Cat tongues defy gravity

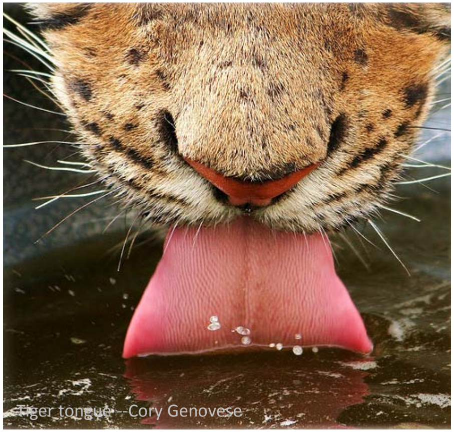
idea stage r m

Bio-mechanical bio-inspiration

Cat tongues defy gravity. The speed and force used by cats to lap up water causes the water to follow the cat's tongue upward into its mouth. By barely tapping the surface of lake or stream, the cat tongue applies pressure and then quickly retreats without breaking the water's surface. A tiny column of water forms, thins out, and splits into upper and lower portions. The top portion of the water column defies gravity and lands into the cat's mouth giving the cat a refreshing sip of water. Researchers could study cats to figure out how to propel liquids upwards could be use their findings to clean up oil spills.

Behavioral bio-inspiration

Cats exploit inertia to counteract gravity using Froude Processes to drink water. Froude forces are hydrodynamic forces caused from the pressure of the cat's tongue on water surfaces. The cat tongue tip touches the water surface without piercing it and rapidly retreats. This causes a miniature column of water to form, which cats catch in their mouths.

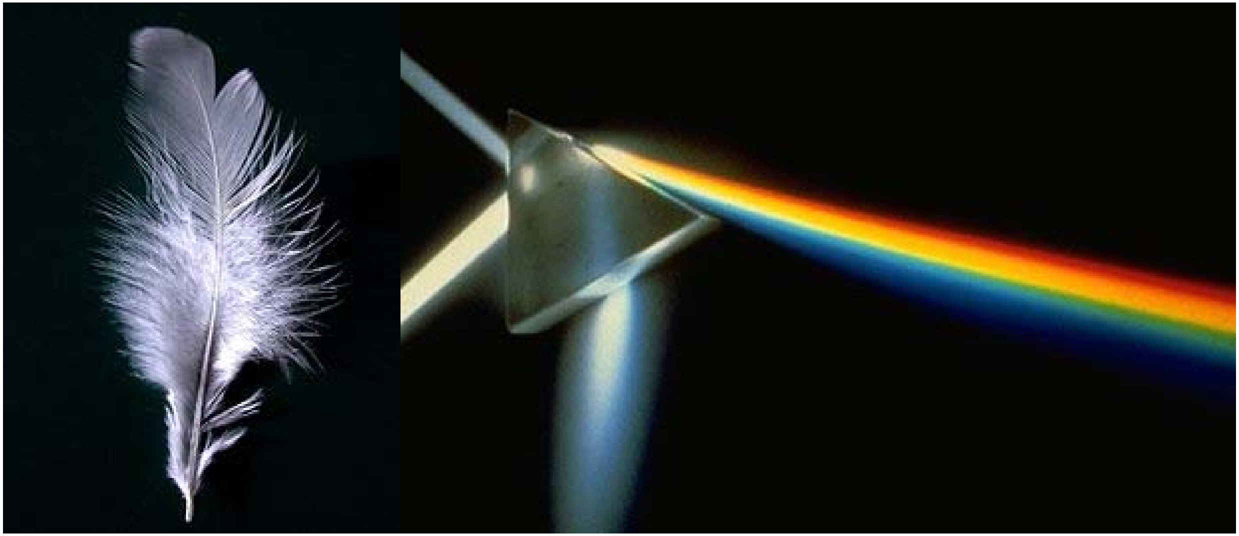

Tiger tongue --Cory Genovese

Hydrostatic pressures force the column to stretch and thin out, breaking into two pieces. The upper portion of the water column follows the tongue into the cat's mouth while the bottom portion of the water column falls back down. By changing the frequency of laps, the cats can maximize the volume ingested per lap.

This principle of Froude forces also is used by animals such as the basilisk lizard (*Basiliscus*; sometimes called the Jesus lizard) to walk on water. The downward pressure on the water causes a surface wave that creates a reactionary force on the animal that propels it upwards and forwards.

Invisible color

i r In market



structural bio-inspiration

How are animals colored? Someone didn't just dump them into a bucket of paint. In nature there are two ways for animals to show color .One is to have pigment, which is what makes your hair and your skin the color that it is. On the other hand, some birds, bugs, and mollusks have something called structural color that gives them those pretty, shimmering colors you see in peacocks. That's because in if you look at a bird feather under a microscope, you'll see lots of bubbles like the foam on top of your soda. This foam causes the white sunlight to break apart in separate wavelengths of color, similar to what happens with a prism. You can also see this in the wings of butterflies and the insides of oysters. A company is now using this concept of structural color to make a cell phone display screen to have colors just as vibrant and energy efficient as nature.

Painting without paint

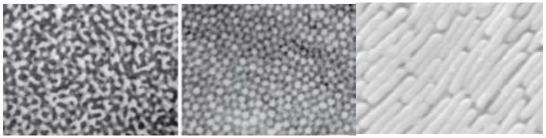
r m *In market*

Structural bio-inspiration

Peacock feathers, butterfly wings, the inside of mollusk shells and the shells of certain beetles all share the same natural phenomenon to have their unique rich and iridescent colors. Those parts of the animal have structural color, while the rest of the animal will be colored by pigment. In birds for example, there are three different types of pigments: melanins, carotenoids, and porphyrines. The main melanin pigment is eumelanin, which absorbs green, yellow and red wavelengths so you see blue and purple instead. Feathers with melanin are stronger and more resistant. Carotenoids make the yellows in goldfinches and warblers and interact with melanin to make olive green in some birds. Porphyrins make pinks, browns, reds, and greens.

However feathers are also colored another way, via structural color. Blue feathers, like on bluebirds and blue jays, are almost always made by structural color, as are the iridescent throat feathers on hummingbirds and peacock tail feathers. On the nanomolecular scale, feathers appear to have a similar structure to beer foam. When you look at them from a different direction you see rods of keratin with spherical air spaces in between. This keratin matrix self assembles when the bird is in the fetal stage forming feathers.

