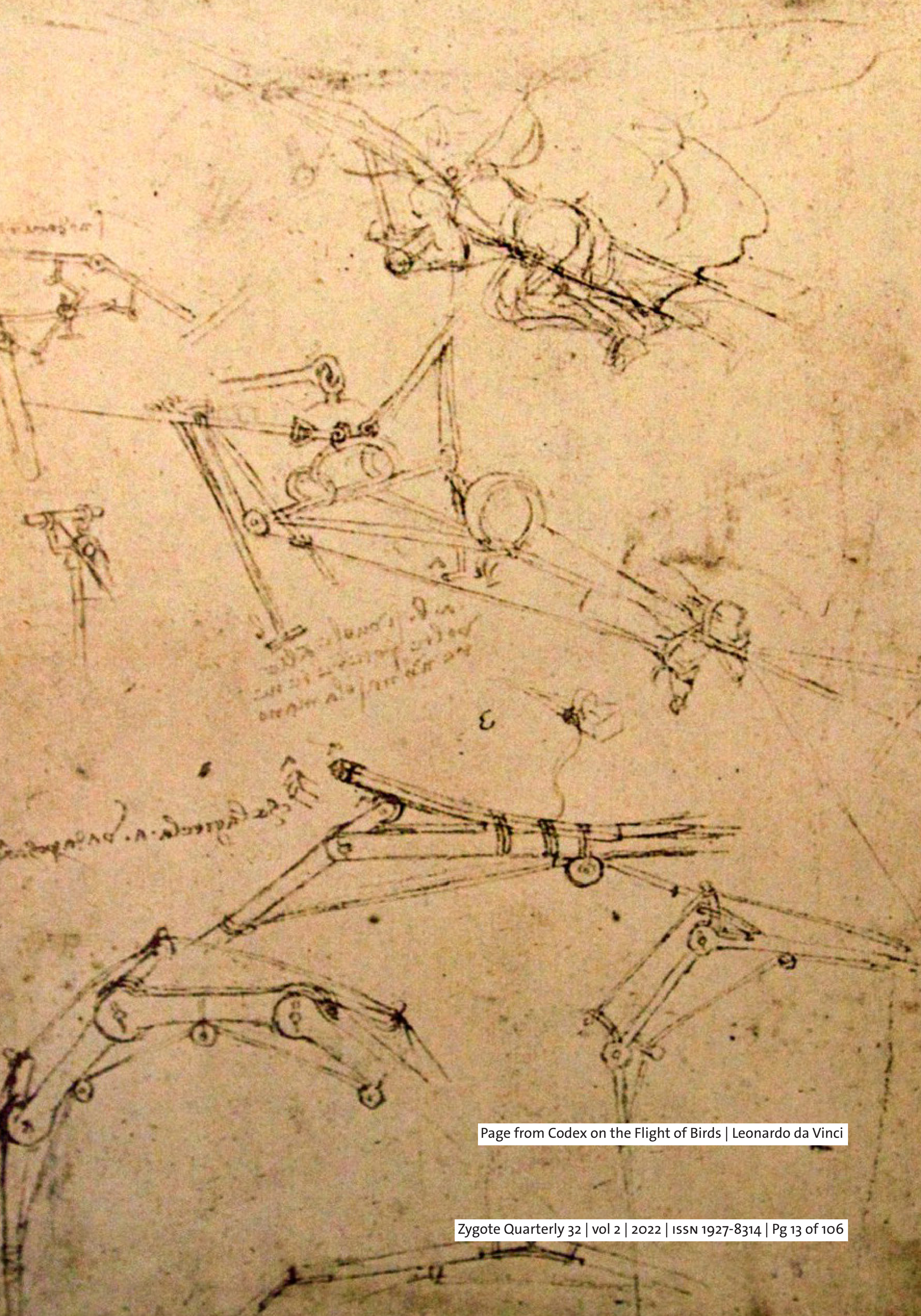
Tom McKeag

lift and drag had not been developed; the Bernoulli effect, for example, would not be proffered until almost 250 years later in 1738. All flight for Leonardo would be human-powered and this was insufficient for lift, even after Leonardo shifted his machine power to legs, rather than arms, in 1503. His study of materials was no less meticulous, but, despite his best efforts, canvas, laminated fir and hemlock struts, steel or bone springs and leather hinges were still too heavy to lift off the ground, taken with the weight of the pilot.

But what a vision! Leonardo understood the crucial concept of the center of gravity and the lifting pressure on the bird's wing, and had some inkling of the relationship between a curved wing and lift. He observed the ascent of birds into the wind, predating the modern concept of the stall, and understood the relationship between the shifting of weight of a pilot and the direction of the craft. He gave the first written account of how birds traverse a circle by changing the geometry of their wings, and how they use their tails to achieve stability and change speed. Finally, he conceived of air as a fluid, a fundamental concept for anyone involved in aeronautics. He never built his "bird", but his keen, scientific observations and meticulous, translational design would place him centuries before his time.

Leonardo da Vinci Ornithopter, 1486
Model: Leo Blanchette, 2019

The human quest to fly like a bird is littered with the wreckage of dashed dreams and broken wings, but it is a fascinating story of the confluence of four factors: scientific observation, material development, aeronautical theory and the demands or desires of society. Tantalizing moments when some of these factors have converged have produced instructive steps along the way to this lofty aspiration. It may just be that we as a species are quite close to perfecting practical flapping flight. If so, then it is because of hard-gained insights into the biomechanics of living creatures, the physics of flight, and the engineering of materials.



Page from Codex on the Flight of Birds | Leonardo da Vinci

Flapping Flight: the human quest to fly like a bird

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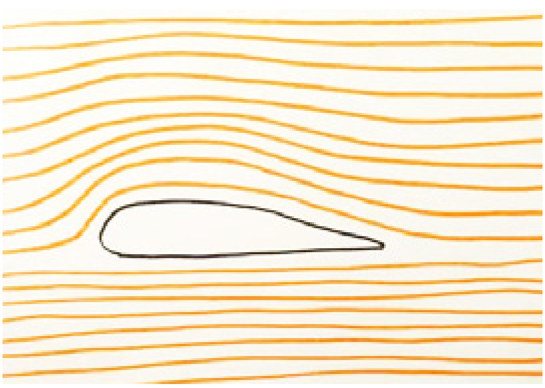
The Model

Like all biomimetic endeavors, the emulation of a bird's flight system has necessarily meant the simplification of a complex phenomenon. In the common seagull, such flight is anything but common, and anything but simple, despite the animal's seemingly effortless grace. On takeoff the gull's wings provide both the thrust and the lift necessary to leave the ground, powered by the oversized pectoral muscles and aided by the legs. These muscles can account for as much as 30% of a bird's overall weight. For most birds a strong depressor muscle (the pectoralis) powers the downbeat and a relatively weaker elevator muscle (the supracoracoideus) moves the wing upward.

Once in the air the wingfoil of the bird takes advantage of the Bernoulli Effect for lift. Air rushing against the curved wing will be split by its leading edge; some going over the top and some going underneath. The air going over the top will travel farther and faster than that going under. This will create a low-pressure area above the wing and the wing will rise, buoyed by the higher pressure beneath. Angle of attack and directional control are achieved through a complex neuromuscular feedback system; the bird's flexible body, wings and tail responding to the most minute environmental changes. While the wings propel the bird forward, the tail is used for directional control, braking and hovering. The body also will shift in several dimensional vectors to change course and maneuver.

A key measurement for the ability to fly is the so-called wingload, the weight of the bird versus the area of its wings. Drag, the bane of all aircraft engineers, is reduced by evolutionary refinements like a streamlined core, and strong but light feathers. "Hollow" bones, and strategically placed air sacks within the body also help the bird to fly but not in the way one might expect. Flying is an intense and oxygen-burning effort and birds have evolved structures beyond the bloodstream that spread this oxygen from the lungs around. A bird's bones are not any lighter than a comparable land animal, but they allow oxygen from the lungs to suffuse the trabeculae-latticed interior of these bones. Nine air sacs within the bird spread



Bernoulli Effect

the air from the lungs to other parts of its body. Finally, and most amazingly, birds have the ability to take in oxygen on both inhalation and exhalation!

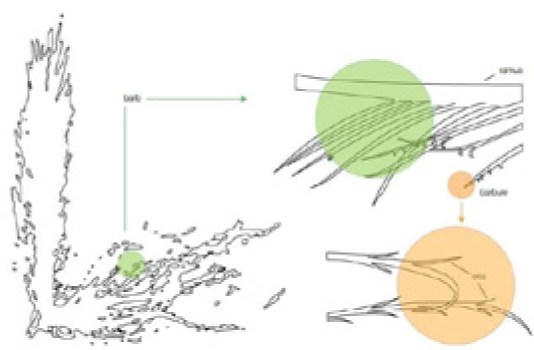
The wing of a bird comprises two functional parts, an inner part next to the body and moved by the shoulder joint (arm section), and an outer part activated by the equivalent of a wrist, the joint at the outboard bend of the wing (hand section). The inner part of the wing is held steady and fairly stiff at an average tilt, or angle of attack, of 3-5 degrees from horizontal. This provides lift almost exclusively except for minor adjustments to maintain that lift. The outer part is flexible within several degrees of freedom and does the work of propulsion through the bird's robust but pliable primary, secondary and tertial feathers, or remiges.

To maintain lift, just like an airplane, the bird must maintain speed; the average minimum speed for birds is about 11 mph. Maintaining speed means flapping, and wingbeat rates among birds vary widely, from 2.0 per second, to about 70 per second for the ruby throated hummingbird, in a class by itself both in wingbeat frequency, in the figure-eight geometry of its oscillations and the dominant size of its elevator muscles.

The wingbeat is not a simple up and down motion. In normal flight the bird fully extends its wing in a forward downbeat, then flexes its "wrist", and, leading with this part, goes up and back with the flight feathers partially separated. At the top of the beat the hand section flaps up and out in a powerful burst before repeating the downstroke, the propelling stroke. The feather separation on the upstroke is to reduce resistance and drag as the bird presses against the air above it.

The bird will change its wing shapes throughout the cycle of up and down movement, sometimes independently. It will compress its wings on the upstroke to reduce drag, but not enough to eliminate any lift. The variable-span wing also retains vortices which increase buoyancy and efficiency.

The bird's feathers are a marvel of design. Flight feathers comprise the shaft or rachis,

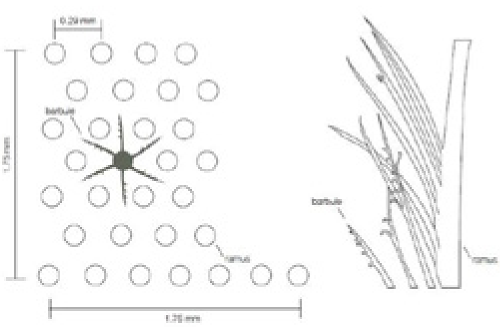


Barb, remus, and barbule
Illustration: Marjan Eggermont

a tube made of cross-laid fiber layers filled with foam, and hundreds of lamellae grown out in a single curved plane, called the barbs. These barbs have side branches called barbules, and these have hooks or hamuli that anchor the barbules together, forming a net. This web is collectively known as the vane of the feather; short on the leading edge and long on the trailing edge of each feather. This design is both strong and light, and the tube of the shaft changes shape from round at the base to rectangular to square at the tip. This allows for different properties of stiffness at different points along the shaft. The barbs are oval in cross section which makes them resistant to up and down movement, but not side to side. They lock together to form a tight foil, but can be easily disengaged by twisting upon impact during cleaning or upon collision with an object. The individual feathers overlap and are customized in shape according to their function in flight.

The alula, for instance, is a small feathered projection at the leading edge of the most outboard joint of the bird's wing. Its function is to maintain smooth laminar flow over the top of the wing during high angles of attack, thus preventing a stall. Otherwise, a wing tilted up too far on its leading edge would create turbulence from the air slamming against its front face, rather than riding over the top. This turbulence would interrupt the Bernoulli Effect, lift would cease and the bird would quickly loose altitude; a stall.

Intelligent bird behavior also aids flight. Three examples are the use of thermal updrafts by soaring birds to gain altitude, flying in "V" formations to take advantage of buoying vortices of preceding birds, and the deliberate and repeated diving through air layers to gain speed and subsequent lift and altitude.



Barbule webbing
Illustration: Marjan Eggermont

Fits and Starts

Much of aeronautical progress in the ensuing centuries after Leonardo was confined to lighter-than-air craft like balloons and dirigibles with the French Montgolfier brothers making the first successful manned balloon flight in 1783. In 1852, this research culminated with Henri Giffard's flight of 15 miles with a steam engine mounted on a dirigible. Flapping flight, although aided by the 17th c. theories of Borelli's *De Motu Animalium*, and the 18th c. research of Sir George Cayley, would be mostly abandoned, first for balloons, and then later for the world's enthrallment with the Wright brothers' historic fixed-wing flight at Kitty Hawk, North Carolina in 1903. Along the way, the experimentation with bird-like flight would blossom at various periods; first in the late nineteenth century in France and Germany, then in the 1930s in Germany, then in the early 21st c. in Canada. Whether manned, or unmanned, powered by the potential energy of a wound rubber band or an internal combustion engine or the frantic work of a human pilot, all of these endeavors would advance the science of flight and bring the world closer to a long-held ideal.

Gustave Trouvé

In fin de siècle France, many inventors designed unmanned flapping craft; often

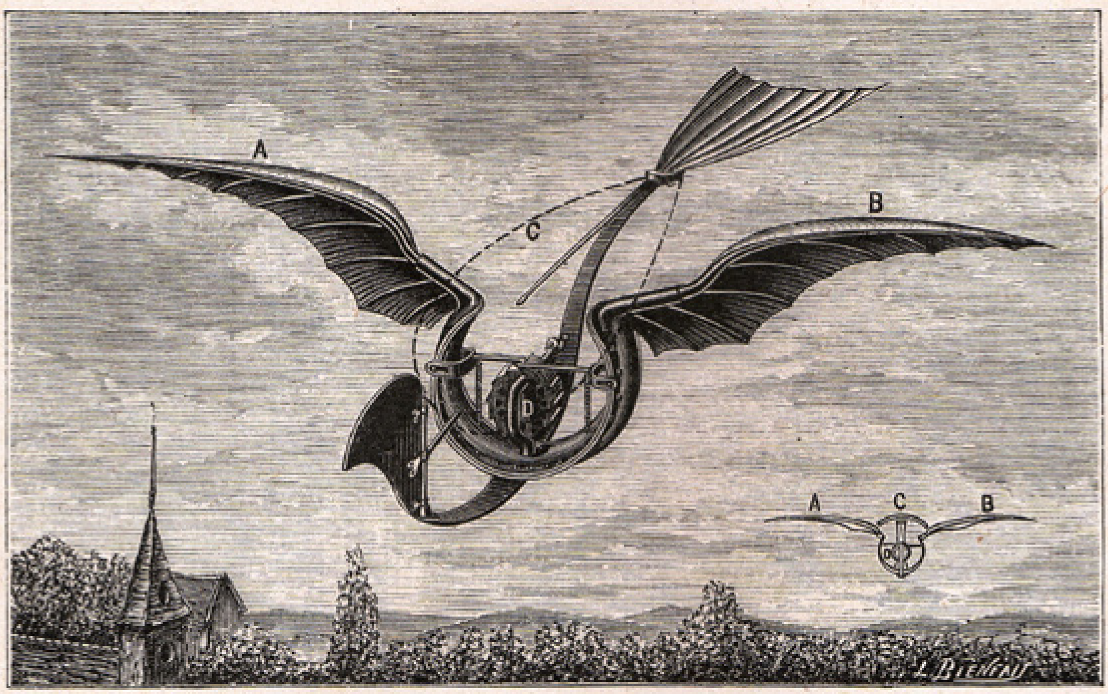


Fig. 282 — Second oiseau mécanique de M. Gustave Trouvé.

