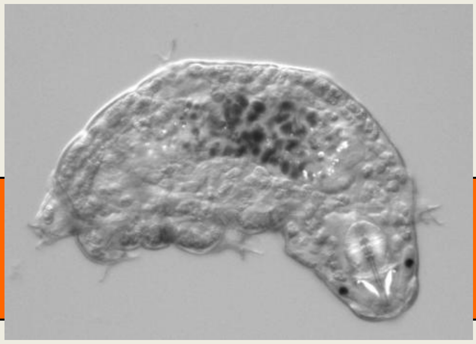

Water Bears

Able to live through the vacuum of space and through 1000 times more radiation than any other living thing. Able to withstand temperatures as high as 303° Fahrenheit (151° Centigrade) and as low as minus 328° F (-200° C). Able to live 120 years without so much as a sip of water, and withstand six times the pressure of the deepest ocean.

No, this isn't a superhero interviewing for a job. This is a real organism, the water bear, and you're probably stepping on one right now.

Water bears, also known as tardigrades or moss piglets, are a group of small, mostly microscopic animals whose most unusual characteristic is their ability to remain alive despite extreme environmental conditions by entering a dormant state. Over 700 species of water bears have been described, while many more species exist. Their size is small while their geographic range is huge: adults measure .1 - 1.5 millimeters and individuals are found from the polar regions to the equator, from the deep sea (below 4000 meters) to the tallest mountains (above 6,000 m). They're commonly found on lichens and mosses, but also in soil, marine and freshwater sediments, and just about anywhere else. Water bears are so common that probably everyone who reads this has swallowed several from a water glass at one time or another.

The ability to dry out and function again upon rehydration is called anhydrobiosis. Usually, the cell membranes of organisms which dry out become fused and so tear upon rehydration, but water bears, which normally are 85% water and dry out to only contain 2% water, mysteriously rehydrate without damage to their cells. Scientists studying their biochemistry have discovered that as water bears dry out, they produce a kind of sugar called trehalose which replaces the disappearing water in their bodies. Trehalose holds cell membranes in their original position until rehydration, like a referee holding two tired boxers apart, thus preventing membrane damage. Think of a miniature scaffolding holding a snowflake up during a warm day, until night falls and it becomes cold enough to maintain its own shape again – that's what trehalose does for the dessicating water bear's cells.

Sugar stabilized organic material has many promising applications that could help people. For example, nearly one half of all antibiotics do not reach patients because of spoiling, a number that would be greatly reduced if antibiotics did not have to be preserved through cooling. Inspired by the amazing biochemistry of water bears, sugar stabilized antibiotics that do not require refrigeration are now being developed.

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Photographs

Courtesy of Goldstein Lab, UNC.

Namib Beetles

The Namib Desert on the southwestern coast of Africa is a tough place to make a living. The oldest desert in the world, it is also one of the driest, and has endured dry conditions for 80 million years. Today it receives less than one-half an inch of rain per year, a mere tap on the drinking fountain button.

But it gets worse.

Because of the blinding fog that characteristically rolls inland from the ocean and covers the coastline, the region was called “The Gates of Hell” by Portuguese sailors and today is known as The Skeleton Coast, a reference to the graveyard of shipwrecks that run its length. Local people simply refer to the region as “The Land God made in Anger”. The fog for which the region is famous is caused by deep, cold ocean water rising up along the coast (the Benguela current) meeting the Atlantic Ocean’s moisture-laden air above. The cold waters cool the air down and cause the moisture to condense out of the air, much like a glass of cold lemonade “sweats” on a hot day, and the ground-clinging clouds of fog then roll across the parched Namib desert for a short period of time before the rising sun boils the fog away.

If you want to live in the Namib Desert, that fog is your only chance to get water. Imagine someone vaporizing your food and sending it as a fine mist over where you live; you would have to be pretty clever to survive. Indeed, the animals of the Namib Desert are some of the most creative collectors of water on Earth. For instance, while most plants absorb water from soil through their roots and then transport this water to their stem and leaves (where it is lost by evaporation through holes in the leaves known as stomata), the Namibian desert plant *Welwitschia mirabilis* turns the process on its head; it absorbs fog through its stomata and transports the precious water to its roots for storage.