Bubbles of water form in the protein rich soup of the developing feather. The bubbles eventually are replaced with air. From the precise shape and size of these nanostructures you get a variety of colors, because the diameter of the bubbles and the spacing will limit what wavelength of light gets trapped. In general, only wavelengths smaller than the spacing between the bubbles are filtered out which are the colors you see. Sometimes the wavelengths of light will cancel each other out and you won't see those colors.



keratin and air nanostructure: Self-assembly of amorphous biophotonic nanostructures by phase separation in Soft Matter Structural rods: Zi, H. et. Al. Proceedings of the National Academy of Sciences of the USA, 2003, 100 (22), 12576.

This technology has been used by the company Qualcomm to make Mirasol display technology. Engineers have designed a reflective display that opens and closes miniature spaces between a mirror and a glass plate in a pixel. With a display made out of thousands of these reflective pixels, there is no need for powered lights behind the screen and Qualcomm claims that this screen is faster, easier to read and lighter than any other display. Structural color has also been used in the past for fashion fabrics and make up.

Georgia Tech CBID center for biologically inspired design ZOO ATLANTA

Listening lessons from Kermit

r

research stage

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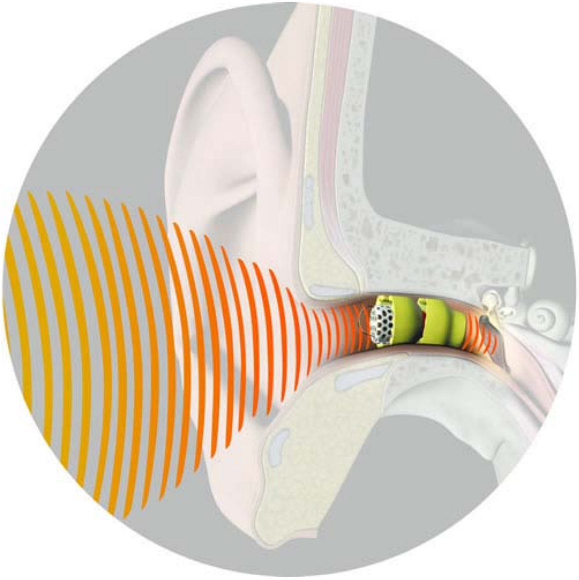
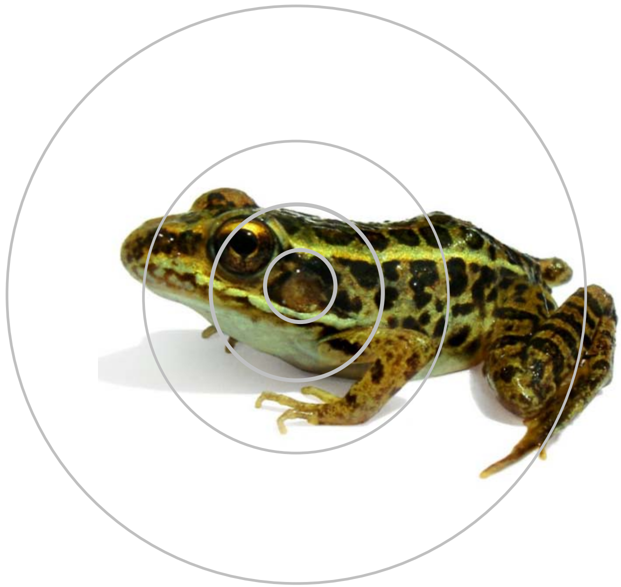
Behavioral bio-inspiration

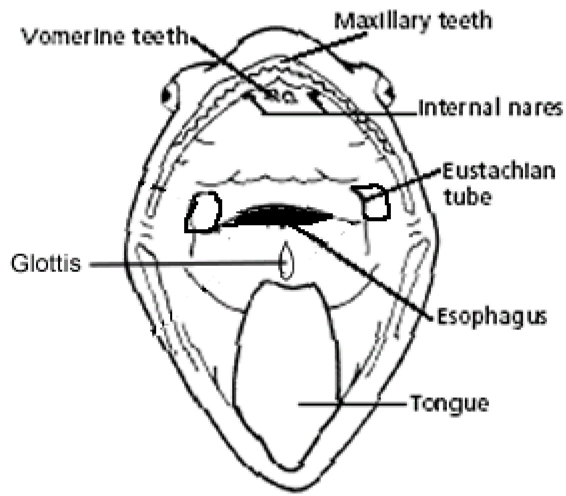




Scientists are studying frogs to make better hearing aids. Currently, hearing aids work by amplifying sound. This makes everything louder, which makes it harder to pick out the sounds you actually want to hear. Interestingly, frogs can selectively pick out the sounds they want to hear and ignore the background noise. As frogs and humans have similar ear canals, scientists are hoping to create more sophisticated, intelligent hearing aids.

Behavioral bio-inspiration

Frogs have the ability to pick out specific sounds and voices from the background, which is known as the *cocktail party effect*. By opening and closing their ears, frogs can ignore and identify specific sounds. When the frogs close their ears, they close their Eustachian tubes, which connect their ears with their mouths. When this tube is closed, the lower frequency sounds are absorbed as they travel to the inner ear and frogs can focus on the higher pitched noises.



For example, frogs can tune out the background noise of running water and focus on the calls of potential mates. Human ears also have the cocktail party effect and can tune out noises, but when humans can't hear low pitched background noises, they use hearing aids. Conventional hearing aids act as a microphone and make everything louder. Instead, a hearing aid benefiting from frog technology will be able to identify and amplify sound signals of interest.

Mother Nature’s finest axe

r m *In market*

structural bio-inspiration

Wood peckers use their beaks to peck into trees to make their homes, find food, and communicate with others. As they are constantly banging their heads around, their skulls have evolved to absorb shock to protect their brains from turning into mush. Their head structure keeps the impact of pecking from reaching their brain through a mixture of spongy bone and muscles that absorb the drumming vibrations to protect the woodpecker. The body shape is designed to produce a strong impact while minimizing internal vibration. Researchers have already started looking at the woodpecker to create more efficient drills and ice axes.

How woodpeckers help us make better tools:

r m In market

Structural bio-inspiration

The entire body of the woodpecker has evolved to protect the animal from detrimental side effects of constantly drumming on trees. In the woodpecker's head, the beak is connected elastic muscle to the body which isolates the impact of drumming. This, in turn, is connected to the hyoid muscle-tissue, which supports the tongue. Shocks are bypassed into this muscle and evenly distributed by the wood pecker's tongue. In addition, the base of the woodpecker's skull is made with dense, spongy bone that also distributes the drumming impact before it reaches the woodpecker's brain.

Other adaptations evolved by the woodpecker include its curved body shape and tail. The tail works as a bracing spring so the woodpecker's entire body is used to hammer into the wood, not just its neck. This way there is more force and the shock is distributed by the entire body. These adaptations have been studied to design ice axes and are in research to create jack hammers and drills.