Mechanical bird
Gustave Trouvé

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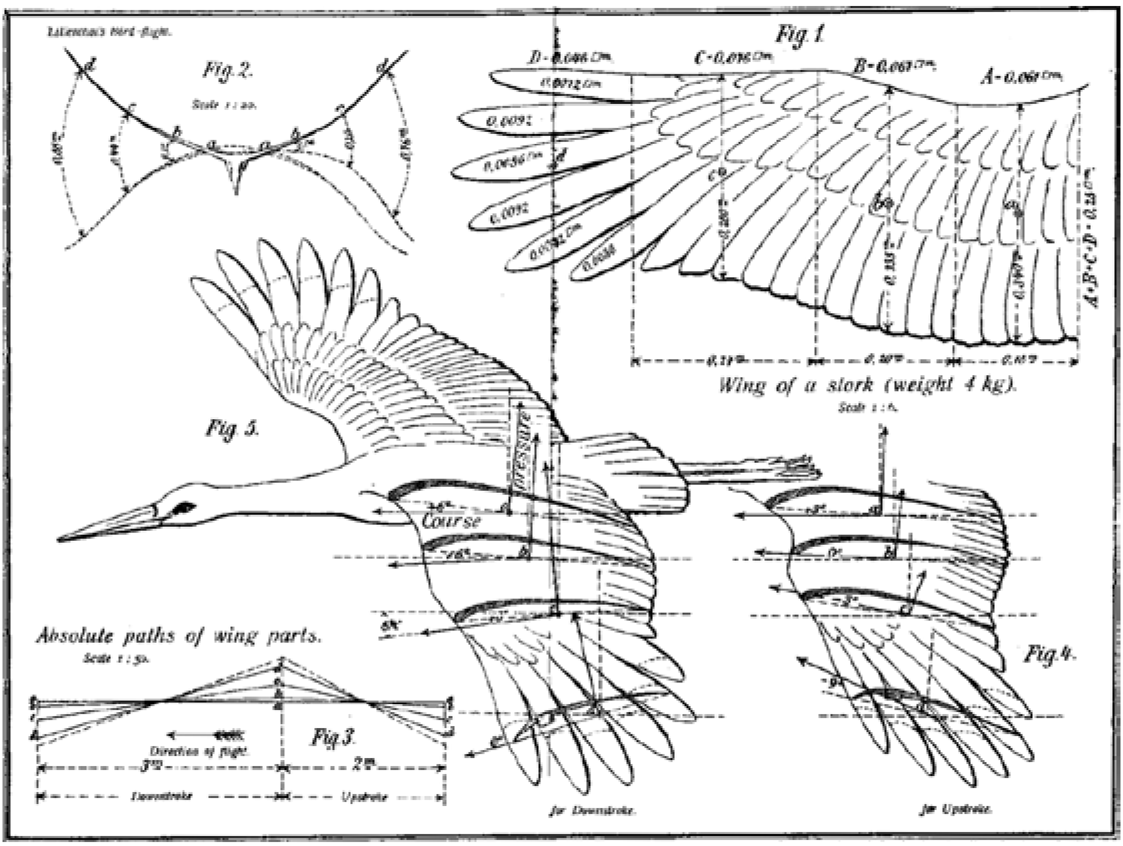
they were powered by rubber bands. Gustave Trouvé, sometimes called “the da Vinci of the nineteenth century”, designed and successfully flew the first mechanical bird powered by internal combustion. Called the *Flugelflieger*, it comprised a pair of wings, tail, front rudder and a centrally located revolver cartridge cylinder. It was demonstrated to a delegation from the French Academy of Sciences in 1890, and Trouvé claimed that it flew 80 meters in 1891, longer than any previous heavier-than-air vehicle. The flapping wings were powered by rapid succession gunpowder charges pushing compressed air into a Bourdon tube. The elliptical cross-section Bourdon tube was formed into a horsehoe shape to the ends of which the wings were attached. They were activated by the changing shape of the tube under the alternately high and



The flight of a white stork
Illustration: Otto Lilienthal in *Der Vogelflug als Grundlage der Fliegekunst*, 1889 | Wikimedia Commons

low pressure from the firing sequence of the gunpowder.

Otto Lillienthal

Well-known for his development of gliders, Lillienthal was fascinated with the mechanics of human-powered, flapping flight and in 1898 wrote, *Birdflight as the Basis of Aviation*, a comprehensive documentation of his study of bird (particularly the stork) and glider flight. This included research techniques, analysis and diagrams of the collected technical information, such as polar diagrams, showing the relationship among drag, lift and angle of attack. Like Leonardo, Lillienthal designed his own tests and devices, including a flapping wing test stand in 1867. He also built his own conical launch hill near Berlin in order to catch updrafts from any direction. In 1893 he was able to fly as far as 250 meters, launched from a hill. The Wright brothers would later credit him as their main inspiration for their pursuit of a manned flying machine.

Lawrence Hargrave

Another inventor of the 1890s was Laurence Hargrave who built various craft powered by steam, rubber band and compressed air. Hargrave's most significant contribution to the field of aeronautics was his recognition that he could design a smaller flapping wing (and thereby reduce the requirement for torque in the linkage) if he provided an

Otto Lilienthal with his small wing flapping apparatus near to the "Fliegeberg", 1894
Courtesy of Ottomar Anschütz | Lilienthal Museum, Anklam

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additional, larger fixed wing to provide lift. This simplified construction and gearing.

Ornithopters

By 1908 in France these flapping contraptions had a name, “ornithopteres” from the Greek words for “bird” and “to rush or fly”. Aircraft design, however, had moved on by then with the first ever manned flight of a heavier-than-air craft on December 17, 1903, at Kitty Hawk, North Carolina, USA. The Wright brothers had ushered in a new age of transportation, and engineers across the world were keen to capitalize on their fixed wing formula for success.

While the design and building of flapping wing craft might have taken a hiatus, the progress in understanding the biomechanics of birds and the physics of flight had not. In the early 1900s Knoller and Betz had recognized theoretically that

Erich von Holst Ornithopter
https://www.youtube.com/watch?v=VdrwOs9owuM

a flapping wing creates an effective angle of attack and produces both lift and thrust. This would be corroborated through the years until 1936 when I.E. Garrick offered the first computational explanation of how a flapping wing could generate both lift and thrust through a full range of oscillation and serve as an alternate to a propeller. The 1930s saw a second resurgence of ornithopter design and building, this time in post WWI Germany.

Erich von Hoist

One inventor active in the 1930s was Erich von Hoist. Hoist, like da Vinci, employed pulleys to increase the torque of his wing action. He also experimented with biplane wing phasing and hinged outer wing panels that mimicked the more flexible natural wing. Some of von Hoists unmanned designs were the most biomimetic in appearance and his rubber-powered ornithopters looked convincingly like birds.

Alexander Lippisch

The Treaty of Versailles, which officially ended World War I in 1919, prohibited German rearmament, but was circumvented by the Nazis when they came to power in 1933. Building a new air force was a top and secret priority. A commercial airline, Lufthansa, was allowed and military pilots were trained through this organization. In addition, the country saw a remarkable proliferation of amateur flying clubs where young men built and flew gliders and ornithopters and learned the basics of flight. Alexander Lippisch led a group of such aviation students before going on to design the ground-breaking ME 163 Komet, the world's first jet powered aircraft, toward the end of World War II.

Lippisch favored the Hargrave model of small, forward flapping wings and an aft fixed wing. He added more rigid airfoils to this model and many of these unmanned craft, powered by either rubber band or combustion, flew for as long as 16 minutes.

Seemingly, his was the first flapping wing design to fly powered solely by the pilot. Launched by elastic cord, the craft covered approximately 250-300 meters before landing. It is unclear, however, if the energy of the launch device merely created a flight trajectory that was aided by the pilot. The record does not show whether the constant speed and height over distance was sufficient to support claims of a truly sustained, human-powered flight.

Lippisch's wing design progressed first to include a flexible outer section that twisted slightly in the downstroke and created thrust and then a flexible trailing edge to greatly increase the propulsive action. This improvement was also biomimetic, with an unlikely source in the Zanonia (*Alsomitra macrocarpa*) seed. Lippisch's fixed inner wing provided lift while the smaller outer flapping sections could produce thrust with less loading.

The Zanonia seed shape had been investigated before by Friedrich Ahlhorn in 1897, and his work was applied by Igo Etrich and Franz Wells in the *Praterspatz*, a monoplane glider of that shape in 1906. The design was later powered by an engine and evolved into

Left: Lippisch ornithopter (Ornithopter Society)
Right: Zanonia seed

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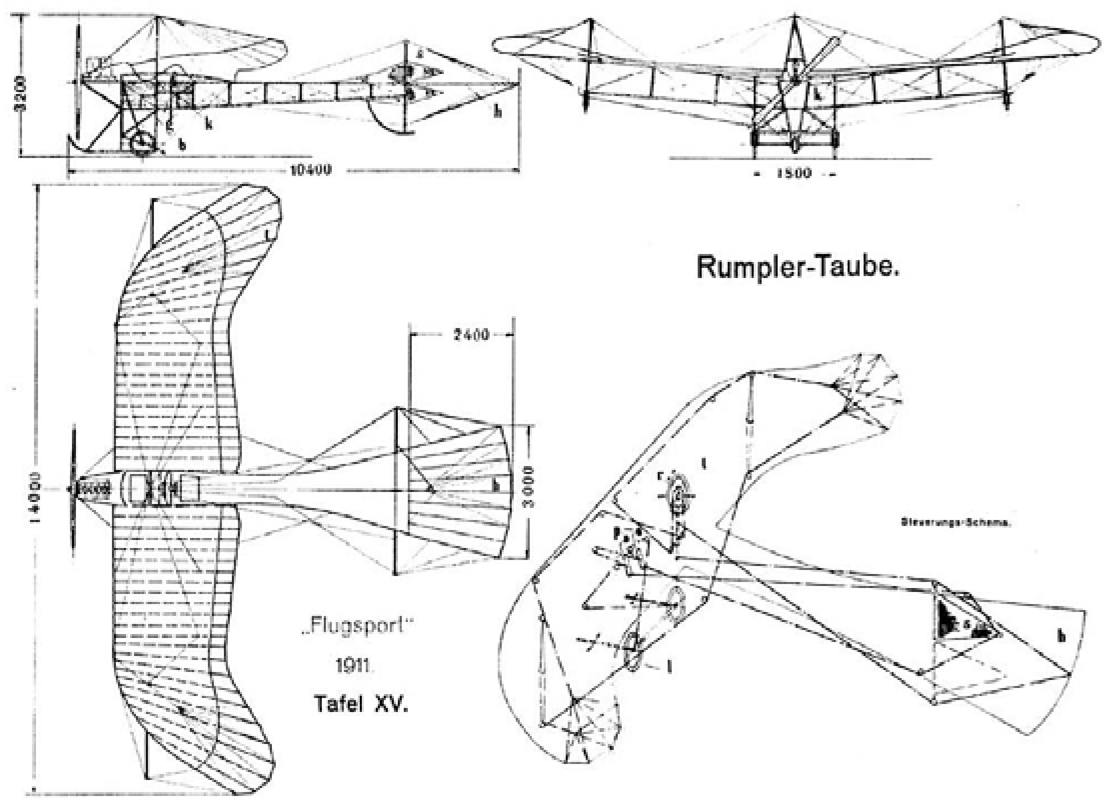
the Rumpler *Taube* (Dove) of 1911, used as a weapon of war in WWI.

Lippisch was determined to prove that a man-powered flight was possible and had been informed by the research of a medical doctor named Brustman, who had measured the power that could be generated by the human arm and leg muscles. This work was refined by the Muscle Flight Institute under Oscar Ursinus including the optimum cycles needed for the generation of flapping. German athletes were able to produce 1 horsepower of energy for short durations using both their arms and legs. The optimum tempo for such work was found to be 1.7 cycles per second. This cycle is related to the size of the wings to be moved and for this reason all of the Lippisch designs included small flapping wings and a larger fixed wing that could provide the lift needed to support a man.



Design drawing of Taube (Dove) from 1911
Illustration: Igo Etrich | Wikimedia Commons

Aldabert Schmid
Schmid continued the design progression of a small, flapping wing pair aided by a larger, fixed wing for lift, and in 1942, in Munich, his human-powered ornithopter made a 900 meter flight at 20 meters above the ground after getting a tow launch. Schmid added a motorcycle engine to the craft and it was able to fly the craft at 60 and 80 kilometers per hour. Although his work was interrupted by the war, in 1947 he retrofitted a Grunau-Baby IIa sailplane to have flapping outer wings and a 10 hp engine that could carry two passengers.

By the 1950s the world of commercial aircraft design had a new darling, the jet engine, and this powerful first mover would completely change the design of things that fly; all in the quest for speed. It would be nearly fifty years before serious attempts would again be made to build a passenger flapping flight aircraft. This time, the effort would be in Canada.

James DeLaurier
In September 1991, the first successful, engine-powered, remotely controlled, flapping wing flight was recorded. The three-minute unmanned flight of a

World's First Human-Powered Ornithopter,
https://www.youtube.com/watch?v=oE77j1imdhQ

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quarter-scale model named “Mr. Bill” would prove the aeronautical concepts developed at the University of Toronto over the previous six years. Five years later, in 1996, their team would begin flight testing of their full-scale, manned model, “Big Flapper”. It comprised an internal combustion engine, complex transmission and wings that flapped through an arc of almost 54 degrees. It was not until 2006 that Big Flapper was able to take off by itself and fly for 14 seconds before a deformation in its ultralight wing forced a landing.

In the same year a human-powered ornithopter (HPO) project was begun at Toronto, led by DeLaurier. Their 95-pound craft would be named the “Snowbird” and would be of ultralight, glider construction of carbon fiber spars, foam ribs and a lightweight flexible skin propelled by the legs of pilot and main designer, Todd Reichert. In 2010, the craft maintained speed and altitude for 500 feet, after being launched by tow.

Festo

The German automation company Festo has been designing and building demonstration robots since 2006 as part of its Bionic Learning Network, including several remote controlled flying models based on the herring gull, the flying fox (bat), the butterfly, the penguin (an animal that flies underwater) and, most recently, the swift. The BionicSwift is perhaps the most biomimetic of these robots as its wingfoil comprises synthetic feather arrays as well as a mimicked flexible wing and body. This is a replication one tier down in the flying system not seen since the unsuccessful attempts by Edward Frost to fly a craft made of willow, silk and real feathers in 1902.