One organism that doesn’t let the stressful environmental conditions of the desert get to it is the Namib beetle (*Onymacris unguicularis*); it literally lets the situation roll off its back. To collect water, the Namib beetle climbs to the top of a sand dune, tilts its head down, and aims the surface of its remarkable wings at the incoming fog. Tiny water-loving (hydrophilic) bumps on its wings condense the water droplets rushing by in the fog until they are big enough to fall by gravity, while waxy water-repelling (hydrophobic) ridges channel the flowing water down its back towards its mouth. Now that’s putting your back into your work!

Material engineers have created synthetic versions of the Namib beetle’s fog-catching technology, and the applications to meeting human needs are impressive. Creating structures like buildings and tents which harvest their own water needs from the atmosphere right onsite, for instance, could help solve water supply issues in cities and refugee camps throughout dry regions in the world; reduce energy expenditures involved in pumping, storing, and transporting water from aquifers and surface water; and provide resilience to water supplies in a world whose climate is changing unpredictably.

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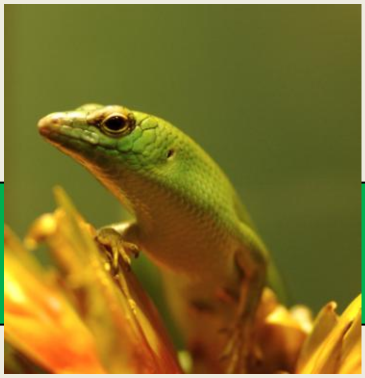
Photo courtesy of birdw0rks.



Geckos

Pick a gecko up and look at the bottom of its remarkable feet and you will not see any suction cups, no magnets, no glue. Touch these feet with your finger and you will not feel anything sticky. But put them down and within seconds these superhero creatures probably will be above your head, looking down at you from the ceiling.

"You're driving me up the wall!" Just a phrase for you and me, perhaps, but if you're a lizard like a gecko – small, tasty, and making your living eating insects and other animals that are frequently landing on things above the ground – it's serious business. You've either got to climb, or starve or be eaten. Fortunately, geckos are some of the best climbers in the world, able to stick to just about anything and hang upside down by one lizardy toe. But what will really surprise you is how they do it, and even further, how it's going to change your world.

It turns out that what we're trying to learn from the gecko, the gecko learned from the atom – those tiny, invisible pieces of matter that have the flexibility to become everything from your eyes reading this, to the chair you're sitting on, to your breakfast this morning. To understand how geckos adhere to any surface, you've got to consider why these piles of organized atoms that make up our world don't just spill across the floor like a bunch of marbles. Atoms stick together, of course, and the way they do it involves a number of different bonds, some weak, some very strong.

The weakest of these forces (called Van der Waal forces) cause atoms to have some attraction towards each other through electrical charge, positive and negative charges pulling each atom towards one another very slightly, and for very brief periods of time. These forces are so weak that, normally, you couldn't lift a grain of sand with them. But add them up, atom by atom, and they start to have a real effect. Geckos capitalize on this by having an enormous surface area on their toe pads, so that this slight attraction atoms on surfaces have towards their toes is multiplied and accumulates. There are two major advantages of using these very weak attractive forces for sticking to things: first, since all atoms have them, you can count on this force no matter what the surface is that you're walking on, and second, all you have to do to pull yourself off any surface (and keep moving) is to peel back one little corner of one toe.

Humans tend to use lots and lots of glues to stick things together, which have the disadvantage of often being toxic and making it very difficult to take things apart to fix or recycle them. Imagine if things were stuck together, though, with "gecko tape" – cell phones, televisions, skyscrapers. These would hold together with the strength of bolts but would have no toxic glues and could readily be disassembled for complete recycling and zero land-fill waste.