Georgia Tech

CBID center for biologically inspired design

ZOO ATLANTA

How to hang from your ceiling

r m *In market*

Sensory Bio-inspiration

Geckos are masters of adhesion. They can dangle completely upside down, barely hanging on by one foot. On each foot, they have millions of tiny hairs coating the surface of their feet. On these hairs are millions of tinier hairs called nanopillars—which are 1/100th thick as a human hair. This allows for so much surface contact that geckos can stick to anything. Scientists are now using this principle to make tape and medical bandages.

Sensory Bio-inspiration

The microscopic hairs on gecko feet are called setae and have a slight positive or negative charge. When climbing up a wall, the setae will cause the wall to have it's own opposite electric charge at each point of contact with the setae. The cumulative effect of these tiny forces between the microscopic hairs and the molecules of the wall attracts the gecko's feet to the wall and allows geckos to walk upside down or even just hang from the ceiling.

Different universities have researched geckos and made tape from the findings in their feet. The challenge is making a tape that is both super sticky, but also detachable. Carnegie Mellon researchers have made a tape where a 1 cm square can 1 kg, but only takes a third of that force to release the tape. That's a size of tape as big as the tip of your finger holding up one of your fattest textbooks.

Speak with your feet

Who would have thought that you could have a language by jumping up and down? Elephants actually speak to other elephants by sending vibrations through the ground. On the flipside, researchers think elephants can also “hear” the signals by using their feet. Elephant feet had a fatty cushion in their feet and researchers believe that the signals are detected in this fatty cushion and also are felt by the elephant when the vibrations run up their front legs to the brain. Frequently, when elephants are trying to listen to others, they will lean on to their toes so their feet can pick up the signal better. Using this same idea of working with vibrations, a company named FeONIC makes speaker systems that turn your floors, walls, and windows into crystal clear, invisible sound systems.

Sensory Bio-inspiration

Elephants have two ways to communicate, by using sounds and by using seismic waves transmitted through the earth. To receive communication, they have both their giant ears and their giant feet. The circumference of an average bull elephant is 5 feet. Notice that an elephant's shoulder height is about two times its foot circumference. The majority of an elephant's foot is made of a tough, fatty connective tissue at its sole. This functions as both shock absorber and a second "ear." The foot pad is ridged so elephants can walk on all sorts of terrain. Yet, the sole is positioned under the feet bones of the elephant, so they're essentially walking on tip toes all day. It's kind of like they have natural high heels, and the fatty cushion of tissue is the wedge of their shoes.

Scientists have observed herds of elephants lean forward on their front legs, than pick up one front foot all at the same time, when they detect a distant noise. From these observations and a series of studies, researchers believe that elephants pick up seismic vibrations through their feet to communicate.

A typical elephant stomp with travel an average of 32 km. In comparison an adult human man jumping up and down will cause vibrations that travel about 1.11 km. Sound energy transmits most efficiently between 10-40 Hz, but scientists believe elephants communicate at 20 Hz. This is a quiet communication channel because no other animals communicate at that frequency and the only other vibration on that frequency is thunder or earthquakes.

The research suggests that elephants can hear through their feet either by vibrations through their bones, or receptors in the cushions of the feet. Many researchers believe in may be a combination of both methods that allow elephants to hear seismic signals. Scientists think that elephants use their bones to hear, because elephants will freeze and lean forward on to the front feet. This puts their feet directly in-line with their ears. The vibrations run up the legs and into the middle ear cavity. In the middle ear cavity, there is a tiny bone called the ossicles. This bone picks up vibrations and oscillations, and is enlarged in elephants.

Additionally, elephants have a fat similar to the acoustic fat in dolphins. This helps receive sound vibrations. Similar to manatees, elephants have fat deposits and air pockets in their skulls that help detect low frequency sound and seismic waves. There are also oils in their feet that are similar in structure to acoustic fat that also helps propagate seismic waves. While the fat reserves in internal organs will deplete in the winter, the fat reserves in the feet do not. Then in the front and back of feet there are pacinian corpuscles, that detect pressure changes and vibrations.

FeONIC audio speaker technology uses the same principles. Similarly to elephants, it also uses seismic waves to control and communicate sound. The system turns any rigid material like glass, word, metal, or plaster, and causes both sides of the material to vibrate and produce sound.

Nature’s mute button

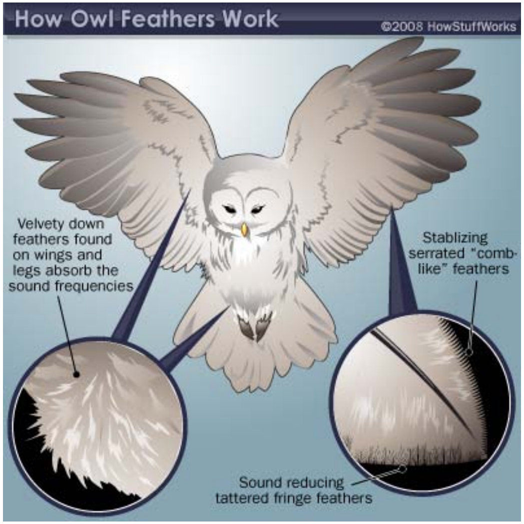
structural bio-inspiration

Owls are renowned for their ability to fly silently through the night and sneak up on their prey. This is because their wing feathers are structured in a way to disperse the air pressure. The largest flight feathers are separated from each other and look like a serrated butter knife from the front. These serrations allows air to funnel softly around the wings, and noise-causing disturbances are broken up. Any surplus noise is absorbed by the wing feathers. The engineers who designed the super fast Tokyo bullet trains that travel 200 mph replicated design on owl wings to the train’s overhead wire collectors to keep it quiet.

Structural bio-inspiration

Owls fly silently because their primary flight feathers are separated with a serrated front edge and fringed back edge. The fringed edge disperses air pressure and prevents any accompany noise energy from air-pressure changes.