Ultra lightweight, weighing only 42 grams (approximately 1.5 ounces), the device is 44.5 centimeters (17.5 inches) long with a 68-centimeter (almost 27-inch) wingspan. Its feathers are ultralight, resilient foam attached to a carbon quill affixed to the “hand” and “arm” of the model. They are arrayed in a typical natural, overlapping pattern that allows for a solid plane on the downstroke, thus producing thrust, and an open pattern on the upstroke, thus reducing drag and effort without losing all benefit of lift.

The model body contains a motor, two servo motors, a battery, a gear unit, and a number of circuit boards for radio, control, and localization, as well as the mechanical linkages for the wings. Festo claims that "intelligent interaction" between the motors and mechanical system allows the bird to accomplish complex maneuvers like barrel rolls and steep dives.

The bird is radio controlled with GPS and ultra wide band (UWB) technology and can be flown in a flock within a space set up with triangulated beacons on the ground and radio markers on the individual birds. Information is sent to a master computer which functions as a flight controller for all the units. They can be flown in preset patterns and the units are able to make onboard course corrections in the event of flight path changes due to the environment.

The Russian Dragonfly

Two Russian aeronautical engineers designed and built a full-scale, unmanned, radio controlled ornithopter based on the dragonfly in 2021. The craft is named "Serenity". A light metal spine supports three rigid wingfoil sets: in the middle a quad array wingfoil set beats in the opposing direction of single wingfoil pairs forward and aft for a total of eight wings (four up: four down). A small motor powers a chain that is linked to individual flywheels mechanically driving pistons to raise and lower the balsa strutted wings. This is a large model, seemingly at over 10 feet in length and weighing 20 kilograms, has limited flight directional control and even

Serenity First Controlled Flight,
https://www.youtube.com/watch?v=ZCrS52sM3Zs

more limited pitch control, but is a remarkable machine.

A New Wave of Applications

As in past periods, material development and societal trends today greatly influence the research and development of flapping flight aircraft. While long, sustained human-powered flight might remain a history-making goal, current commercial trends appear to be toward research and development in the unmanned, micro aerial vehicles (MAVs), slow-flying drones, swarm technology, and the ever-increasing miniaturization of propulsion and communication. It is here where some of the advantages of flapping flight might find a best-fit application in noise reduction, slow-speed maneuverability, and vertical takeoffs and landings.

Regardless, large-scale aircraft will no doubt continue to benefit from the study of natural flight, as the recent anti-vortex improvements to fixed wing commercial jets attest. Flapping airfoils provide both thrust and lift, and therefore could be more efficient, reducing drag structures. During flight, the foils could conceivably be set at zero angle of attack. Flapping allows for vertical takeoff and more maneuverability. Moreover, flapping flight aircraft, unlike jet or propeller fixed-wing craft, are not dependent on powerful thrust to maintain an efficient angle of attack and therefore can operate at slower and more economical speeds. The colorful history of inventors in the continuous development of flapping flight has sometimes masked their important contributions to the field of aeronautics. They, and the continued study of Nature, should not be ignored. ×

Talking bubble murmuration
Photo: Sue Cro, 2017 | Flickr cc

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Detail from Codex on the Flight of Birds
Leonardo da Vinci

“I Am the Keeper of Our Conversations" (detail), cast resin
Photo: Axel Jensen, 2020

Portfolio

Karen Atta

Portfolio

Karen Atta

Karen Atta is a sculptor whose work explores forms that are rooted in nature, science, and the supernatural. A Lebanese American, Karen was born in New York City, and raised in Southern California. Growing up in a mid-century surf town fostered an intense appreciation of art, music, and the natural environment. After receiving an MFA in sculpture from Concordia University in Montreal, Karen dove into music and secured a contract with Atlantic Records. Her music career led her back to New York, where she worked as an independent artist and ultimately founded Atta Studio.

Karen is a pioneer in cast-resin sculpture. For over 25 years, her commercial studio has created unique objects for design and architectural applications across a range of disciplines. Sculptures and installations by Atta Studio have appeared everywhere from Lady Gaga's performance at Barack Obama's inaugural ball, to Tim Burton's retrospective at MoMA, to the celebrated High Line Park in Manhattan. Now part of the fabric of New York's Chelsea art community, Atta Studio is known for its expertise in combining classical sculpture with contemporary fabrication and engineering.

High Line view, Karen Atta with "Wildflower", cast resin
Photo: Timothy Schenck, 2019

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

Nature is the architect of architects, the highest form of order and disorder, the omnipotent model that I am constantly in awe of. The endlessly impossible complexity and gravity defying feats I find in nature leave me seeking ways to reinterpret and honor it. As a sculptor I have always envisioned my work outdoors, enhancing the viewers' experience of their surroundings and punctuating the natural beauty around it.

What kind of techniques do you use for your work?

I'm often inspired by an image or a photograph that I've come across or taken. To begin, I study the form or portion of form that I'm exploring and burn it into my memory. Then begins the process of transferring that memory to clay. Nearly all my work begins in clay – it's how I draw. The sense of touch is key for me and is integral to working with clay. What I love about clay is its' forgiveness as a material – the ability to easily alter it. I model the clay until I'm happy with the form, which is usually a scale model for a larger piece, I make a mold and cast it in a quick setting polyurethane resin that I then refine. Next comes modern technology! The scale model is digitally scanned and reproduced in an enlarged version - most often carved in foam. Many of my pieces are quite complex from an engineering perspective. So, hand in hand with this enlargement is developing the technique to achieve the final cast form. It may be because my father is an engineer that I have an innate ability to understand structure, form and generally conceive of fabrication and installation techniques in my head, rather than on paper.

High Line view, "Wildflower" detail, cast resin
Photo: Timothy Schenck, 2019

Portfolio
Karen Atta

Who/what inspires you creatively? What do you 'feed' on the most?	What are you working on right now? Any exciting projects you want to tell us about?
Surrealism has always been a great source of inspiration for me. I am also drawn to the freedom of movement in dance, the electricity of great music, the everchanging qualities of light, the work of many other artists, the tenacity of my Welch Corgi and the ingenuity of sea life and insects and the structures they instinctively know how to create.	Now, my fabrication studio is working on the creation and installation of an 8,000 lb. abstract cast resin sculpture of a beehive for the new Gilder Center at the American Museum of Natural History. In my personal work, I am exploring a series on black holes. The title "Black Hole Light at the End of the Tunnel" was inspired by the collective despair of the global pandemic.

Studio view, *Wildflower* production mold, silicone + fiberglass, and Karen Atta + team w/ *Wildflower* casting, 2019

What is the last book you enjoyed?

The Sound of the Sea: Seashells and the Fate of the Ocean by Cynthia Barnett. A Must read! A very detailed and enthralling history of seashells as well as their role as a barometer of the state of the planet and the peril they predict.

What are your favorite websites, and why?

1. scientificamerican.com (always fascinating)

2. mcmastercarr.com (addicted to the endless selection of every kind of hardware on the planet!)

3. nytimes.com (great writing and reporting)

4. newyorker.com (great writing and quirky impossible crossword!)

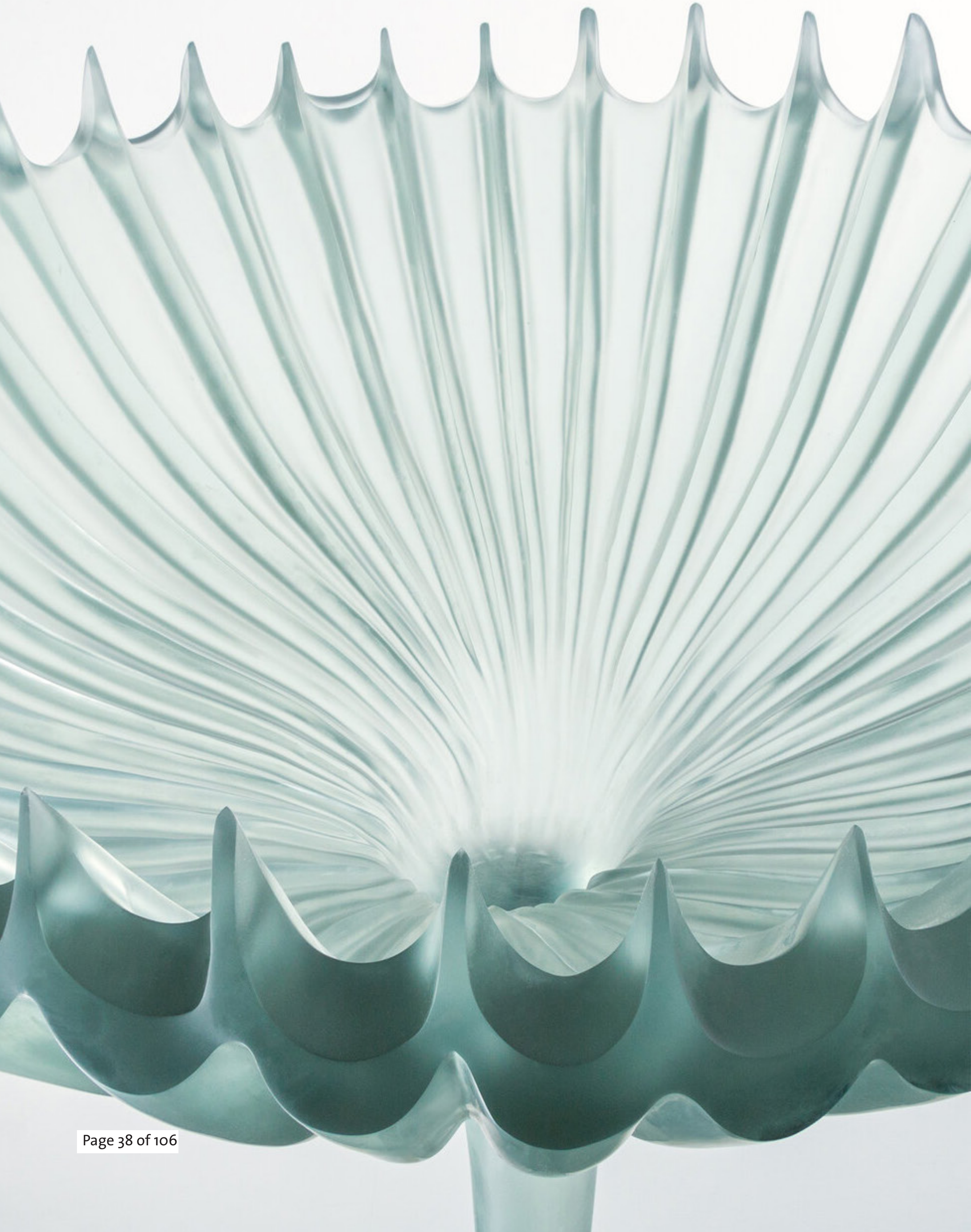
5. wikipedia.com (trivial pursuit!)

What's your favorite motto or quotation?

Respect the process. ×

Model Studio view, various models, molds, castings, 2022

1/6 scale models, cast resin
Photo: Axel Jensen, 2021



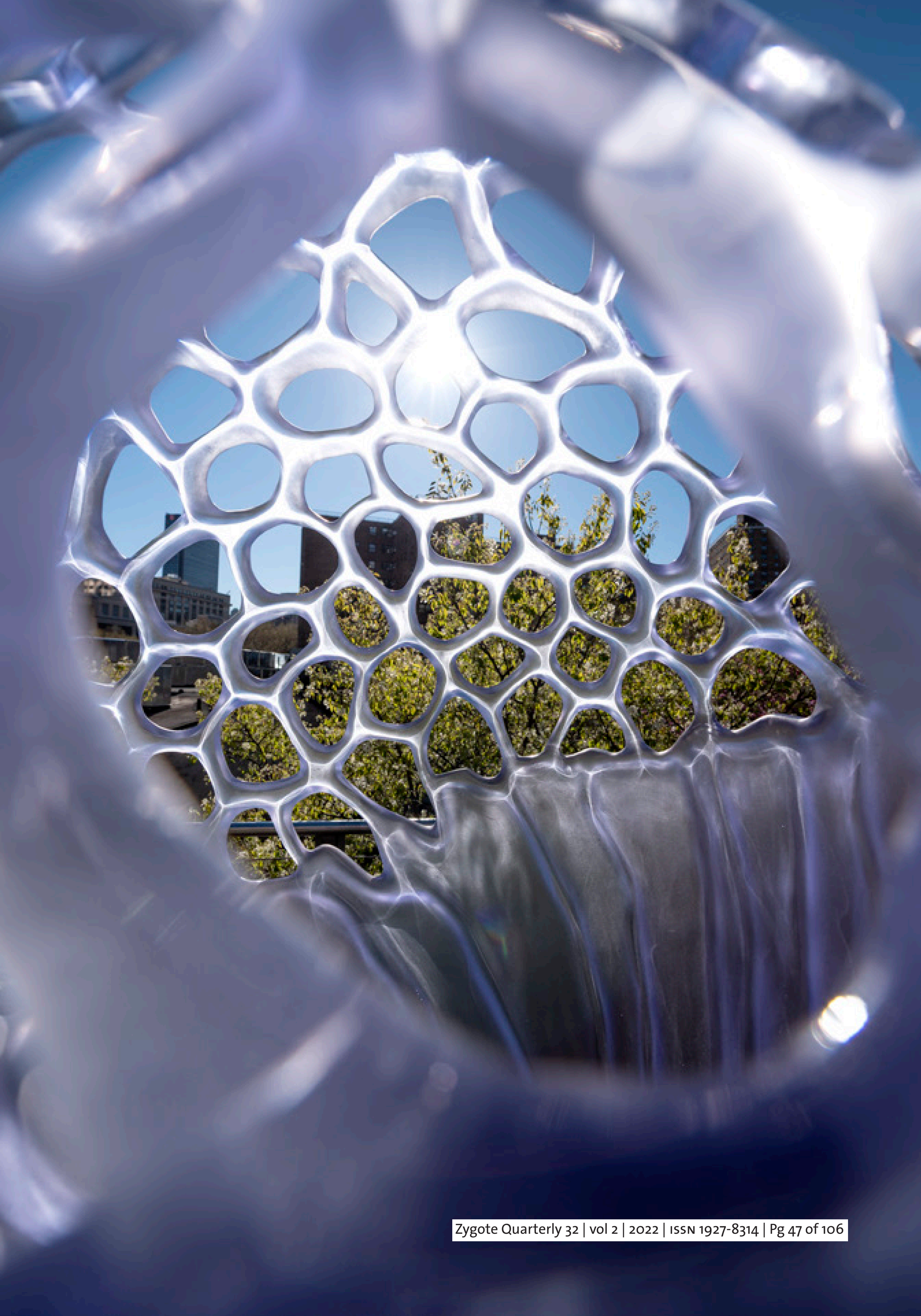
“Cloudbusting” (details), cast resin | Photo: Axel Jensen, 2020

Installation view, “Unearthly Delights” exhibition detail, cast resin | Photo: Timothy Schenck, 2021

Scale model, “Crown of Creation” detail, cast resin | Photo: Timothy Schenck, 2021

Installation view, “Unearthly Delights” exhibition detail, cast resin | Photo: Timothy Schenck, 2021

Scale model and High Line View, “Molly Bloom” details, cast resin | Photo: Timothy Schenck, 2021



"Untitled Spike" (details), cast resin | Photo: Axel Jensen, 2021

We would appreciate your feedback on this article:

Fruit Bat (flying fox)
Photo: Mike's Birds, 2017 | Wikimedia Commons

The Science of Seeing
Night Flights
Adelheid Fischer

Night Flights

Adelheid Fischer

Years ago, as I was driving on a moonless summer night up an isolated canyon in the Chiricahua Mountains of Arizona, I experienced something that made me hit the brakes and gasp with wonder. It was as if the sky had suddenly opened up and dumped a cargo of snow flurries. There swirling in my headlights and drifting up around the windshield was a cloud of white flakes. But this was no snow storm. It was June, spring opener for emerging moths, and the lights had lured them to my car. The most thrilling part was yet to come. Trailing the moths were bats, lots of them. Some of them were small, like sparrows outfitted with tiny capes. They flitted around the edges of the light, pursuing the insects with short, staccato wingbeats while larger, daredevil bats sliced through the beam in kamikaze dives. They burst from the dark, momentarily spotlit, before disappearing back into the night.