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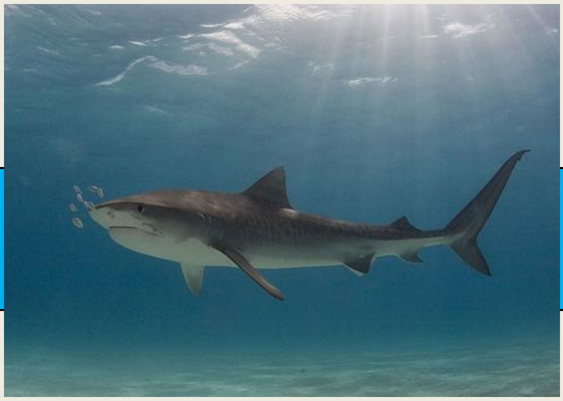
Photographs

Courtesy of Rune Johnsson.



Sharks

Beauty may not be the only thing that's skin deep. So might be the secret of the sharks' success. Around before the dinosaurs, sharks have been hunting successfully in the ocean for over 200 million years, a pretty tremendous track record. It turns out that at least some of that success is likely due to the sharp teeth not in their mouths, but covering their *bodies*. Shark skin is actually made up of very small individual scales, called dermal denticles (little skin teeth) or placoid scales. They have the same composition of teeth, with the outer layer being enamel, then dentine, and then a central pulp cavity. A key feature of these body teeth is that they are not smooth, but rather have grooves in them.

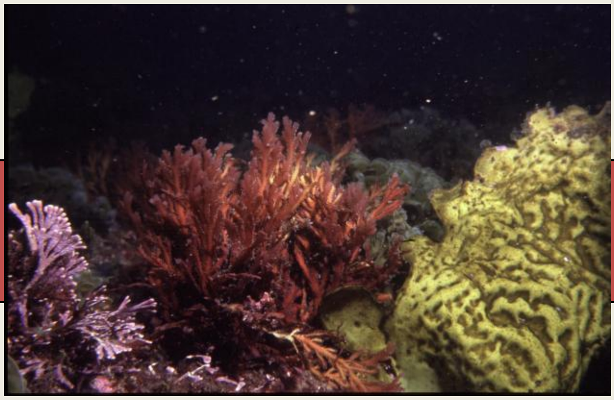
Probably one of the great lessons Nature has for humanity is that a fluid flowing over a completely smooth surface turns out to be less efficient than fluid flowing over "strategically" roughened surfaces. Water flowing over a smooth surface results in large eddies – turbulence – in part because the water flowing at the surface of an object moves slower than water flowing further away from the object. The difference in speed causes the faster water to get "tripped up" by the slower water (imagine leaves floating on a river – the ones near the bank move downstream more slowly than the ones towards the middle of the river, with the leaves near the bank occasionally sweeping out towards the middle of the river in swirling arcs, as the faster water catches the slower water and causes it to swirl towards the middle of the river).

An animal swimming through these large turbulent swirls would have a tough time, as the water hits at angles perpendicular to the animal's direction of travel. This is where the grooves on shark scales come in. The grooves reduce this large-scale turbulence in a number of ways: (1) they straighten the water flow by channeling it, which minimizes turbulence, (2) they speed up the slower water at the shark's surface (as the same volume of water going through a narrower channel increases in speed), reducing the difference in speed of this surface flow and the water just beyond the shark's surface, (3) they pull faster water towards the shark's surface so that it mixes with the slower water so this speed differential is lessened, and (4) they divide up the sheet of water flowing over the shark so that any turbulence created results in smaller rather than large vortices.

Human aeronautical design has been the history of trying to make things smoother, not rougher. Imagine how much more efficient boats – and perhaps all objects moving through fluid material -- could be if they took some lessons from this king of the oceans.

Photographs

Courtesy of Willy Volk.



Red Seaweed

Bacteria are a big part of our world, even if they're too small to see with the unaided eye. Some kinds of bacteria are critically important in helping the plants we eat grow and the food we eat digest inside our bodies. Other kinds of bacteria are no help at all – they can make us sick and even kill us. To deal with this problem, our strategy has been to attack these offending bacteria by pouring an arsenal of toxic, anti-biotic chemicals into our bodies that are hard on our livers and kidneys to process and which, while often killing the offending bacteria temporarily, increasingly create "super bacteria" that are resistant to our anti-biotics and for which we have fewer and fewer options for treating the next time around – not a sustainable situation.