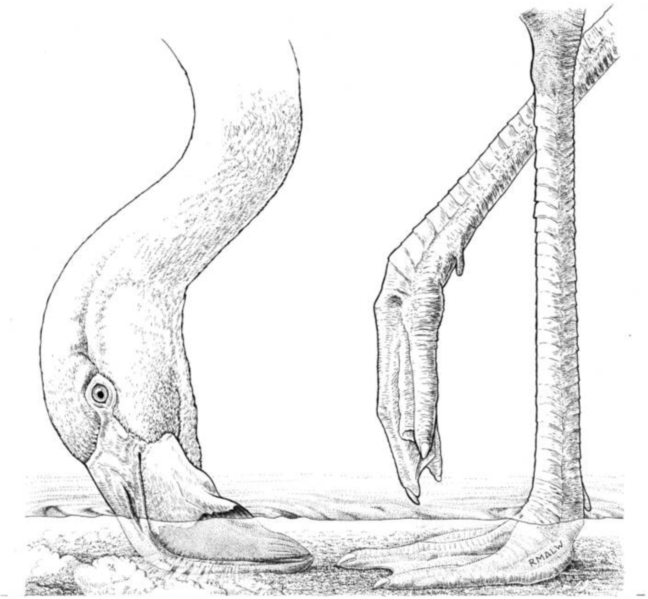
The saw toothed serrated feathers create miniature airflow vortexes that break up the larger, noise-creating air vortexes. Additionally, the wings delay the separation of air turbulence and cause the air to funnel smoothly over the owl wings.



Without an abrupt change in air pressure, noise is eliminated and the pressure on the wing surface area is greatly reduced. Additionally, owl wing feathers absorb sounds over 2000 Hz, making it the ultimate stealth machine.

Engineers incorporated the serrations from owl wings into the pantograph of the Tokyo Bullet train to make quieter. The pantograph is the little arm on top of electric trains that holds on to the cables overhead.

Flamingo filtration



Flamingos are special. Unlike other birds, they have big, bent bills. Their bottom bill is larger and stronger because flamingos feed with their heads upside down. However when flamingoes eat, they actually are pumping water in and out of their mouths at a speed of four pumps a second. This lets them use their bills to filter for food. Their beaks are lined with horned plates covered in miniature, comb-like hairs (called lamellae) that strain water, trapping the flamingo's dinner. Researchers are actually studying flamingo beaks to make the filters of the future.

Structural bio-inspiration

Flamingo head and beak, from Zweers et al. 1995

The flamingo bill is perfectly adapted for bottom scooping filter feeding. The hooked beaks allow the birds to separate mud and silt from their food while filtering for food.

As flamingos dangle their heads upside down in the water, they can swing their heads back and forth to increase water flow, while also using their hairy tongues as a pump to suck in and out water. They will also stir the water with their feet to cause any animals living in the mud to rise to the surface.

Greater Flamingos can trap crustaceans, mollusks and insects up to an inch long, while Lesser Flamingoes have such precise filters that they can sift out single-celled plant organisms that are less than 1/200th inch in diameter. Other birds that filter for food include some penguins, auks, and ducks (like the Mallard Duck).

See in the dark

r m *In market*

What do highway signs and cats have in common? In 1934, the British inventor Percy Shaw, took inspiration from observing cats and seeing how their eyes reflected light back in the night. Many nocturnal animals have a layer of tissue at the back of the eye called a tepetum, which reflects the light back onto the photoreceptors. This helps cats and other animals see better in dim light and creates the eye shine. Shaw created the devices for highways that would do the same thing: reflect light back from headlights to let drivers navigate the road. This technology has been improved and applied to make reflective tapes, paints and surfaces. These are known as retro-reflectors, are used to make reflective surfaces on bikes to alert drivers, and also on street signs to improve visibility at night.

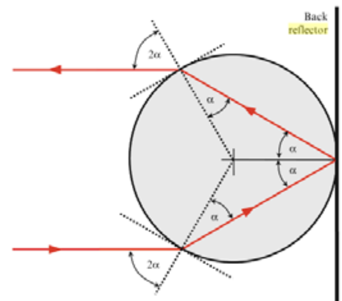
How cats have helped drivers for generations

r m In market

Sensory Bio-inspiration

Retro-reflectors are objects that reflect back light to its source with minimum scattering. The original retro-reflector which was inspired by an English man named Percy Shaw driving down a twisting road on a foggy night. He suddenly saw a glint of light which caused to stop his car to investigate.

Realigning his car, he realized the glint of light was the reflection of his headlights on a cat. He also realized he was driving on the wrong side of the road and if he kept on driving straight he would have plummeted right over the edge!



Percy Shaw made the first “catseye” retro reflector, which is the father of the reflective bumps you see on roads today.

The reflector is essentially a little glass marble set in a rubber dome to protect it from cars and weather. Light from your headlights travel through the glass and refracts twice to return the light in a parallel path to meet your eyes. This is more or less what happens in the eyes of cats or other nocturnal animals, which we see as eye shine.

Over time, scientists have taken this technology to a microscopic level. Today, retro-reflectors are tapes and surfaces made with millions of tiny, reflective spheres, each acting like the original retro-reflector devised in 1934. You can see them today on our street signs, safety vests, and bikes.

Slice through sound

r m *In market*

Structural bio-inspiration

Images courtesy of Biomimicry Institute

Scientists and engineers took the aerodynamic shape of Kingfisher bills to improve the Tokyo bullet train. The new tapering shape of the nose essentially silences the noise created from the train speeds through at over 200 miles per hour. Apart from being quieter, the new nose allows the train to use 15% less electricity and travel 10% faster.

Structural bio-inspiration

Scientists and engineers chose to study the kingfisher as a model for the Tokyo Bullet Train because these birds face drastic changes in pressure when they dive from the sky into the water to catch fish. The head and beak of the kingfisher has such an aerodynamic form that kingfishers barely make a ripple when they dive in. Engineers modeled the front of the Tokyo Bullet Train after the kingfisher, giving it a 50 feet long, tapering nose.

Without this tapering "beak," the train would create a huge sonic boom every time it exited a tunnel that reverberated through all the buildings within a quarter mile radius. Since the train traveled so fast, when it went through a tunnel a cushion of air would form in front of the train. At the moment the train exited the tunnel, the air would expand and cause a loud bang, rattling windows and startling people.

Many Japanese high-speed trains have been redesigned to follow the geometry of the kingfisher bill. Even the train headlights are modeled after the nostrils of the kingfisher. Now the bullet train slices through air, reducing the pressure against it, allowing it to travel smoother, faster, and quieter.

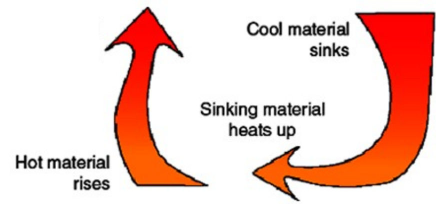
Images courtesy of Biomimicry Institute

Black and white, hot and cold

Top: Zebra--Mattias Karlsson; Right: Fan--Tran Minh Duc, ‘underwarehouse’, 2006. www.flyingbay.tumblr.com

Scientists are as befuddled as anyone else, when asked why a zebra has its stripes. There are many theories flying around, but no one is certain. Some believe the stripes are for camouflage, others believe they deter flies, and more believe that the alternating black and white stripes work as a miniature AC unit and keep zebras cool. This theory reasons that since hot air rises while cool air drops, that means the air near the zebra moves and circulates. The hot air heated by the black stripes is pushed out of the way by the falling cooler air. This circulation keeps the zebra cool. Naval architects have suggested alternating patterns of light and dark on ships may allow them to use the same principle to keep cool, thus minimizing energy use.