In the Chiricahuas, a bounty of moths attracts a bounty of critters such as bats. Located in a remote southeastern corner of the state, the mountain range is home to 16 species. And a bounty of bats attracts a bounty of people who study them, including Sharon Swartz. A biology professor at Brown University, Swartz began her science career some four decades ago focusing on the comparative anatomy of humans and mammals, in particular, gibbons. During her postdoctoral studies, she dabbled in a bat-research project, embarking on what she thought would be a temporary detour from her primate work. Swartz never looked back. “The bat-research community is just full of fascinating people who are passionate about the things that they study,” she observes. “It’s a very welcoming and enthusiastic group of people. It’s difficult to break away from that once you are engaged with it.”

Welcoming and enthusiastic are the exactly the words I would use to describe Swartz and her collaborator, Aaron Corcoran, faculty from the University of Colorado, Colorado Springs. I caught up with them one night in summer 2022 on the grounds of the Southwestern Research Station in the Chiricahua Mountains. The evening sun was just settling into dusk when the two biology professors gathered with a group of graduate students around the entrance of a screened tent. The makeshift outdoor laboratory, which was stocked with moths netted from the surrounding forest, housed six high-speed cameras and a set of infrared lights. In preparation for the night’s data gathering, some of the students were engaged in the painstaking work of precisely calibrating the cameras’ focus while others concentrated on syncing the

Mexican long-tongued bat (*Choeronycteris mexicana*) | Photo: Doug Greenberg, 2017 | Flickr cc

Night Flights
Adelheid Fischer

visual feed on computers. The meticulous technical setup, which had to be repeated each afternoon, was laborious and often frustrating.

Yet despite the long nights and exacting work, the group was surprisingly cheerful, more like tailgaters at a championship baseball game than scientists under pressure to maximize their limited time for research. I soon understood why. Once the cameras and computers were readied, the students began to retrieve captured bats one by one from temporary pens. But before releasing them into the experimental tent, the students paused briefly to gaze into their faces. Although they worked with the bats night after night, the students seemed to take advantage of every opportunity to examine the strange and marvelous creatures that usually only skirt the edges of our vision, fleeting as smoke. And why not? Who wouldn't want to make a closer acquaintance of the Townsend's big-eared bat with its scalloped ears three times the size of its head? Or the pallid bat with its whiskery goatee and stylish coat of thick blonde fur edged in dark-brown leather sleeves? Or the big brown bat that seemed to want nothing more than gobble mealworms like french fries from the students' fingers?

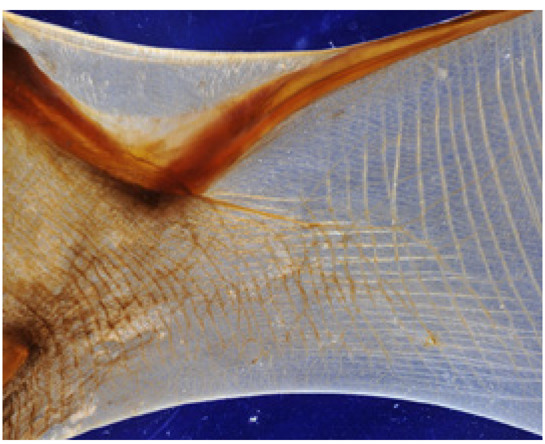
Most studies involving bats and moths focus on bat echolocation and the sonar-jamming counteroffensive mounted by their winged prey. But Swartz is the world's expert on a lesser-known aspect of bats: the biomechanics of their wings, which she studies under the microscope and with high-speed cameras. As the bats pursue the moths circling the tent's infrared lights, the cameras record their flight. Swartz points out that bats flap their wings 10 to 15 times per second. The cameras record at speeds ranging from 800 to 1,000 images

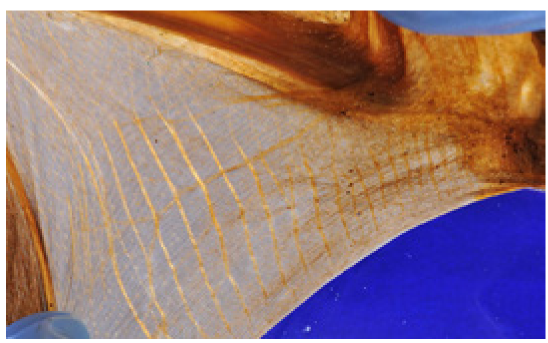
Left: Townsend's big-eared bat (*Corynorhinus townsendii*) | Photo: PD-USGov, 2002 | Wikimedia Commons
Right: Pallid bat (*Antrozous pallidus*) | Photo: © John D. Chenger/batmanagement.com

per second, rendering in splendorous slow-motion detail an aerial ballet that, to the unaided eye, is just a blur of movement.

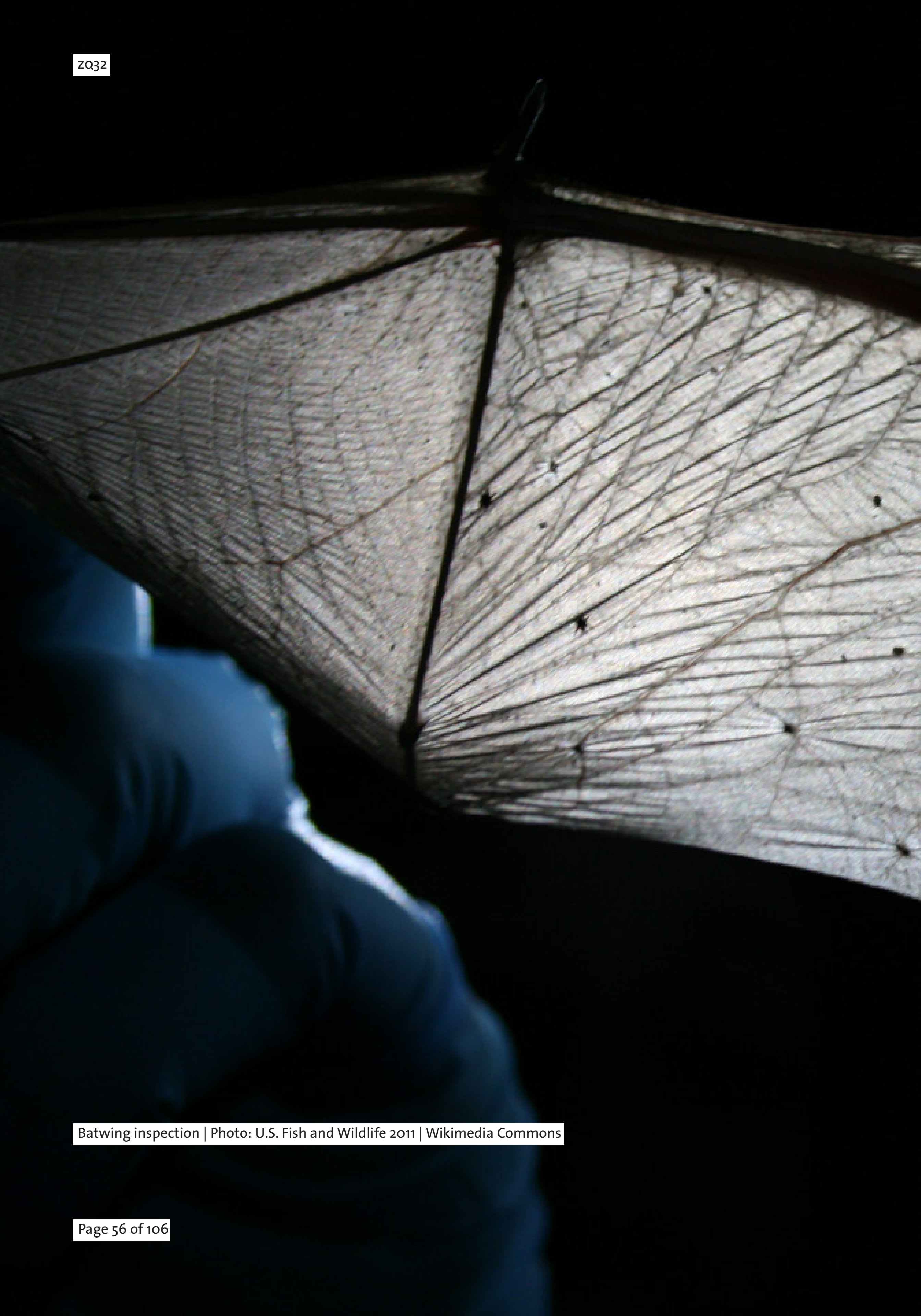
Swartz's studies demonstrate that bats execute a kind of nimbleness that would make Top Gun gulp with envy. Thanks to their wings, she points out, bats are one of nature's most ultramaneuverable flying animals. Even seasoned experts like her are stunned by their agility. Swartz recalls one video depicting a bat that had missed its target moth. Turning on a dime, the bat retraced its flight, zeroed in on the insect and then twisted in the air as it folded its wings to successfully scoop up the prey. Although Mexican free-tailed bats have been clocked at impressive speeds of nearly 100 miles per hour, Swartz points out that it's this control at slow speeds that distinguishes bats' flight prowess, from snatching prey in mid-air to hovering over a night-blooming flower while draining its nectar.

The list of superlatives doesn't end there. Not only are bats agile, but they are profoundly resilient. In a flight corridor in her lab at Brown University, Swartz has run experiments in which a wing of a flying bat is hit with a gust of air nearly three times the animal's body weight. The bats are completely knocked off balance, she says, but it only takes a single wingbeat cycle for them to get back on track. Researchers have documented a similar capacity for rebounding in nature. One of Swartz's former postdoctoral students, for example, recorded the exodus of Mexican free-tailed bats as they streamed out of a Texas cave on their nightly forage. "Tens of thousands of bats fly out every night over a relatively short period of time, and they're flying pretty fast, probably 20 miles per hour," Swartz observes. "We always wondered how they were able to fly so fast at such close

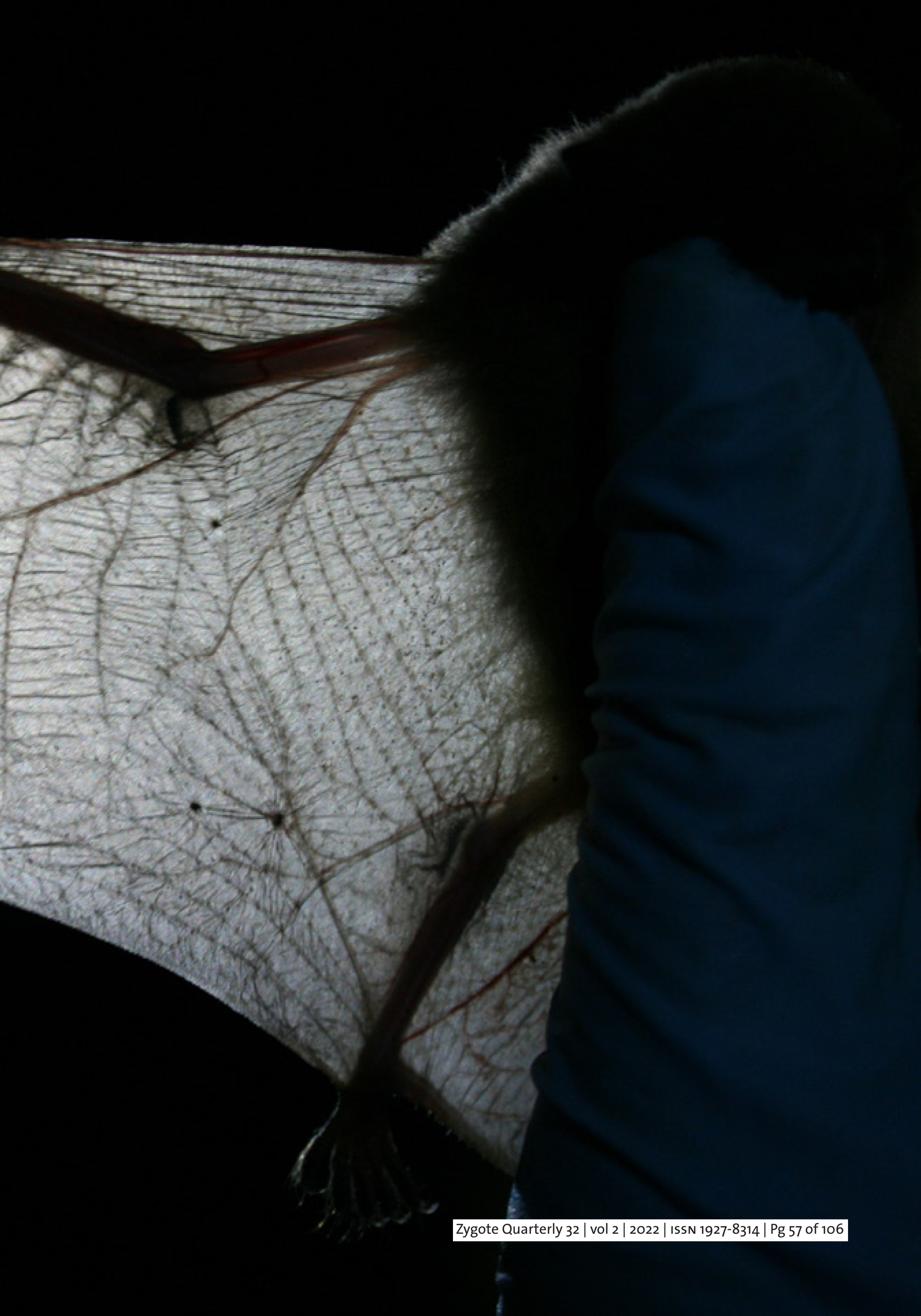




Left: Lesser mouse-tailed bat *(Rhinopoma hardwickii)* showing wing membrane muscles. | Right: Lesser bulldog bat (*Noctilio albiventris*) showing wing membrane muscles.
Photography: Photo: Jorn Cheney, Phil Lai, Rosalyn Price-Waldman, Sharon Swartz



Batwing inspection | Photo: U.S. Fish and Wildlife 2011 | Wikimedia Commons



proximity without crashing into each other. But after watching this video, we realized that they crashed into each other all the time, and it doesn't bother them. The question is how do they collide and just keep on going?"

