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Inspiration Comes from Nature

Bionics and biomimetics

By simply casting a look towards our surroundings we can say that the amazing "inventions" of nature compete with the most advanced high technologies. The convergence between the living and the artificial world gave birth to an increasingly fecund science called bionics. This term was used for the first time by major Jack Steele in 1960 during a congress of US Air Force. Condemned to invent and find specific life modalities or disappear, living creatures managed to come up with ingenious survival methods. This is in fact evolution - a long chain of trials. Only the fittest, the most daring and the most adapted survive. The selection on a large scale enriched the nature's technological patrimony. Researchers have been looking for increasingly refined technologies in this data bank, older than 4 billion years. Bionics started in fact during the 19th century, when the English gardener Joseph Paxton, with the occasion of the Universal Exhibition held in London in 1851, built the famous Crystal Palace, a revolutionary greenhouse, 600 m (2,000 ft) long, inspired by the structure of the gigantic leaf of Victoria amazonica water lily. For a long time, architects have been the main beneficiary of the nature's models. The square of Royan mimics the shell of the giant bivalve Tridacna. Jacques Couelle, the founder of the Center for the Study of the Natural Structures invented some tubular bricks inspired by the stem structure of the sedges. Sometimes we do not copy nature, but we re-discover our own inventions in nature, like in the case of some bridges that recall the bony structure of the pelvis of an ostrich or other birds. **Composite materials** As toddlers, we fall, hit our heads, experience accidents and yet, in most cases we escape without much damage. At the same weight, a bone is harder than steel, because of its shape and molecular structure. This mix of strength and resistance is encountered everywhere in nature. Small trees spread their roots in concrete and rock rifts which they widen, while turning into vigorous trees. They can stand storms that break down electricity posts and destroy houses. Woodpeckers carve holes in wood and the forces applied to their heads would smash any normal brain in an instant. The skin of crocodiles and alligators rejects spears, arrows and even bullets. If you thought that optical fibers are a wonder of engineering, you are wrong. First optical fibers were made in 1951, and they caught light, transmitting it in broken lines. But this is actually an old trick for the sponges living in the Ross Sea (Antarctica). These giant sponges, living up to 30 m (100 ft) deep, have spicule-like fibers going out of their bodies and capturing and transmitting light under an angle of 90 degrees to the symbiotic algae living inside the body of the sponges. Lateral spicules capture the light falling under other angles. The latest technological advances allow us to take a peek at the natural secrets in order to copy and apply these patterns in a science called biomimetics, for new materials and technologies that characterize a new technological revolution in human history. The composites are solid materials achieved by combining two or more chemicals, in order to obtain a new substance with qualities superior to the initial components. The glass fibers, made of glass and plastic, are a synthetic material employed in making boats, fishing canes, bows, arrows, and other sports items. They are made by inserting extremely thin glass fibers in a plastic material, which can be liquid or gelatinous. When the plastic hardens, it forms the light, hard yet flexible composite. Graphite and carbon-based composites permitted the development of new components for planes and spacecrafts, sports items, cars, yachts and light prosthetic materials... However the man-made composites are inferior to natural ones. Instead of glass or carbon fibers, human and animal composites employ a fibrous protein called collagen that confers strength to skin, intestines, cartilages, tendons, bones, and teeth (except the enamel). Plant composites are based on another fiber: cellulose. Collagen-based composites are amongst the most advanced known materials and we can take for example, the tendons, whose function is to attach muscles to bones. Their strength is given not only by the collagen-based fibers, but also by the remarkable pattern through which the fibers are woven together. The forearm tendons resemble a bundle of twisted cables, similar to those used for suspended bridges. Each cable is, in turn, another bundle of thinner twisted cables. And this one too, a bundle of twisted molecules...**The cetacean skin** Let's take the humpback whale as an example. An adult individual can weigh 36 tons (79,000 pounds), much the same as a fully loaded truck. Even if it has a pretty stiff body, this 16 m (48 ft) long mammal equipped with extremely long pectoral fins similar to wings is remarkably agile in the water. In fact, these unusually long and odd-shaped fins - no other cetacean, whale or dolphin, has such long fins - are the secret. When it comes to feeding, this whale swims upward, in spiral, under a shoal of fish or crustaceans that it is going to feast on. It then starts producing a cloud of bubbles, with a 1.5 m (5 ft) diameter, which pushes the little living things to the surface where the whale swallows them at once. The upward edge of the fins is not smooth, like a plane's wings (and like the wings of other whales) but serrated, provided with a row of swells, called tubercles. While the whale is swimming upward, these tubercles increase its ascendant force, defeating the water force exerted on its body. Due to the tubercles, the water flows over the fins, forming a vortex around them, even when the whale rises almost perpendicularly. If the edge of the fins were smooth, the whale could not rise in such tight circles, because froth and water vortexes would emerge under the fin, and the ascendant force would be low. The wings of planes have also adopted this model; less flaps and other mechanic devices would be necessary to modify the air flux. Such wings would be more secure and also easier to carry. Whale bubbler is another amazing natural material: a floating mechanism, an excellent isolating material in the cold seas inhabited by whales and the best food reserve for long migrations (the same fat amount produces 2-3 times more energy than sugar and proteins). But the bubbler is also extremely elastic, similar to rubber. The acceleration achieved by the elastic turn of the bubbler, which is compressed and stretched with every fluke beat, can save 20% of