Material Bio-Inspiration



Zebra stripes are the fingerprints of each individual zebra. While each species has a similar general pattern, every zebra's stripes are unique. Apart from identification, researchers say the stripes protect zebras from lions and other predators by camouflaging the individual zebra in the larger herd, making it harder for predators to pick one off. Other scientists think the stripes deter flies.

A study published in early 2012 shows that horseflies are less attracted to black and white stripes, and attack other colors and patterns more. Scientists explain the reflected light patterns from zebras keep horseflies away. Horseflies are attracted to horizontal polarized light, and lucky for zebras, the polarized light from zebra stripes are the least attractive to horseflies.

There is another theory for why the zebra has its stripes. Other scientists believe this is for regulating heat by convection cooling. Convection is the movement of gases, like air, or liquids. Air expands when it's heated and rises, however it falls when it cools because it becomes denser. Scientists believe this is what happens to zebras. Black absorbs sunlight, whereas while white reflects it. This causes the air above the black stripes to heat up more and rise, while the air falls above the white stripes. This up and down movement causes convection currents around the zebra and keeps it cool.

How to make a crash resistant car

idea stage r m

structural bio-inspiration

The big horn sheep is known for horn to horn combat that can last up to 24 hours. Although these battles sometime result in death, the honeycomb structure at the horn base and perfectly aligned spine for shock transmission through elevated back legs equip the big horn sheep for survival. This provides an interesting model for how to cushion shocks occurring when cars collide by using materials similar to horn to absorb impact forces.

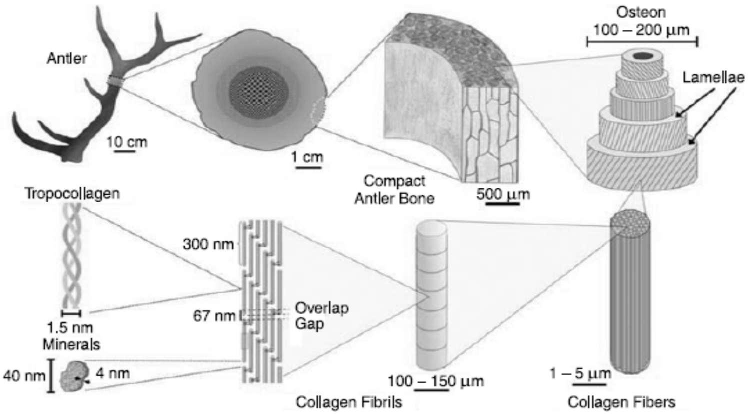
Bighorn sheep survive collisions at 40 mph

idea stage r m

Structural bio-inspiration

Can we design better crash resistant materials for our cars?

The horns of a Bighorn Ram can resist multiple high speed collisions, and may one day help scientists design better collision resistant materials for our cars. These rams use their horns during mating to fight other rams and frequently collide at speeds up to 20 miles per hour.



Kulin et al. 2010

One reason why horns and antlers are so effective is because these structures are hierarchical, and built from small components assembled together and aligned in different ways. The combination of hard material like bone or protein, combined with softer material between these layers, functions as a super-efficient shock absorber. Many scientists are studying the structures of bone, horns, and other biological materials to learn how they absorb impacts and develop ways to use these same principles in human products.

Go with your gut

From November to April the tiny and smooth-skinned body of the Boreal chorus frog is frozen solid and has tolerated freezing temperatures, down to 11°F. The frog's blood sugar increases as temperatures dip below freezing, resisting the formation of ice crystals in tissue. Scientists are studying how the frog survives being frozen to improve techniques for transporting vaccines.

Store vaccines in the belly of a frog

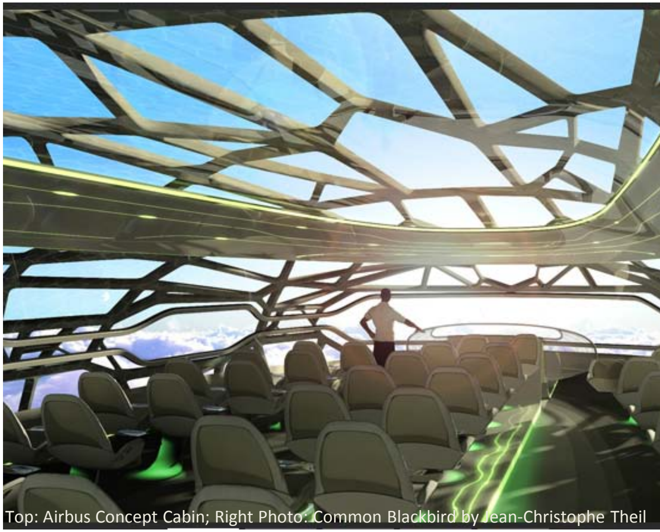
Boreal Chorus Frogs could bring vaccines to save Third World Countries.

Boreal Chorus Frogs hibernate though the sub-zero temperatures of winter partly because of their high blood sugar levels. During the cold winter months, the frog has a higher concentration of sugar in its blood than in its tissues to keep the blood from freezing. This works along the same principle of salting road in the winter to prevent the road icing over. The more stuff—aka solutes—that is dissolved in the water, the lower its freezing point.

This principle also works in reverse. The addition of more solutes to a liquid also changes how heat affects the liquid by increasing the melting point. Recently, scientists have discovered out a way to use a similar principle to transport vaccines in places lacking refrigeration. Most vaccines spoil if they are kept at temperatures above 4◦C. However when sugar is added, the sugar solutes alter the temperature properties of vaccines and they can be transported without spoiling. This means life-saving medicine can be delivered in large quantities, even in remote or tropical places without spoiling quickly.

Wing it

i research stage m




Top: Airbus Concept Cabin; Right Photo: Common Blackbird by Jean-Christophe Theil

Material Bio-Inspiration

The airplane makers AirBus unveiled their new vision for flight in 2050. In forty years, they want sky cruises instead of cruise ships,. The seats and carpets will be self cleaning and self repairing. Airplanes will have transparent cabins, so you have 360 degrees of panoramic views from the sky. The planes will have a structure that mimics bird bones to make planes lighter and stronger. Borrowing from nature, AirBus plans to make a speedier, sustainable, and more enjoyable way to travel.