This agility and resilience are due, in large part, to the physiology of the wing, starting with the composition of its skin which is soft and supple to the touch, like the skin that covers the inside of your wrist. The skin covering of a batwing also is stretchy like bread dough. These properties give the wing the ability to recoil in a collision.

Batwings, however, are composed of far more than just inert tissues stretched over a scaffolding of bones. Batwings are modified hands. Indeed, they share a remarkable number of characteristics with the human hand, having nearly the same number of joints and muscles. Bats utilize this complex system of bone and strings of muscle and tendons embedded in the elastic skin for high-level sensing and exquisite flight control that is unlike any other flying animal.

Skeleton of the Samoa flying fox (*Pteropus samoensis*)
Photo: Ryan Somma, 2012 | Wikimedia Commons

In fact, bat flight requires such complex coordination that, even after some four decades of intense study, Swartz still has many unanswered questions. Next on her lab's agenda is an investigation of the tiny hairs that are embedded in the wing's skin and muscles. "They're like miniature whiskers," she observes. "We don't know what they do. They could be sensing airflow or how much the wing is stretched by movements during flight. Presumably these hairs are collecting information from the wing as the animal is flying and sending that information to the brain so the brain can process it and send the information back to the muscles, allowing the bat to make adjustments."

Someday the answers to these and other questions could be used to design more resilient UAVs, Swartz says, or flying devices that help people with physical disabilities safely retrieve items in their home environments. "There are so many things about the natural world that we haven't observed yet," she adds. "The challenge for us as organismal biologists is deciding where to look because there's an infinite number of things that have not been studied." ×

We would appreciate your feedback on this article:

Greater short-nosed fruit bat *(Cynopterus sphinx)* showing wing membrane muscles.
Photography: Photo: Jorn Cheney, Phil Lai, Rosalyn Price-Waldman, Sharon Swartz

Physarum polycephalum
Photo: Seiya Ishibashi, 2006 | Flickr cc

Interview

Kreepingarten: the nature inspired classroom

Shoshanah Jacobs talks to Aaron Senitt

Kreepingarten: the nature inspired classroom

Shoshanah Jacobs talks to Aaron Senitt

Aaron Senitt is an educator and artist working with kindergarten students in Guelph, Ontario. He has taught for over twenty years in early elementary grades as a classroom teacher and art specialist. He approaches research as a bricoleur, combining narratives, drawings and artefacts. Aaron shares his work in journals, academic books, chapbooks, blog posts and newsletters. His muses include Friedrich Froebel, Kurt Schwitters, Donna Harraway and *Physarum Polycephalum* (the many-headed, plasmodial slime mould).

Aaron Senitt

Sho: Visiting Aaron Senitt's kindergarten class is like being delightfully out of control in a world meant for small people. There is a background buzz of giggles and excited bursts but it is not overwhelming, and there is constant movement. Twenty or so small people move about the room, entering and departing from different groups, engaging and then walking away, grabbing something and then disappearing behind a half-wall. And in all of this, Aaron has time to tell me about his idea.

That was over four years ago. And his idea, much like his biological muse, has grown, taken on different forms, and now is written up in a short and beautifully written booklet called: Kreepingarten: Proposal for cryptopedagogical knowledge transfer from/to/between *Physarum Polycephalum* and Kindergarten Children. *As both a biomimetics and education researcher, this could not have peaked my interest more. What can slime mould tell us about teaching or learning children? What can children teach us about slime mould? With an opportunity to interview Aaron Senitt after the release of his booklet, I learned that he has only just begun to explore this relationship. And, to my knowledge, Aaron's work is the first to explore a biomimetic approach to pedagogical theory.*

Kreepingarten

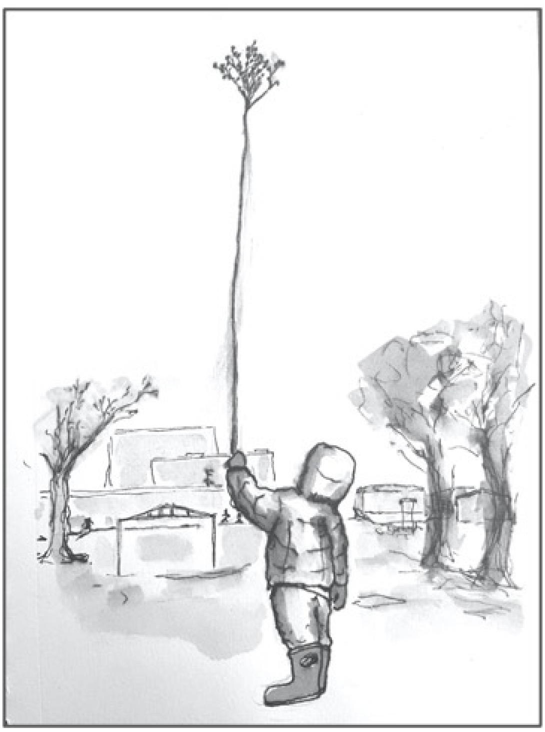
Proposal for cryptopedagogical knowledge transfer from/to/between
Physarum Polycephalum and Kindergarten Children

Aaron Senitt

Kreepingarten: the nature inspired classroom
Shoshanah Jacobs talks to Aaron Senitt

Sho: Aaron, thank you so much for sitting down with me to talk about children and slime. I never thought that slime might be a perfect biological model for teaching children. What can we learn from slime exactly?

Slime mould is like pedagogical play dough to me; it's an amorphous blob that is something we can work with in practical terms (experiments in the classroom), while at the same time use as a metaphor. For me, slime mould (aka *Physarum polycephalum*) has provided an entry level topic into biology;



Child Reaching
Illustration from Kreepingarten

it can be worked with using a minimum of equipment and laboratory knowledge. I have admittedly spent a whole lot more time thinking about slime mould than I have spent working with it, but bringing it into the classroom has been essential to keep the thinking grounded. Working with slime mould presents an important opportunity to become entangled with a non-human object of study. Like any amorphous blob though, slime mould is hard to pin down so as I got more and more excited about aspects of slime mould, and compiled notes about different ideas, I needed a way to focus it all. Curriculum is a useful organizational tool and I like toying with the language of education so I decided that I would invent different categories for this network of slime mould ideas. I appropriated the term 'gifts' from the inventor of "kindergarten", Friedrich Froebel, and called these concepts 'The 'Gifts of Slime Mould', aka GSM, (pedagogs seem to thrive on acronyms!). In doing so, I've indicated that slime mould has something to offer you...a transfer of knowledge. Each of these aspects of slime mould are characteristics that aptly describe human experience as well.

- GSM1 Emergence, a coming-into-being of things that are unexpected. Emergence may be the hardest of slime mould gifts to describe because it points to situations that exceed our expectations. No one would have expected that slime mould would be able to recreate or improve the entire Tokyo subway system routes (it has in repeated experiments!) The notion of a whole being greater than the sum of its parts (1+1=3) is on full display in slime mould behaviour. It is a single cell collective that functions as a problem solving, amoebic entity.

- GSM2 Embodiment, represents knowledge of the world that has been obtained exclusively or primarily through bodily interactions with the world. Slime mould has no nervous system or sensory organs so it only knows the world through any direct contact that its body has. Its body is its brain, and its brain is its body. But there is a forward edge of the slime mould that reaches for food called a pseudopod or a 'false foot'. The gesture of a child reaching is common...reaching for a toy, reaching for an answer.
- The third Gift of GSM3 Biomimicry itself, such a big topic, but essentially it is learning from, and with nature, which we are a part of. We can learn about ourselves by watching how slime mould tries to solve some of the same problems that we face. I had seen that numerous researchers were putting slime mould into experiments that required that it navigate a maze and decided to ask students to draw their way through large scale mazes. I was amused to see that most of them dutifully stayed within the lines, maybe following the trails that their friends had drawn before them, and made their way towards the exit...except a few children who simply drew their way straight through the walls (a behaviour observed in slime mould as well.) These parallels between children

Left: Child navigating a maze
Right: Child draws slime mould approaching oats.

Kreepingarten: the nature inspired classroom
Shoshanah Jacobs talks to Aaron Senitt

and slime mould have been deeply amusing to make but I'm convinced that there is more to learn from these comparisons of their capabilities.

- GSM4 Stigmergy (from Greek, a mark or sign of work or action) is like an external harddrive of memory. Humans leave traces and trails behind us with pens and pencils, and we can pretty much guess what slime mould leaves behind as it moves along at around 1 cm an hour. Among my jobs as a teacher, I am tasked with helping children learn to make meaningful marks for other people, be that printing words or drawing pictures. These marks take us back to what we were thinking and feeling at the time. Slime mould leaves a chemical trail of slime to remind itself and/or those that come after, that there is good stuff ahead, or that there is something to be avoided.
- Lastly, GSM5 Care is about reciprocal relationships required to take care of one another. I think the essential value of slime mould in the classroom is that it can be a kind of mirror, that reminds us that humans function as individual organisms and in organic groups, it reminds us of our scale...some things are much bigger and some things are much smaller, and all of them are interconnected, we leave meaningful traces behind us, sometimes purposefully and sometimes inadvertently. We learn from watching others, from watching the world, and our interest in how animals behave mirrors concerns we have in our own lives.

▫

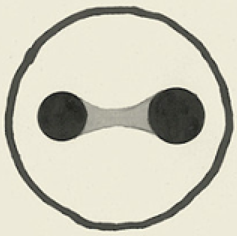
Sho - to the reader: The concepts of both teaching and learning are as old as Earth's biological history. Slime moulds, like other organisms, can communicate and behave. Though human systems of teaching and learning may be more complex, the foundations can be observed in other species. I am deeply appreciative of the learning journeys that those in search of nature-based solutions and inspiration are undertaking. I have built my research career around it to understand the way in which we approach and handle new information, and how we apply it to our own knowledge set. The opportunity to ask Aaron about his impressions of biomimetics more broadly, could not be overlooked.

▫

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

Biomimicry is a new area for me and I'm pleased to have discovered the broad community of researchers and artists focused on learning with and from nature.

GSM1, Emergence



Cells fuse into a single organism

Life on our planet is Emergence in its primacy; each living being is a dynamic force that is greater than the sum of its aggregate parts. Slime mould: a blobby amalgam of singular nuclei growing in the environment and reaching for food, an "it that becomes they." In his unconventional computing work, Andrew Adamatzky creates models showing that the interaction of a multitude of slime mould particles can result in emergent behaviours not found in individual particles. Thom Long (member of the Hampshire College "Plasmodium Consortium"), created a visual register of these behaviours (reproduced as drawings here), which include the ability of slime mould to: swarm and fuse, form networks, learn new behaviours, transfer learned behaviours to naive slime moulds (by fusing with them), explore environments, sense and search for nutrients at a distance or in

Search for nutrients in a labyrinthian space

Cells mutate and evolve rapidly

Determine previous activity by other plasmodia by detecting foreign chemical markers

GSM1, Emergence
Detail (page 19) from Kreepingarten

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I think that the work of the biomimicry community appears accessible and is exceptionally applicable and engaging. There are quite a few initiatives that come down to us at a school level and to me, it seems like biomimicry is the best answer to the need for elementary school environmental education; it should be a core element to any elementary “green initiatives”.

▫

Sho - to the reader: One of the branches of my research is to learn about who is sitting at the design table. Which disciplines or sets of expertise are represented? What is the level of formal and experiential training? When does the biology part come into play? Is biology knowledge best transferred through people? Or through paper? I had to ask:

▫

How did you get started? Who was with you on your journey?

My first glimpse of *Physarum polycephalum* (slime mould) was in an essay titled “The Internet of Snails” by Justin E.H. Smith in *Cabinet magazine*. It featured an image of how slime mould had been used to redraw the US interstate highway system. *Cabinet magazine* had rigorous and adventuresome writing and is represented by the notion of “the fox and the hedgehog”, using animal characteristics to describe different ways of approaching the world. Justin E.H. Smith is a great science writer by the way, he asks questions such as “are there more legs or eyes in the world” not just to look for answers, but to look at HOW we look for those answers (most people, myself included, tend to answer that question initially from an anthropocentric point of view).

Now I’m totally distracted! My mind is wondering whether the ‘eyes’ of an oyster count and if they do, do the ‘legs’ of their byssal threads count?

Smith’s article led me to Heather Barnett’s work. She has worked with slime mould a great deal, and is an interdisciplinary artist, scientist and researcher focussed on nature, and our relationship with it. In the TED Talk introducing her slime mould work, she emphasized how much “collective behaviour is a really big thing with this organism”; hearing that, it seemed to me that she could have been describing a group of kindergarten children. One of Barnett’s participatory experiments was Being Slime Mould in which she encouraged participants to ‘enact slime mold’, and put themselves into the place of a microorganism (in search of beer rather than the preferred food of slime mould which is oats.) I had the good fortune to attend a talk, and then a workshop that she gave in Toronto a few years ago. This gave me a chance to learn more about the ways that she asks people to consider what it might be like to be a slime mold. I was expecting the experience would be as I'd seen in previous documentation; that I'd be tethered to other participants, asked to communicate using only non-verbal cues, and navigate some kind of maze or route. But in the workshop I recall that she posed questions such as "What would slime mould be drawn toward in the neighbourhood?" and "What would it avoid?", "What would be hazards for slime mould?", and "Where would it be safe?" Participants were partnered up, given a small section of map for the area and sent out of the workshop space to explore the streets with a non-human POV in mind. Once we returned to the workshop space, we discussed how a square petri dish with agar could be overlaid on top of the map in order to construct a model of the area for slime mould to navigate. After the workshop, I did manage to demonstrate how a slime mould might cross Spadina Ave by building a small agar bridge to facilitate a successful crossing!

In regard to the booklet, I wanted to produce a document that piqued interest; as research, as a proposal, and also as an interesting object. I have a small but ever growing collection of booklets, pamphlets, artists' books etc that I treasure...I wanted to make something that would fit into that kind of collection. It is a text that has been set out into the world for an unknown future. Whenever I have produced a small book, I look at that hot-off-the-press stack and think of those multiple copies as a kind of currency. I think it's interesting that now, an idea that quite honestly began as a kind of purposefully absurd, 'writing as performance art' has become something that I can literally share around the world. The booklet also represents just a glimmer of what could be possible if there were, you know, networks of people devoting their lives to a pedagogical revolution based on the Gifts of slime mould! As it is, the kindergarten classroom, and my captive audience of minions supply all the amusement and subject matter I really need. The day to day

Why did the slime mould cross the road? To get to the oats on the other side! A *Physarum polycephalum* sample living in a petri dish that had been formed over top of a section of map from downtown Toronto; we made a bridge over Spadina Avenue in order to provide the *Physarum polycephalum* a route to cross over; oats were placed at the other side as incentive. This experiment was a success.