Not only are bacteria too small to see with the unaided eye, but until recently, we couldn't hear what they were saying either. In fact, we didn't even know they regularly communicated with one another. Indeed, many bacteria use chemicals to communicate with one another to say such things as, "Hey, come land over here with me; I've found a great habitat!" and "Hey, there's enough of us now to overwhelm this host; let's create a biofilm!" Biofilms – just what they sound like: pernicious veneers of bacteria that can cover everything from the lungs of infected people to equipment in hospitals to the inside of oil pipelines – are the state bacteria get into when they switch on their nastiest chemicals and overwhelm the defenses of their host.

Bacteria are an issue not just for humans. Every other organism on the planet has to defend itself against these invisible little critters. One organism that apparently does this very well is red seaweed (*Delisea pulchra*) found in the oceans off Australia. Whereas all the seaweeds around red seaweed are frequently covered in biofilms, the surface of red seaweed remains clean. How does it do this?

It turns out that red seaweed has been listening to what the bacteria have been saying for a lot longer than we have, and produces a mimic of the chemicals – called furanones – that bacteria use to communicate with one another which plugs the bacterias' receptors. So if a bacteria happens to land on a red seaweed and send out the message to other bacteria swimming by that "Hey, come land over here with me; I've found a great habitat!" the other bacteria don't hear it -- they just keep swimming by. Without companions, the lone bacteria cannot form a biofilm, and so it gives up and swims away itself.

The real brilliance of this approach to fighting bacteria is that it doesn't kill them, so there is no selective pressure for the bacteria to evolve new strategies of overcoming the red seaweed's defense. In other words, bacteria that are fooled by the red seaweed's tactics go right on living, and producing the next generation of bacteria which likewise are fooled by the red seaweed's tactics. Indeed, the red seaweed has been employing this strategy effectively for millions of years, and the bacteria haven't figured it out yet!

<u>Photographs</u>

Courtesy of the Centre for Marine Bio-Inspiration.

Butterflies

Look around you and you will instantly notice that it is not a black and white world that you live in. Blue skies, green trees, red birds, yellow pencils, black chalkboards, brown desktops – we live in a world exploding with color but rarely think about how this color is created. People who make things, however (such as yellow pencils, brown desktops, etc.), think quite a lot about how to create color. In order to make many of the things in our world have the color desired, pigments and dyes must be added to paints, inks, plastics, fabrics, cosmetics, foods, and other materials (for example, look at the ingredients listing of a food you bought at the grocery store – have you ever wondered what Yellow No. 5 is?).

Whereas natural colorants break-down and are recycled by the environment, synthetic colorants are designed to behave in the opposite way, to be permanent and stable over time. Permanence and stability are highly desired properties of colorants, so that colors don't fade over time and remain relatively consistent in hue. As a result, these synthetic pigments and dyes can be unhealthy both for people and the environment. Synthetic pigments are commonly based on heavy metals such as lead, chromium, and cadmium, which accumulate in the environment and in people resulting in various health problems. Where use of heavy metals is regulated, synthetic colorants are often made of organic materials, but these still commonly result in environmental pollution from their manufacture (such as phosphates).

Pigments and dyes create color by absorbing certain wavelengths of light, and reflecting others (leaves look green, for example, because the only color they do not absorb is green). There is an entirely different way to create color, however, the way many organisms in nature create it – not with pigment, but by using biological structures to interact with light in novel, creative ways, i.e., "structural color". Color resulting from biological structures are what give blue Morpho butterflies their extraordinary blue iridescence, for example, even though the only pigment they contain in their wings is brown. How do they do it? Their wings contain layers of transparent material which act like multiple prisms, separating white light into its rainbow of different wavelengths. As these wavelengths bounce back out of these layered prisms, certain wavelengths become amplified while others become dampened depending on the layers' spatial arrangement, so that certain colors become greatly enhanced (e.g., blue in the Morpho) while others colors disappear entirely (imagine rowing a boat through some waves. If you ride with the waves, you feel lifted forward with unexpected speed; if you crash into the waves, both your boat and the wave slow down).

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Courtesy of Steph Mathews