Material Bio-Inspiration

Ever since the Wright brothers, planes have incorporated biological designs. A common feature of early planes was the use of wires to bend and twist the wing (wing warping), which enabled steering by controlling the amount of lift on the wing. Although this technology was replaced by ailerons (the little flaps on the wings), wing warping may soon be part of the supersonic aircraft, where ailerons are less effective. Current bio-inspired features of planes include the Airbus A350CWB, which has probes in its wings that detect wind gusts and change the wing shape for more energy efficient flight. This is just like how sea birds will sense gust loads in the air and change the shape of their wing feathers to stay on course.

Similarly, the A380 (the world's largest passenger plane) uses pieces of machinery that mimic eagle feathers. These are called "winglets" and curl upwards like eagle feathers. This characteristic upward curl lets eagles get as much lift as possible with the smallest wing length possible when eagles fly using rising columns of warm air.

The 2050 AirBus concept plane takes bio-inspiration to a new level by proposing to make the support structure like that in birds. Bird skeletons are marvels of light-weight support. The future 2050 planes will have spacious, transparent cabins with a bionic structure mimicking bird bones.

Bird bones have evolved overtime and become specialized for flight. These adaptations include high bone density, the fusion of certain bones, and changes in bone shape. Bats, another flying critter, have the second densest bone material. Dense bone material means strong bones. Scientists have found a direct relationship of high density to increased bone strength and stiffness. Not only is the bone material really dense, but the bones themselves are hollow to save weight. The bones of the high fliers like hawks and albatrosses have bones are filled with air spaces that are reinforced with tiny little bones called trabeculae that provide support. So if you popped open one of those bird bones it would look a little like a steel wool sponge. This makes bird bones as strong as possible while also being small and light.

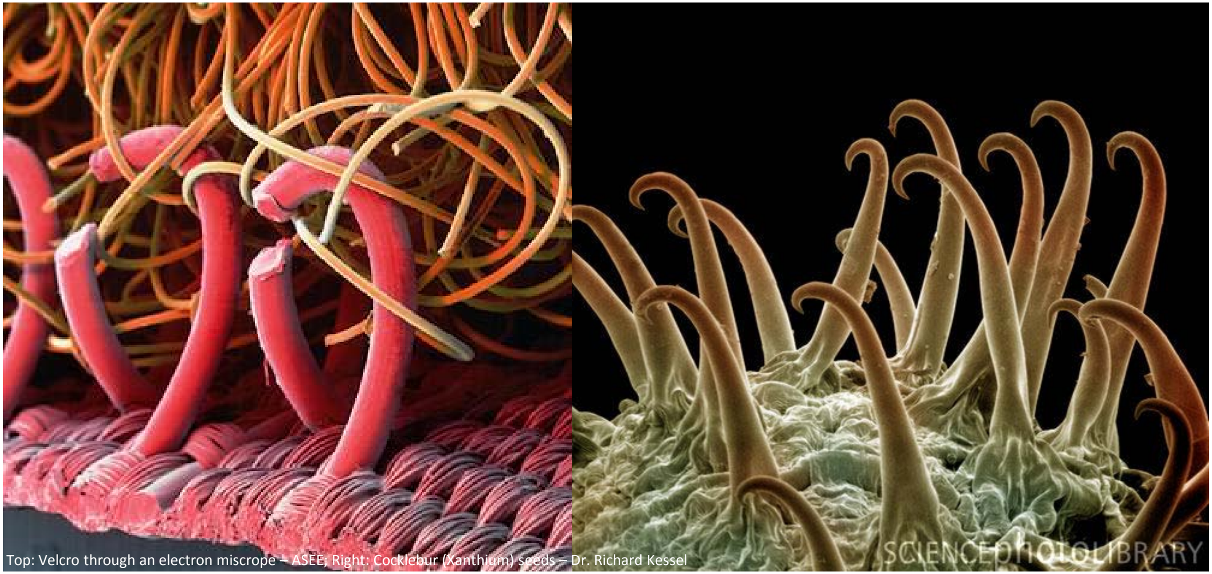
Some of these bones are also stuck together in a way that increases resistance to forces from particular directions without making the skeleton massive. This is a particular trick of animals that we often find difficult; humans tend to make uniform structures that resist the greatest force in any direction, which means overbuilding. For instance, a lot of little bones are fused together around the bird's tail bone, create the giant bone mass called the synsacrum. It's made out of bones from the pelvic girdle, lumbar, sacral and some vertebrae. The synsacrum absorbs compression shock when the bird lands on its feet. Apart from the interior structure of bones and the organization of the bones themselves, some bones also have a certain shape that makes them stronger. For example the main bone in bird wings, the humerus, has a round cross section. This is better than flat bones because round cross sections are more resistant to the twisting forces encountered when flying.

The concept plane borrows from other animals as well, it's a mash up of biomimicry innovation. The self-cleaning chairs and carpets are inspired from the lotus plant, which keeps itself clean even though it lives in dirty, mucky swamps using surface roughness. Engineers study the self-repairing abilities of your skin and blood vessels to make self-repairing airplane parts. The outside of new airplanes also have tiny grooves that sharks have to resist drag and make speedier planes.

Fetch!

i r *In market*

Material Bio-Inspiration



Top: Velcro through an electron miscrope – ASEE; Right: Cocklebur (Xanthium) seeds – Dr. Richard Kessel

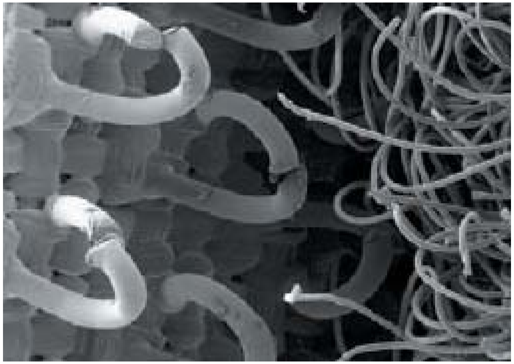
Once upon a time about 70 or so years ago, a Swiss inventor went hiking with his dog. When they got back home there were cocklebur seed pods stuck all over his pants and his dog. They were so difficult to pick off, he studied the cocklebur under a microscope to see what gave it such a strong hold. Seeing the tiny hooks on the burrs that fastened so tightly onto the miniature loops of fabric on his pant cuffs, he made the hook and loop concoction that is known as VELCO today.

Material Bio-Inspiration

Today Velcro is used all over the place. We've got Velcro shoes on our feet, and up in space astronauts use Velcro to keep their plates on the dinner table when they eat.