Kreepingarten: the nature inspired classroom
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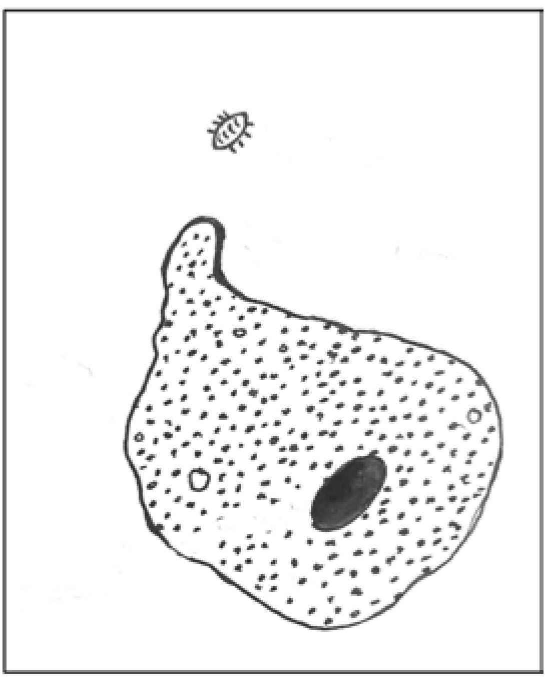
demands of teaching, and accountability keep my aspirations grounded, and act as a kind of filter for any of these flights of fancy.

What do you see as the biggest challenges?

Aaron: Well, due to human shenanigans, our umwelten[1] are clearly in deep trouble. As far as addressing the power structures that are contributing to the climate crisis, I'm not sure that in kindergarten we can really do that directly, or with immediacy. But connecting students to the natural world, by pretending that we are slime mold for instance, is a good antidote to a growing 'nature deficit'. Perhaps our biggest problem is that we've forgotten or resist admitting that we are animals.

With regards to this project, I chose to work beyond my usual interests, and was well aware that I may have been 'reaching beyond my grasp'. I studied design and furniture making, and then art and education, and have very little experience with science. I was so happy to learn about the forward edge of the pseudopodium or 'false foot' that slime mould sends out in search of food. For me this was such a perfect



1. umwelt: the environmental factors, collectively, that are capable of affecting the behaviour of an animal or individual

Left: Pseudopodium Reaching. Illustration from Kreepingarten
Right: "I am the oats".

metaphor for the booklet itself, which I've sent out in search of an audience in order to sustain further growth of the ideas. My hope is that my 'modest proposal' is convincing and viable, and that anyone who finds a copy of Kreepingarten in their hands is moved in some way.

By what criteria should we judge the work?

Putting aside the artistic merit of the Kreepingarten booklet as an artefact, this is a good question for me as an educator. We are required to evaluate and assess most things from an acquisition-of-skills point of view (life skills, language and math skills, problem solving skills...) Observing that students are engaged with the ideas and enacting these ideas also indicates that the work has agency for them. Are kids interested in slime mould? Do they regard slime mould as an entity worth emulating? Are they able to empathise with this single/multi celled life form? If students are enacting the slime mould, pretending to be slime, then, to me, it would mean that they have internalised it. As an aside, during one precious moment, I also saw a student 'flip' the narrative and declare 'I am the oats!' (slime mould food)". This moment was highly unexpected, but poignant, suggesting to me that we might not just be slime mould, that which is eating, but at some point, also the food which is eaten. To me, this high level of engaged involvement is what we are looking for, but it might be difficult to reduce to a rubric.

What are you working on right now?

Aaron: When I'm not trying to bring slime mould into the classroom for a regular visit, my focus is on language. Most recently I have been excited to see if there are ways to use the concept of linguistic reduplication in early language instruction (there are), but also I'm continuing to dig into the idea that forms of visible language (letters and structures of text) have links to the natural world. It's been exceptionally useful to discover the ABC Pattern system (na2ure.com) devised by Alex Wolf and Vijal Parikh; it's a nature-based set of elemental forms and patterns

Water bottles for use in sandbox. Visual reduplication of natural forms from the ABC Pattern Language.

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that I have embedded into art and language to help ease young children into the task of forming letters. These interests circle around each other and connect because the ABC Pattern system is a good example of reduplication of images, (which I learned about from Megan Luke's writing on the artist Kurt Schwitters.)

Friedrich Froebel is considered the founder of contemporary kindergarten learning. He based his approach to teaching on his belief that encouraging natural behaviours and play in young children would catalyse learning. But what about Schwitters? How do you connect the two?

Like Froebel, Schwitters had a philosophy that evolved from the work he did, and it was similarly based on the concepts of growth and relationship. Schwitters' philosophy of Merz was apparent in his various Merzbau installations; these were spaces which he altered in continually evolving ways. I'd say that there was a distinctly accretive and crystalline quality to the way that Schwitters' transformed those spaces. Merz was a broad brush philosophy and for Schwitters it was all about relationships. Schwitters was known primarily as a collage artist and as such he dealt with many parts that were brought together as a whole. Froebel used the model of crystalline structure as the basis for kindergarten, taking the notion of 'parts and the whole' from his study of crystals and applied that across his "kindergarten", from the way that blocks fit together to create larger forms to the way that individuals are socialised and fit into a community. It was a comforting revelation for me to discover that despite his inevitable influence, Froebel's writing was all over the place, and has been described by Helge Wasmuth as "unwieldy and unsystematic"...I can relate. Also, Schwitters was referred to by a family friend as a "miseducator"; I like that term as well. It's worth noting that neither Froebel or Schwitters lived to see their work achieve the level of wide acceptance and continual growth that it has now.

An original Kindergarten.
Illustration from Kreepingarten

Did you learn something from slime moulds that was not already well known?

I am taking my cues from researchers who have already broken ground with slime mould research, notably Andrew Adamatzky, Heather Barnett and John Bonner. There are only a few instances that I know where slime mould is presented to children; there is a primary school teacher named Peta McDonald in Australia who does hands-on work with microscopes and creates lovely drawings to identify various kinds of moulds. I also found an early reader book for children called *Stink and the Attack of the Slime Mould* by Megan McDonald. I inherited a couple of teachers' guides from the late 1960's that point the way to working with slime mould; one focuses on the microscopic world, the other on making "microgardens" of mould. A quick internet search shows that there are more and more references for children to slime mould ...as a topic it is 'on the move'. My contribution then is to suggest that slime mould could be the basis for a model that updates Froebel's work with crystals, and that it can not only be a subject for curriculum, but that the characteristics of slime mould can inform curriculum. In a way it's an audacious suggestion, and it's not a project that I can fully handle by myself. I can bring it back to the classroom. There's surely a broader application of these ideas in a way that I can't foresee.

As a teacher, not a 'real teacher' like you, but one of adults, I've experienced the pandemic in a different way. At the beginning, I was challenged to move my craft to a different level, to explore what teaching actually is in the context of changing platforms, from in-person to virtual. Despite everything going on around me, I was fully engaged with my job. It was a time of significant development. What was your experience?

The pandemic really stripped everything down in a way and it seemed for a while that anything would be possible, but what I was afraid of seems to be happening now which is a bit of doubling down, back

Still from *Wonder Wednesday-The Slime Mould edition* 2020 online learning video for Kindergarten recorded in kitchen.

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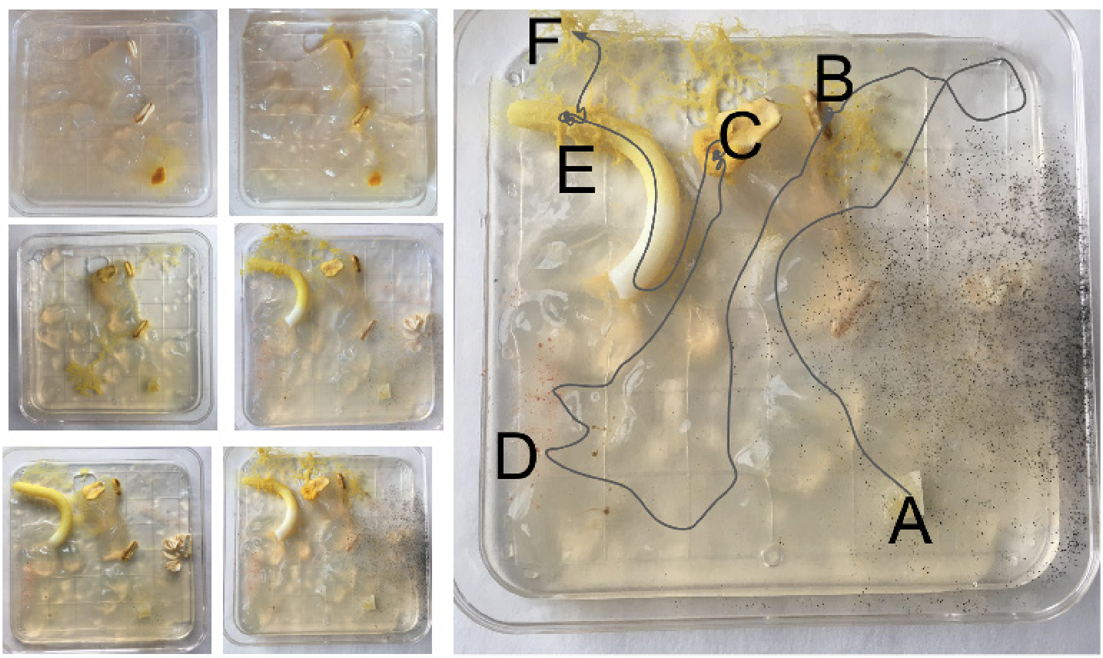
to basics and so the opportunity to look toward alternate forms of education didn't really happen. I feel like, within the world of elementary schools, there was a missed opportunity to emphasize at least outdoor education, from the basic point of view that it's healthier to be outside and have children experience education in a way that reaches outside the walls of the classroom, beyond the virtual 'flatland' that constitutes much of their day. A friend recently told me about Maryanne Wolfe's research that shows we use the same part of our brain to follow animal tracks as we do when we are reading fluently. That's the kind of profound connection that is best activated out of doors! On the flipside, the pandemic allowed me time to workshop some ideas; I created an "Intro to Slime Mould" video that showed me cooking up agar in the kitchen. I also used photos of the slime mould obstacle course that I created to encourage children to make their own obstacle courses at home. I have to say though that aside from a few examples that I saw of educators making the best of the online format (a local improv group, and teachers in Reggio Emilia Italy for instance), I couldn't help but think of



Slime mould obstacle course.

"online kindergarten" as the punchline to a very unfortunate joke.

As a kindergarten teacher, I imagine that there isn't much time in the day for anything else but what's next on your to-do list?

I like making little books... small artist books like Kreepingarten. There are more little books that could come out of this. I'd like to take a text about slime mold, natural history, stories, and replace the words 'slime mould aka *Physarum polycephalum*' with 'kindergarten child' to see what we get. So, for example, kindergarten children tend to behave in what is called a 'ballistic manner'; once they have sensed a stimulus they will try to flow toward it taking the most direct route possible. Except when they don't. You see? It fits!

I am always interested in finding collaborators in general and will continue working with ideas related to language. A madcap musician friend Richard Marsella has shown interest in working together to work with kids making machines for creating and

"Six heads are better than one because you have more eyes and you can see more places"

from daily newsletter, May 3, 2022. Kindergarten Conundrums transcribing sound; I'll want to make a book to accompany that as well.

What is the last book you enjoyed?

Sound Writing by Tobias Wilke. It's about early twentieth century scientific theories and devices to transcribe spoken language and how these were co-opted by modernist artists...it's about the embodied physicality of language. I'm impressed that there are charts and visuals (for the lip positions of various sounds) that are pretty much in line with what I am directed to put up on my classroom wall today!

Who do you admire? Why...

The German artist Kurt Schwitters (1887-1948) has been a constant muse for me; the life he lived was adventurous and playful, and he continued working until the end of his life. He endured personal loss, war and displacement, yet he kept on with his work. I think one of my favourite (undocumented) works of his were the sculptures he reportedly made from leftover oatmeal when he was interned as an "alien" on the Isle of Mann. He worked with whatever was on hand, and was least concerned about the response he received (in this case the oatmeal turned moldy, and various colours before dripping through the floorboards!) Schwitters is a keen example of someone who was involved in worldmaking, and I'm pleased to be a contributing member to the society of artists and historians that bears his name (The Kurt Schwitters Society).

What's your favorite motto or quotation?

"For heavens sake don't be afraid of talking nonsense! But you should pay attention to your nonsense."-Ludwig Wittgenstein.

I have had this quote posted in each classroom that I've worked in, since I began. It reminds me to prioritize "messing around" in a serious way.

What is your idea of perfect happiness?

...so elusive, but I'd have to say it would be: seeing things fall into place. Finding ways to connect ideas, helping kids become interested in something, putting ingredients together for a meal, bringing a project to some degree of completion... knowing that I've been able to be a part of making something happen. ×

We would appreciate your feedback on this article:

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Sho - to the reader: If there isn't a saying about kindergarten teachers it should be this: 'when you find yourself in the pit of despair, look around for a kindergarten teacher to help you out'. Speaking with Aaron has not only excited the part of my brain that focuses my attention on biomimetics research, it has made me feel as though the things that we can learn from and about nature are truly infinite. Practitioners of biomimetics tend to walk between the silos of biology and engineering, even now still. And yet, we have all tried to understand how we might be able to wander into other disciplines and pull from nature. Aaron's case, both curriculum and pedagogy that is informed by nature-based solutions, is fascinating and I am grateful for having been able to learn more about it.

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Dr. Shoshanah Jacobs takes a systems approach to answering questions that are relevant within the communities that they work. Their research expertise includes biomimetics and higher education and they apply this training to help communities develop nature-inspired solutions to challenges. They have worked with the community of Guelph in identifying ways to accessibly reduce the use of single-use plastics and have tracked the way that personal-protective equipment (PPE) moves through and away from the waste stream to affect wildlife around the world. Dr. Jacobs started the BioM Knowledge Access Lab research group in 2012 to make science knowledge more accessible to community members and to engage the community in designing more inclusive ways of collecting information. They are an Associate Professor in the Department of Integrative Biology.

Shoshanah Jacobs

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Photo: Lone Jensen, 2014 | pexels cc

Article

But Where is Everybody?

Jacquelyn Nagel and Noah Pentelovitch

But Where is Everybody?

Jacquelyn Nagel and Noah Pentelovitch

There is no shortage of praise for bio-inspired design or its potential. Indeed, it sometimes seems we are surrounded by the promise of bio-inspired design (BID) for solving thorny and pressing problems. The potential, especially to those who steep themselves in this world, is undeniable; its benefits demonstrated to great effect and acclaim in high profile examples: hydrophobic coatings inspired by lotus leaves, dry adhesives inspired by gecko feet, bullet train noses inspired by kingfishers, wind turbine blades inspired by humpback whales. Indeed, it sometimes seems a foregone conclusion that all problems will be solved by looking to nature for solutions. Yet, in the apocryphal words of Enrico Fermi, where is everybody?