the energy consumed during the period of continuous swimming. These properties were explained quite recently by the fact that half of the bubbler's volume is represented by a complex collagen web, which wraps any cetacean. Military torpedoes are covered with a "skin" mimicking that of the dolphin, that attenuates significantly the turbulence of the water. Firemen of New York use for their water special resins, called polyox, obtained by studying the mucus secreted by the trout for a more rapid slipping in the water. The polyox brings more speed to the water jets used for extinguishing fires. **Spider silk** A natural composite "hunted" for long by scientists is the spider's silk. It is five times stronger than steel and extremely elastic, stretching by 30% more than nylon (about 2-4 times before breaking off). Still, it does not vibrate like an elastic web for circus jumps because, if it did, it would throw away the spider's food, and it does not get soaked during a rainfall. Calculations showed that a fishing web made of spider silk with fibers the thickness of a pencil would stop a passenger plane. There are spider species that can produce even 7 types of silk! Imagine what we could do if this silk was made industrially: better security belts, sutures, artificial ligaments, light fibers and cables, and so on. And all this, non-toxic! (no need to mention that many plastic materials can cause cancer, fertility problems, and other health issues). For example, anti-bullet jackets are made of Kevlar, a product obtained using concentrated sulphuric acid, heated up to almost boiling point. The secondary products of the process are extremely toxic and their removal creates issues. Instead, the spider weaves its web from proteins with water, at an acidity point similar to the one found in the human mouth. **Amazing models in nature** Studying a fossil fly preserved in amber, scientists saw that the insect's eyes were crossed by networks which they believed helped the fly capture more light, especially when the light fell under high incidental angles. Subsequent experiments confirmed this. This could also be applied to the glass of the solar panels, which would generate more energy and would eliminate the need for tracking systems, which are expensive and continuously orient the panels towards the sun. Nature is also far ahead in the gearbox department. The fly has a gearbox that connects the body (engine) to, in this case, the wings. The fly has a gear shift working in three speed levels, allowing the insect to change speed during the flight. The gear shift represents in fact a second pair of minute wings that control the movement of the fore wings. Squid, octopus and jellyfish have a propulsion jet that allows them to speed up in water. But these "jet engines" have properties that people can not copy: they are soft, do not break, are resistant to deep depths, and work effectively and noiselessly, allowing a squid chased by a predatory fish to reach speeds of 32 km (20 mi) per hour, and even jump a few meters out of the water. Have you ever wondered about the history of Velcro? The inspiration for it came from the little hooks of the thistles and it took Swiss engineer George de Mestral 8 years of research, starting with 1957, to develop it. Wings of flight devices already mimic the shape of bird wings. Researchers at the University of Florida made a prototype of a robot plane, 60 cm (2 ft) long, with a remote control, that has the capacity of a gull to plane, plunge and raise rapidly. The gulls do it because of a great flexibility of their wing articulations. Mimicking this, the plane has a small engine moving a series of metal bars which in turn move the wings. These wings allow the airplane to plane and plunge even between high buildings. Such a high manoeuvrability device could be employed by the Army to detect chemical and biological weapons inside big cities. Gecko lizards are amazing due to their capacity of walking on walls and upside down on ceilings. The lizards' ability to defy gravity and attach themselves to smooth surfaces like glass is due to their setae, hair-like structures of their feet. They do not secret glue, but use weak molecular forces, called Van der Waals, to get stuck to any surface (except Teflon). This creates adherence and thousands of small hairs create enough power to defeat gravitation. Synthetic material imitating this could be an alternative to Velcro and would be extremely useful in medicine to replace chemical adhesives. NASA intents to make multi-legged robots imitating the walk of a scorpion, and Fin engineers have already made a 6-foot tractor that crosses obstacles like a giant insect. Other teams made a material mimicking the way a coniferous cone opens and closes. A car company works on a vehicle imitating the hydrodinamic shape of box fishes. Abalone snails are investigated for their shock buffering ability, in order to develop a lighter and stronger anti-bullet jacket. Snakes too fascinate researchers. For instance, French researchers were inspired by the scales of Guyana vipers for developing a non-skidding coating for ski. If you think that the helmets of the American troops, equipped with infrared detection represent an achievement of human technology, it's best you learned they are in fact no big deal for many snakes. Rattlesnakes and all pit vipers have over 1 million of microscopic thermal sensors placed in two small pits located between their eyes and nostrils. The sensors detect the most minute temperature differences, enabling the snakes to hunt warm blooded creatures (mammals and birds) during the night. In the case of pythons, these receptors are placed in smaller and numerous pits located on the edge pf the upper lip. The movements of earthworms are also studied, in order to develop robots that could move in any corner in dangerous places for humans, like nuclear plants, chemical plants or mines. Many other amazing traits found in nature are still a puzzle that, once solved, could revolutionize our lives, like the cold light emitted by fireflies and some algae; how arctic fish and frogs can become active again after freezing during winter; how seals and whales can last so much without breathing and dive repeatedly to impressive depths without experiencing the decompression disease; how cuttlefish and chameleons can change colors and hummingbirds cross the Gulf of Mexico with just 3 grams of "fuel".Still, above all, the biggest dream of researchers is that one day we would mimic photosynthesis with the same efficiency like in nature. This would literally release mankind from the dependency on non-regenerating resources, like fossil fuels. And one day, who knows, our computers may be biological...