In the 1940's, George de Mestral took a look at cockleburs under a microscope. He had just come back from a walk with his dog, but before he could sit down and rest, he needed to weasel out every single spiky bur that had stuck onto his dog and onto his pants. Seeing the burs close up, he realized that at the end of the burs spines were tiny hooks. These hooks would grab on tenaciously to anything they could, like his pants and his dog's fur.

From this observation, he came up with Velcro, which is a two part fastener. If you look very closely at a Velcro strip, one side has mini hooks while the other has dense little loops of nylon. The name Velcro comes from two French words: "velour" and "crochet."



Top: Velco--Philip Execter Academy; Bottom: Cocklebur seed pod --Dr. Brad Mogen

Arabian Nights

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Behavioral bio-inspiration

Anyone whose been to the beach knows it's tricky to race across the sand. It's flaming hot, and dry sand slides around all over the place. However more than 1/5th of the earth is desert, so a lot researchers have been studying how to make robots that can help us move around on the sand. One animal in particular has fascinated scientists. This creature hops across the sand, leaving curious tracks behind. But it's no bunny rabbit, it's a rattlesnake.

The *sidewinder* rattlesnake, to be specific.

Biomechanical bio-inspiration

Sidewinder rattlesnakes are no strangers to biomimicry. In 1946, the first successful heat seeking air missile was created for the US Air Force, the AIM -9 Sidewinder. By taking a cue from the heat sensing pits by the sidewinder's nose to catch prey, the missile has a photovoltaic cell that detects heat from enemy plane engines.


Snake Robot: Photo by Dr. Gavin Miller


Snake Sidewinding: Photo by Dr. Gavin Miller

However today, researchers are studying this snake because of the way it moves across the desert. Whenever the snake approaches slippery surfaces, such as loose sand or slick mud flats, it pushes off the ground and glides sideways across the sand.

Sidewinders are known for their method of locomotion, which leaves the characteristic J imprint in the sand. The snake will throw loops of it's body obliquely across the sand so only two points are in contact with the hot, slippery sand at any time. This prevents the sidewinder from overheating because of too much contact with the desert sand. By studying how these snakes move, engineers are making robots to search for groundwater and land mines, that can navigate desert terrain and don't need wheels.

All caenophidian snakes, the family of snakes the rattlesnake belong to, have the ability to sidewind. In research studies, when confronted with smooth surfaces, the snakes would sidewind across. While scientists are primarily studying these snakes for sand locomotion, sidewinding robots could also be used on ice or other slippery surfaces.

Swim through solids

Gary meek

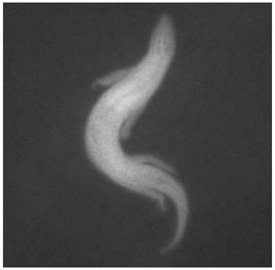
Dan Goldman

Let’s think of typical superpowers. Flight, invisibility, walking through walls… the list goes on. This little lizard has a superpower. These lizards can travel through solid earth. They live in the desert, and they can move through the sand as easily as a fish in water. Aptly, they’re named the sand swimming lizard.

Biomechanical bio-inspiration

We've got some interesting robots. We have ones that can fly, orbit in space, swim and dive deeper than any human can. Now, we have one that can travel underground. By studying the sandfish, researchers have figured out ways to let robots swim through sand. Burrowing through sand is actually a lot tougher than flying or swimming because sand can behave like a solid and a fluid. With no equations to work with, researchers looked at the sandfish lizard, who travels through sand effortlessly.

Sandfishes bury themselves under the sand to escape predators, cool off, and find food. Previously, scientists thought the sandfish had super slick skin with low friction scales and used its arms and legs to paddle through the soil. However, using x-rays to capture images of the sandfish underground, researchers find that the lizard uses an undulating motion like the dolphin kick we use when swimming butterfly in the pool.



With its arms pinioned to its side, the sandfish resembles a snake or a fish weaving its way through the sand. It moves in a sinusoidal pattern and can go through any density of sand. Its wedge-shaped head forms a 140 degree angle with the horizontal plane that negates any vertical drag forces, making it easier for the sandfish to bury itself. Scientists are hoping to create robots with the same maneuverability to save people who are trapped in rubble from earthquakes or landslides.

Many talents of Termites

i r In market

Ew. Nasty. Termites. While I don't want a termite anywhere in my house, termites turn out to be rather ingenious architects. Their homes have been studied by scientists and designers and actually are the inspiration for a building in Zimbabwe. Termites have formed their own version of air conditioning that keeps their home at the perfect temperature to grow their food.

So termites, you stay in your house, I'll stay in mine and no squashing will be necessary.

Biomechanical bio-inspiration

House breakers or house makers?

i r In market

Biomechanical bio-inspiration

Zimbabwe is in Africa. Africa is hot. Oddly enough, a giant pink and white building in central Harare, Zimbabwe has no air conditioning. It has sealed windows, deep eaves and tall chimneys that work like the shafts in termite mounds.

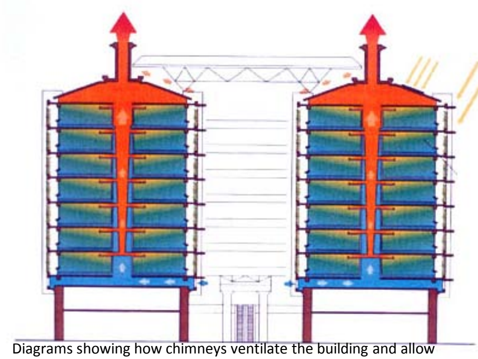
Even though the outside temperatures fluctuate from 35 to 105 degrees Farenheit, termites keep their homes as a steady 87.0 degrees. This temperature is perfect to grow a fungi they eat. In order to keep their mounds at that precise temperature, they have shafts that go from the top to the bottom of their mounds. The hot air rises and is replaced by denser cool air when breezes blow by.

In a similar fashion, the Eastgate Center has the chimneys open to the breezes. Fans on the first floor pushes air through the chimneys to constantly replace the stale air inside the buildings. The building is built mostly out of concrete, which also has insulating properties, like the insulating mud of a termite mound.

The Eastgate Center was designed by architect Mick Pearce and built in 1995 and uses 35% of the total energy typically needed for temperature regulation. On the building itself, the owners saved 3.5 million dollars because they did not have to pay for an air conditioning system.

Interesting fact about termites, not only are they clever architects, they are also strategic generals who engage in chemical warfare. As termites grow old, they build up blue rings on their backs storing poison. When there are competing termite colonies nearby, the elderly termites will travel to enemy lines and blow themselves up, coating the enemy in toxic sludge.