Noah Pentelovitch has worked in product design and engineering for over 12 years and, over that time, has become increasingly interested in the potential of bio-inspired design. He began looking for tools and methods that could be used in the day-to-day design and engineering that he was doing at OXO but couldn't find anything that seemed practical or effective. In the winter of 2018 Pentelovitch came across a paper by Jacquelyn Nagel on analogy categories [1]. At the end of the paper Nagel called for future studies to be done with engineering professionals. Beyond the utility of its content, the paper was exciting for the explicit interest the authors expressed in a collaboration between academia and industry. Pentelovitch had grown frustrated by the lack of methods or tools that really considered the perspectives of industry professionals and the limitations within which they work. He reached out to Nagel. She was thrilled to be contacted by an industry professional who was eager to learn more about the process of bio-inspired design and her work. They began discussing how she could teach engineers and designers at OXO about the bio-inspired design process and some of the tools. As discussions progressed, Nagel proposed that the training be turned into a study so that the insights from industry professionals could be analyzed and shared more widely with the community studying bio-inspired design tools and methods.

The academic literature overflows with approaches for practicing bio-inspired design as well as engineering achievements that demonstrate the potential of bio-inspired solutions. Most tools developed in an academic setting for practicing bio-inspired design are tested with college students rather than practitioners. There are trade-offs with this approach. Ease of access to students trades off industry experience and knowledge. Large sample

Macro of fern unrolling young frond | Photo: Skyler Ewing, 2017 | pexels cc sizes of student populations result in descriptive statistics rather than deep qualitative understanding. Our paper [2], "Understanding the Use of Bio-inspired Design Tools by Industry Professionals," published in the journal *Biomimetics* earlier this year, explored some of these questions. Specifically, we wanted to know the value of bio-inspired design tools in an industry context. To understand this, we invited engineering and design professionals from OXO and Hydro Flask to participate in bio-inspired design training with four selected tools. The selected tools were the engineering-to-biology thesaurus [3,4], biosearch [5], visual analogy sketching [6], and BID canvas [7,8]. During the training, qualitative and quantitative data were collected at four points: (1) pre-survey, (2) after learning the bio-inspired design process, (3) after using each of the four bio-inspired design tools, and (4) a post-training discussion of the experience.

It seems logical to assume that a demonstrably better tool or process should justify adoption on its own; however, the reality is that over time companies reinforce existing processes by hiring people whose skills fit into the business needs and culture. New tools, and especially new processes, require a company to disrupt what they have built themselves up around. A new process can disrupt individual and team workflows, something few companies are willing to allow as they are incentivized to stay on schedule and within cost, no matter how valuable the change could be. Barriers to implementing BID in product development and BID product commercialization have been researched, but do not examine the influence of individual tools in industry applications.

By focusing on the tools rather than the outcome from using the tools, we identified a range of interesting insights:

- Teaching a suite of tools has higher value to industry professionals than teaching a single tool. The industry professionals found value in all four tools.
- The industry professionals used the tools in expected but also unexpected ways. They expressed a desire to combine them in various ways for different parts of the BID process.
- The process framework (BID Canvas) was highly valued as it allowed for flexibility in tool use as well as workflow. The tools for facilitating bio-inspired design that focus on usability and integration with tools and processes already in use rather than optimizing for a specific output (such as novelty or sustainability) have a higher likelihood of adoption.

- When introducing a new tool to a group of engineers, designers, or other professionals, it is essential to explore how it might fit into their existing process. The participants in this study frequently referred to their own process and how the tools that they learned fit into it. Therefore, the most preferred tools were also the easiest to comprehend and integrate into existing workflows.

Our hope is that, in the future, this collaboration between industry and academia will not be the product of serendipity. Bio-inspired design is a powerful approach that has enormous potential for solving hard problems, but if it isn't used then the potential is not realized. Engaging more industry professionals and focusing on how usable a tool is and whether and how it can be adopted will result in better tools that are more likely to be used. ×

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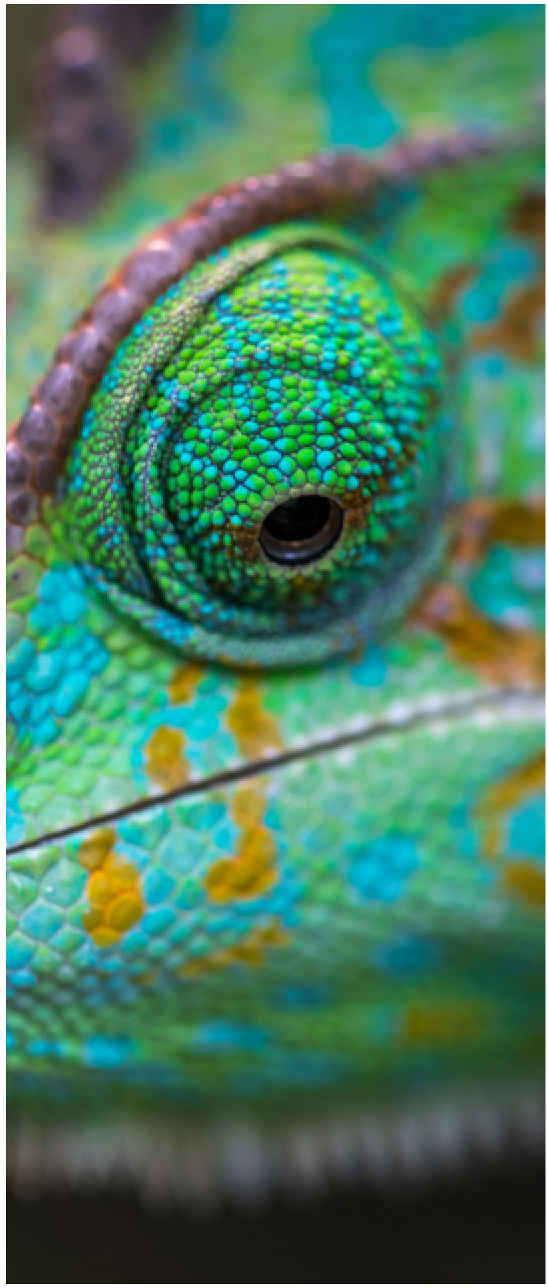

Selective Focus Photography of Chameleon
Photo: Egor Kamelev, 2017 | pexels cc

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

Dr. Jacquelyn K. Nagel is an engineer, academic, and consultant. At James Madison University she is Assistant Department Head and Associate Professor in the Department of Engineering. Dr. Nagel has multiple years of engineering design experience in both industry and academia. She has worked for Mission Control Technologies, Intel Corp., Motoman Inc., and Kimberly-Clark Corp. Dr. Nagel is internationally known for her research in bio-inspired design process and pedagogy, and has given invited talks to SWE, INCOSE, NASA, and at universities in Canada, France, and USA. https://jacquelynnagel.com/about-me/

Jumping Spider
Photo: Tibor Nagy, 2014 | Flickr cc

Article

Where The Wild Things Are

Adelheid Fischer

Where The Wild Things Are

Adelheid Fischer

At a recent staff meeting, my colleague Victor Surovec described a memorable morning working at home during the COVID lockdown. He was on the phone in his backyard in north Phoenix. On hold for the umpteenth time, his frustration was building along with the Arizona heat. He was close to losing it. Nearby, a large wasp repeatedly buzzed the side of his house. With phone in hand, he walked over to investigate. The wasp was on a mission and took no notice of him. It would fly off and then return to the same spot, over and over again. Turns out, it was putting the finishing touches on a new nest. But not just any nest. Glued to the stucco wall was a structure that resembled a miniature clay pot, perfectly formed with a wide belly with a delicately turned neck. Victor had never seen anything like it so he decided to pull up a chair and watch what happened next. It was then that the wasp returned from one of its forays, not with more of the dull-brown soil it had been gathering as a building material, but with an emerald-green caterpillar, which it gingerly inserted into the lip of the pot as food for the developing young inside. Surprised and transported by the strange beauty of the scene, his irritation melted away.

Time stopped. "It was a perfect moment," he recalls. "The light was just beautiful. The wasp had an orange tint to it. And there was this bright green caterpillar."

I heard similar stories of wonder and appreciation from other friends who found themselves sequestered at home during the pandemic. There was my friend Loren in Bend, Oregon, who on a typical morning would have rushed out the door to a yoga class in town. During lockdown, however, she switched to yoga instruction via Zoom on the TV in her living room. It was early spring, and the maple tree outside her window was bare. Though she had hardly noticed the tree before, Loren began watching it as she went through her daily yoga routine. "The tree went from having a little bit of green in the buds to having leaves and then more leaves and then different kinds of green," she recalls. "I noticed the way the leaves were hanging, the way the light hit them, and then seedpods began to grow. It brought me some happiness to see those changes. Each day there was an element of surprise even though I knew where it was going. I found myself asking, What's my surprise going to be today? What's going to be new?"

Debra, a university librarian, told me a similar story of a new and unexpected engagement with nature. No sooner did she set up her home office when a jumping spider began to regularly visit her desk. "It

Potter wasp nest
Photo: Victor Surovec

Where The Wild Things Are

Adelheid Fischer

Potter wasp and caterpillar
Photo: Victor Surovec

seemed to come out every time I had a conference call," she says, laughing. "I like to think that it was attracted to the sound of my voice."

Slowing down and staying put during the pandemic have created new opportunities for people to encounter nature on their home ground or for getting reacquainted with the plants and animals that have grown invisible through familiarity. I heard so many people waxing enthusiastically about the natural history of their home turf that I began to wonder: Are these post-COVID experiences episodic and fleeting — the equivalent of Snapchats with nature — or could they signal a bigger, more foundational shift in our relationship with the nonhuman world?

For many of us, nature has come to be regarded as a temporary destination — think Costa Rica, Yellowstone, Kruger National Park or the Great Barrier Reef — rather than the everyday world in which we are immersed. By scribing a tight circle around our home ground, however, the pandemic lockdown seems to have inadvertently enlarged the boundaries of possibilities for encountering nature to include our own zipcodes.

And that is a good thing. For too long, says environmental writer Emma Marris, we have privileged so-called pristine places — those that she says appear to lack the obvious fingerprints of humans on them — over the nature that is near at hand. This has created an aura of elitism around nature since many ecological destinations around the world are far removed from where people live and largely only accessible to those with the time and money to visit them.

There are other downsides too. Traveling long distances for nature experiences increases our carbon footprint at a time when many parts of the world are sagging under the weight of climate change and the toll of human visitation.

But there is something even more troubling about our oversight, even disdain, for the everyday world around us. By glorifying the exotic locales we see on nature programs, we train our kids and ourselves not to see a lot of nature, Marris points out, and as a result, we "talk them out of enjoying a lot of the nature that's available to them on a daily basis."

A nature outing for Marris and her two kids typically includes a visit to vacant city lots, grassy strips along commercial buildings or a roadside verge, many of which can host an astounding diversity of plants and animals. "I think that nature is anywhere where life thrives, anywhere where there are multiple species together, anywhere that's green and blue and thriving and filled with life and growing," she observes in a 2016 interview on the "TED Radio Hour." Marris points to an abandoned elevated railway in the middle of Philadelphia, for example, that hosts more than 50 different plant species. Scientists have a term for these places. They're called "novel ecosystems" since they host combinations of native and exotic species never before seen in nature. Overlooked for decades, these organisms have formed improvisational communities beyond the reach of an intentional human hand. Together, they perform valuable ecosystem services such as storing carbon, building soil or stemming storm runoff.

Increasingly, the human-mediated nature in our midst isn't just capturing the imagination of people like Marris and her kids. It's become the focus of serious biological study. And researchers are publishing some astounding findings. In his book *Darwin Comes to Town*, Dutch biologist Menno Schilthuizen, for example, profiles the carrion crows of Sendai, Japan, that have learned to exploit the abundant nuts from the city's walnut trees by dropping them in front of moving vehicles. Turns out that tires double as reliable nutcrackers for the tough shells that the crows can't penetrate on their own.

And to see something as exotic as evolution at work, Schilthuizen maintains that you don't need to go visit the storied Darwin finches of the Galapagos Islands. All you need to do is check out the mosquitoes that have taken up residence in London's Central, Bakerloo and Victoria tube lines. These mosquitoes have so adapted to their subterranean digs that their life histories are now unrecognizable from those of their above-ground cousins. The subway mosquitoes, for example, feed on human blood unlike those at street level that pursue birds, and they don't form breeding swarms. And because the climate is tempered, the tube mosquitoes have dispensed with the need to hibernate and are active all year round. Perhaps the most astonishing is this: Isolated from each other in the three trunk lines of London's tube system, the below- ground mosquito populations have speciated. They are genetically distinct from one another. "We all know about evolution perfecting the plumage of birds of paradise in faraway jungles or the shape of orchid flowers on lofty mountaintops," writes Schilthuizen. "But apparently, the process is so mundane that it is not above plying its trade below our feet, among the grimy power cables of the city's metro system."

Now that so many of us have slowed down to the speed of life, could the witnessing of what Schilthuizen calls the "relentless adaptability of the living world" in our urban areas serve as inspiration as we too are called upon to be relentlessly adaptable in our post — pandemic lives? Could slowing down to the speed of life inspire new and better ways for humans to invent novel communities of habitation that are more lifesome? Recall the potter wasp that so entranced Victor Surovec. The grains of soil in its earthen nests are glued together by the animal's saliva. Could a green chemist find a recipe for a less toxic adhesive from a chance encounter with an animal in her own back yard?

Could an engineer study the ocular apparatus of a jumping spider that visits his desk and invent new sensing devices that monitor and heal our broken lands?

Or, could we experience in our near-at-hand nature something just as vital for healing our own breaking hearts: the easing of the painful loneliness of the pandemic's social isolation? There is a huge comfort that comes from observing without thinking, says the nature writer Elisabeth Tova Bailey, and simply feeling "connected to another creature; another life [that is] being lived just a few inches away." ×

This essay was first published on Medium Jul 6, 2020.

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Jumping spider
Photo: Debra Riley-Huff

Objects of attention 1
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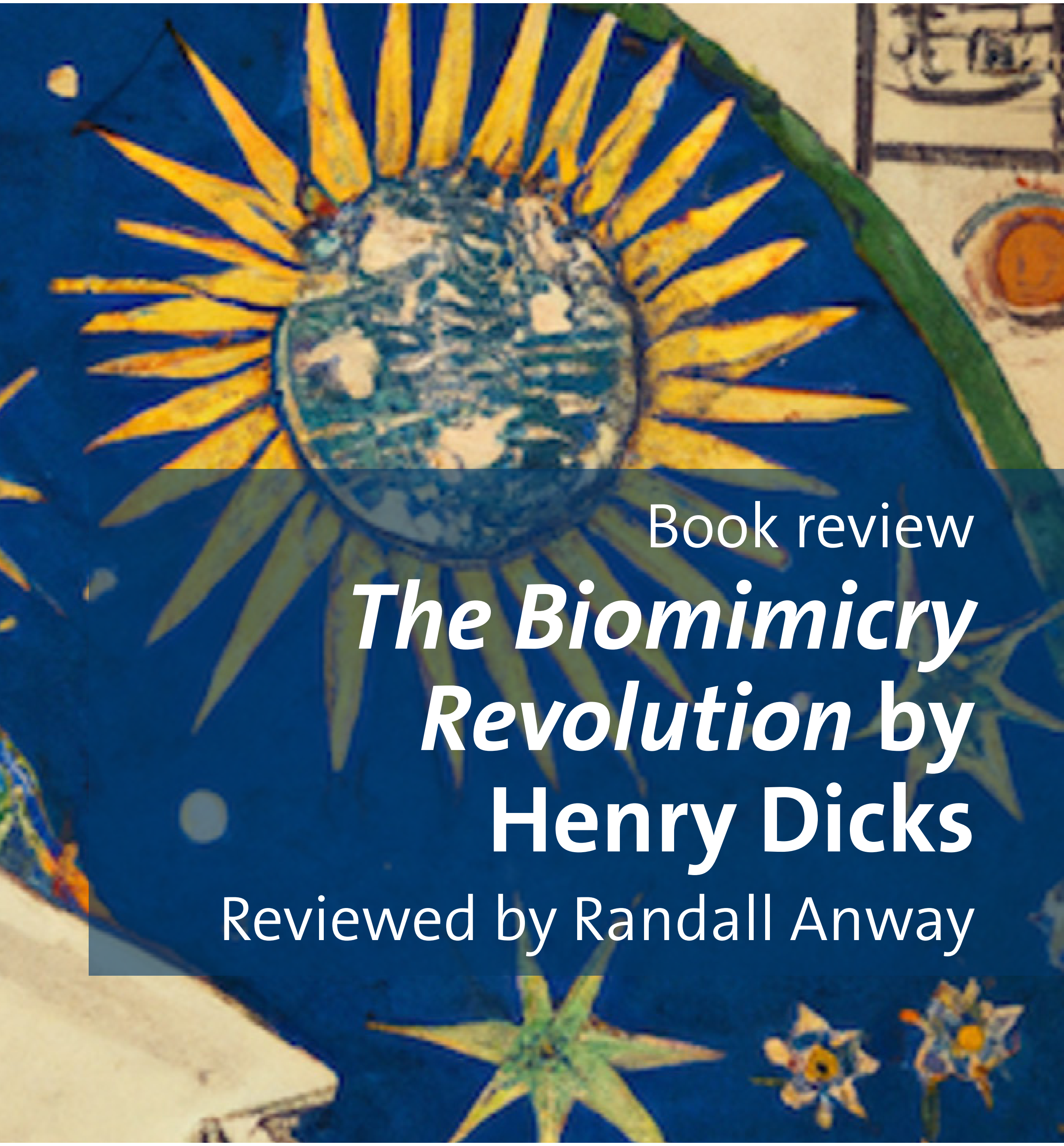

Book review

The Biomimicry Revolution by Henry Dicks

Reviewed by Randall Anway

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Getting Philosophical

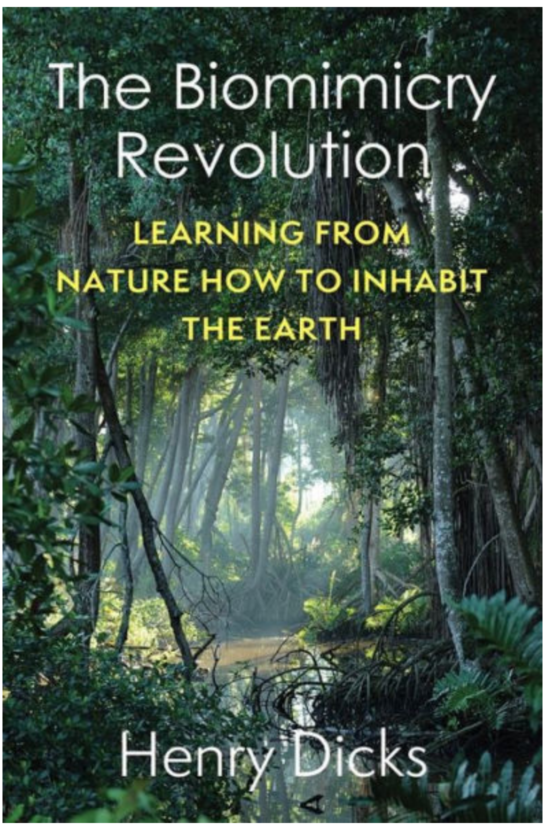
Writing a philosophy book is a risky proposition. The audience tends to be limited to serious academics, as it can be difficult to understand, dense, finely nuanced, and intellectually taxing. The motivation for reading, apart from meeting some academic requirement, might be similar to intense exercise: strengthening neural pathways to become a stronger, more capable, and more resilient thinker. Reading can be hard work, and a degree of preparation may be needed to attain a benefit.

Philosophy books can help to clarify complex ideas, provide historical context for current debates, and offer new ways of thinking about long-standing problems. In addition, philosophy books can be a valuable resource for students and scholars who are interested in exploring a particular philosopher's work in depth. Further, there are many potential benefits to or outcomes from writing a book on philosophy. Generally, it could help to spread philosophical ideas and promote critical thinking in society. It could serve as a resource for people who are interested in philosophy but don't know where to start, thereby aiding recruitment for a new way of thinking.

Henry Dicks

Henry Dicks finds this a calling in the context of the ecological crisis. His DPhil is from the University of Oxford, with a postdoctoral work at the Institute of Philosophical Research at the University of Lyon. He is currently at University Jean Moulin Lyon 3 and Shanghai University teaching environmental philosophy and is a visiting fellow at the University of Leeds Centre for History and Philosophy of Science (HPS).

His new book is *The Biomimicry Revolution: Learning from Nature How to Inhabit the Earth*. He envisions a new philosophy in terms of the key theme of nature as Model, Measure, and Mentor that was woven through Janine Benyus' 1997 book *Biomimicry*. Although related, biomimetics, bio-inspiration, and bionics are considered as 'just' design strategies. Over the past decade or so, only a handful of authors have addressed the biomimicry movement in philosophical terms, let alone in relation to philosophies of science, systems, technology, or design. But given the scope and structure of philosophy as represented in a massive body of historical work, even a few good references could lead to an expansive field of academic study and practice. This one is squarely focused on biomimicry and its potential role in transforming technology



with the aid of science, and articulates some interesting, if not previously overlooked, directions for both philosophy and biomimicry.

On the surface

There seem to be two poles of thinking on the present ecological crisis. Some regard it as more than just inconvenient: it's horrifying, it's a nightmare. It's happening right now. It's going to get worse and worse and worse, and there's nothing we can do to stop it. We're in the middle of a mass extinction event that's going to kill us all. It's too late to recover though maybe a few survivors in the not too distant future can look back at this time and scoff at how deluded we all were. The nihilism of this view can be deflating and self-fulfilling.

Looking at it another way, as horrible as it is, the crisis isn't nearly as bad as we may think. It's an opportunity to build a better world. We're not going to all die. We're going to adapt. We're going to change the way we live, and we're going to thrive. This crisis moment is just that, a brief moment, and it's a chance to evolve ourselves into a new world, a better world. We can do this. But now is the time to act and get a lot more granular:

1. We need to stop burning fossil fuels.

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2. We need to stop destroying forests.

3. We need to stop polluting the oceans.

4. We need to stop over-consuming.

These are both views of the 'same' reality. Dicks sees these as just surface issues. What's hard to get our minds wrapped around is our minds, what is regarded as knowledge. The underpinning beliefs that got us here. Pervasive ideas like "nature", "technology", and "measurement" are so taken for granted they aren't even questioned.

The gist of Dicks thesis is that we need to start questioning them. We need to start thinking about the world differently. We need to start dreaming about a different future. He sees how this 'crisis' is brought on by our own thinking. Dicks suggests that reorienting philosophy, science, and technology in relation to nature could provide a big nudge in a healthy direction. If the biomimicry revolution heralds a technological shift, it's better accompanied by a revolutionary realignment in the relationship between philosophy, science, and the conception of nature.

As normal activities in the conduct of science and technology, Modeling, Measuring, and Mentoring provide context for Dicks' questioning and a deeper look at a hidden narrative in the foundations of science. It's unambiguously about evolving philosophy, and particularly looking again at underpinnings of the present ecological crisis and for navigating towards a better future. In that sense it's about a philosophical crisis - on a gut level, the confusion or dislocation some may feel when trying to make sense of the climate situation. In my work with professional colleagues there's a phenomenon I call the 'black bag': when a colleague’s eyes glaze over and the conversation derails. The train of thought goes over the shoulder into an invisible nowhere land; over the bridge that never got built.

If passion and commitment aren't enough to get to well-intentioned ends, patterns of thinking may have gotten too deeply rutted to readily accommodate a very different way of thinking. Dicks doesn't have the answer to this, but part of an answer may be found through his reconfiguration of the Western view of nature. Dicks brings biomimicry into new perspective by illuminating it as a coherent philosophical paradigm that he hopes can reinvigorate western environmental philosophy. It can take patient reading and curiosity to see the coherent structure in the bits he methodically uncovers and reveals.

Getting there

For someone who cares about a planet that continues to be habitable, there is no such thing as 'winning' arguments - only finding shared truths, and doing what can be done to act on them. This philosophical position could be called 'epistemic humility'. The word 'epistemic' comes from the Greek: 'epi' - near, and 'histasthai' - to stand. To stand near each other, to bear each other's stances in humility is something we should all strive for if we want to make any progress on the climate crisis. For those of us schooled in the west (with a biomimicry layer or not), or those just wanting to better understand western environmental weirdness, working through Dicks' book could provide lessons.

Bringing biomimicry into broader acceptance and practice will take time and entails evolving mindsets. If we are to approach what we know and how we know it with humility, then we also need to be honest about our own limitations. We need to admit that we might be wrong, and that we might not have all the answers. We need to be willing to change our minds in the face of new information. And we need to be open to the idea that, even when we think we're right, we could also have the context wrong.

For many people schooled in western thought this can be challenging because it can go against the propensity to think of ourselves as rational individuals who are in control of our own destiny and know enough to do so. In broad swaths of the west there is a lingering bias toward thinking of knowledge as certain and objective truths 'out there', waiting to be discovered, waiting to be used. In contrast, Dicks presents biomimetic knowledge as something that occurs in our openness to others, particularly things and beings in nature itself. In an honest search for truth, epistemic humility is a strength. I think it's possible to read this kind of humility in the way Dicks uses language to explore every avenue, but it can be as frustrating as it is instructive to parse out salient points.

But that shouldn't be a barrier for detail-oriented readers. There's a feast of intellectual nutrition and exercise here. To provide a flavor of the substance, Dicks endeavors to extend Janine Benyus' approach to biomimicry into a 'new philosophy' that is “only environmental in nature” but nonetheless could be key to helping bring about a 'new enlightenment' in which western thinking deeply comprehends that:

- dwelling within the constraints of earth's web of life ('Gaia') is the context for human freedom

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Objects of attention 2
AI generated image: Randall Anway/Dall-E2, 2022

- imitating nature more imaginatively expands human creativity and technological innovation
- learning what is right entails providing for and maintaining the self-evident good of another
- emulating accumulated knowledge in nature itself is best pursued thoughtfully and humbly

Summary

With ambition and maybe a little license, the text veers away from biomimetics and bio-inspiration towards something of a distinctive work of environmental philosophy. Some proposals could chafe. Among students of biophilia for instance, the idea of prioritizing technics over aesthetics in favor of practicality and function could at first seem nonsensical. It's important to understand that 'technics' is rehabilitated as the imitation of nature. Dicks' enterprise of shaping "a new structure for philosophy" makes use of the main propositions of biomimicry to make bold and potentially controversial suggestions about its philosophical foundations. He also seeks to set out a useful philosophical theory to help guide science.

In the midst of this, he discusses at length how various branches of philosophy can help biomimicry develop and provide firmer intellectual foundations for broader and deeper practice, building a case for a broader response to the crisis. More practically, he also suggests how to productively operationalize biomimetic research through a specialized form of science. There are several aspects of this, including:

- a typology of natural models - what can be imitated, and how;
- the way of being of Gaia as the ultimate standard or measure for a science of nature imitation;
- what distinguishes biomimetic knowledge - how it is ethically drawn from nature itself;
- models as the eco-technical thing to be imitated rather than the template for technology.

These are subtle and important distinctions touching on an expanded scope for biomimicry practice, and the philosophical core is likely a far reach for many biomimicry practitioners.

Don't read it to learn about the basics of biomimicry. It's neither basic nor electrifying in the way encountering and translating biology can be. Though it's structured in terms of an extended reflection on Benyus' 'Model-Measure-Mentor' meme, it goes far beyond that into the philosophical substrate. More importantly, it's a serious

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treatment of the underpinnings of multiple, deepening, systemic environmental crises. I believe that this is what Dicks considers the most compelling motivation for reinventing philosophical thinking.

Do read it to better understand:

a) How Dicks positions biomimicry within western philosophical traditions - however radically - and brings outmoded philosophical positions into serious question. There may be some controversy around how successfully Dicks has done this.

b) The cognitive dissonance in the encounter between the prevailing western cultural narrative and biomimicry, how the current map misread the territory, and what could be done about it.

c) Some practical approaches to broadening the scope of biomimicry by bringing environmental philosophy and biomimicry closer together: strategies for more or less immediate consideration, and others that will take more time but could lead to more niches of practice.

A book of this nature raises more questions than answers. It's intentionally open-ended and aims to generate further dialog. It's a winding path through a pastiche of thought replete with post-post-modern theories and imaginative, if not bracing, reasoning. It's heady and abstract. For readers who can get past those hurdles it could provide an expansive frame for environmental philosophy. That's not a bad start. There's room for new thinking about not just the ecological situation, but also philosophies of science, systems, technology, and design, and the nature of more-than-human relations. All that could open the door to the biomimicry meme finding new friends and influencing more people. If that happens, maybe there's hope for a 'new enlightenment'.

Overall, I found it valuable for some deep context and broad yet clarifying insights, but it’s a nuanced read. That said, my main concern is that it's both steep and narrow. For instance, as a starting point for 'revolution' he primarily expands on a subtext of Janine Benyus' important book with a dash of Gaia theory that's key to his arguments. However, he fails to even mention Lynn Margulis. Considering how her scientific work reset evolutionary microbiology and influenced James Lovelock, similar to how Dicks is trying to reset environmental philosophy and influence his field, it seems a curious oversight.

Revolutionary? Not in the way some might think. The term "revolutionary" typically connotes a dramatic and sudden change in the existing order of things.

While some may apply this term to Benyus' insights, Dicks proposals are more apt to slowly build on the accumulations of philosophical thought. What's revolutionary could be not how fast, but how far they go.

Noticing that ancient philosophers had geo-technocentric propensities is interesting and impressive scholarship but bringing that into the present seems a heavier lift: this is not a return to Ptolemy's geocentric universe, but it strikes me as a Copernican-grade shift. Even if the book only makes it into graduate level seminars, I'd expect it's eminently worthwhile for its take on environmental philosophy. If you can stick with it, dig in, and have fun. A wide-eyed, optimistic reading could bring new dimension and meaning to either or both biomimicry and philosophy careers. If the latter is true, biomimicry's best years may lie ahead. ×

Dicks, H. (2023). *The Biomimicry Revolution: Learning from Nature How to Inhabit the Earth* (320 Pages). Columbia University Press. http://cup.columbia.edu/book/the-biomimicry-revolution/9780231208819 (publication date: March 2023)

We would appreciate your feedback on this article:

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