The Eastgate Center with it's characteristic chimneys. Photo by architect Mick Pearce.



Diagrams showing how chimneys ventilate the building and allow heat energy to escape and keep the Eastgate Center cool. Diagrams by architect Mick Pearce.

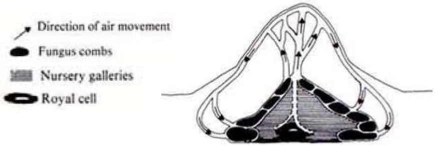


Diagram of the tunnel shafts inside the Inside macrotermes michaelseni termite mound that inspired the chimney shafts of the Eastgate Center

Georgia Tech

CBID center for biologically inspired design

ZOO ATLANTA

Kobe Bryant’s best friend

Hedgehogs love to scamper up trees and climb walls with reckless abandon. Lucky for them, hedgehogs have their own built-in, super-strong trampoline strapped to their backs. Their spines are shock resistant and make an excellent cushion for whenever they fall off the side of a tree or wall. Hedgehog spines have an thin outside protein layer and a foamy core that resembles a bunch of square air pockets stacked beside each other. This structure makes sure the spines don’t get squished and absorbed impact. The spines will bend, but not break, protecting the hedgehog. Researchers are now studying these spines to super strong materials to make fast cars and better bumpers for buses and trains.

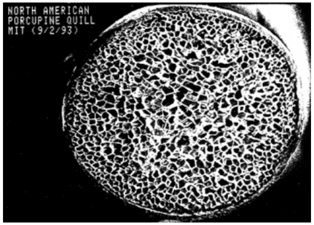
Biomechanical bio-inspiration

Do you know how to tell the difference between a porcupine and a hedgehog? If you pick up a porcupine by it's spines, they will slide out. However you could lift an entire hedgehog by one of it's spines (though that will be very painful for the hedgehog). Hedgehog and porcupine spines are made of the same material as the hair on our head, but the porcupine's spines are designed to be as long as possible without bending while a hedgehog's spines are made to be as shorter as possible with bending.

If you imagine a drink straw in an ice cold soda, that's like a porcupine's spike. If you're really strong and push the ends together, the straw with bend. Both porcupine and hedgehog spines have a spongy foam within a thin shell of protein, but the reason the hedgehog's spines are so much stronger is because it's foam is organized in a square honeycomb with longitudinal and radial stiffeners that run up and down, as well as around the spine. These stiffeners keep the spine from bending like your straw. The foam inside keeps the spine from local buckling, the hedgehog spine has a spongy, honeycomb-like middle that resists local buckling and reinforcements that run longwise and around the straw's circumference. Those stiffeners resists the axial loads which happens when you push the ends of the straw.

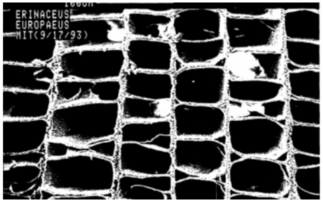
The internal structure is designed to maximize the ability for the spine to absorb impact and a mushroom-shaped bulb at the bottom of the spine anchors it into the hedgehogs skin. A considerable amount of force is needed to bend a hedgehog spine but then 200 times that force is needed to actually snap a hedgehog spine in half.

Researchers have been mimicking this structural organization to make stronger ship masts and strengthen circular metal bars used in car design.



Porcupine Spine cross section, spongy foam apparent. Credit: MIT labs

Hedgehog spine longitudinal section. Credit: MIT labs



Longitudinal section of hedgehog spike detail, shows square honeycomb interior. Credit: MIT labs.

The Turtle and the Shell

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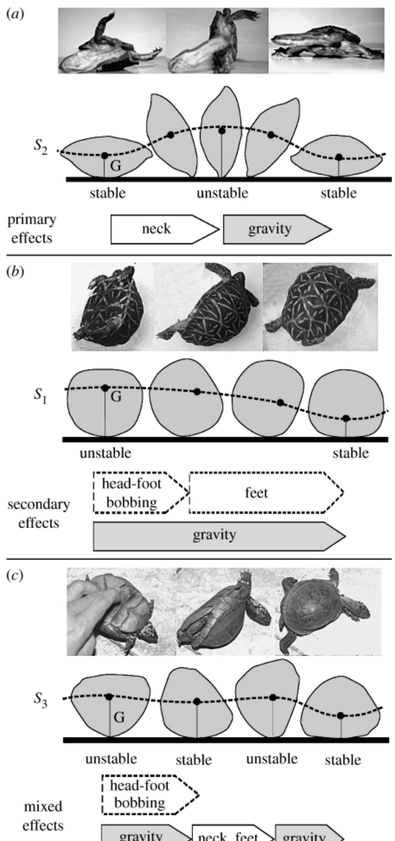
Biomechanical bio-inspiration

If you flip a turtle on its back sometimes it'll lay there flailing it's legs. However the turtle's shell isn't only built-in protection from predators, it also forms a teeter totter where a turtle can rock back and forth and roll onto it's feet. Scientists have studied turtles and formed the mathematical relationships to create a shape that has one stable point. No matter what way this shape is placed, it stands itself back up.

Biomechanical bio-inspiration



Diagrams showing how turtles with different shell depths flip back onto their front.

Turtles, Terrapins, and Tortoises—these reptiles are often mixed up with each other because they all look the same and they are called different things depending on where they live.

All turtles, terrapins, and tortoises are reptiles in the Chelonia order. A tortoise is not a really old turtle, but it is any chelonian that lives on land, eats shrubbery, and does not have webbed feet. They typically live in hot, dry places. On the other hand, a turtle spends most of its life in the water. A terrapin does both. He lives in the water and on land, and his home will be near a river, or a pond or some source of water.

Terrapins and tortoises will have taller, domed shells while turtles have flatter shells which are good for swimming and digging. These taller shells are mathematically proven to help terrapins and tortoises flip back on to their feet. The scientists who found these relations created a self-righting shape called a Gömböc that has one stable point and one unstable equilibrium point.

The Gömböc can be placed in any position and it will always flip back to it stable point. The unstable equilibrium point is a delicate balancing act., like balancing a pencil on its tip. The Gömböc can balance on this point, however the slightest disturbance causes it to fall over and it’ll reorient itself around the stable point.

This is the first shape discovered that has the ability to self-right itself and was hypothesized by the Russian mathematician Vladimir Arnold in 1995 and proven by Hungarian scientists Gábor Domokos and Péter Várkony in 2006. Domokos is an Engineering Professor and Várkony is an architect and Professor of Economics. They spent a year measuring turtles in the Budapest zoo and in pet shops and analyzing their shells.