Drink like a beetle: The researchers who look at nature in order to find solutions for the humankind

How does lizards survive in a barren desert, how plants transport water and how all of that is connected to the end of ketchup bottle content? The biomimetics researchers are inspired by the wisdom of nature.

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In "Dune", the ruthless desert world invented by Sci-fi writer Frank Herbert, humans rely on devices that collect moisture from air in order to get water and to survive. Hundreds of years before Frank Herbert wrote his classic book series, the Incas, which their empire prospered in the Andes quite a bit because of their elaborated techniques for water control, built similar devices that collected water from the mist.

While updated reports are forecasting that in the nearest decades a quarter of the human population will live in conditions of severe water shortage, developing new methods to produce water without burdening the environment is becoming from a curious to a necessity. Inspired by the Incas and other cultures that survived water shortage conditions, scientists are building from the beginning of the 20th century, various devices that produces water from air humidity and morning dew.

One of the approaches , which already has become a commercial product is to use devices built on the principle of air-conditioners. But instead of chilling the air, those devices are planned to collect the moisture and use it for drinking. At the world tallest building "The Burge Khalifa" in Dubai, the air conditioning system produces more than 50,000 cubic meters of water during the year. Those water are used to water the plants in the enormous luxurious tower. But the energy costs of this method are incredibly high, and the energy needed to produce 1 liter of water is significantly higher than the energy demands of other water producing methods – even desalination.

Another option is to use passive devices, on which the water is collected naturally into collecting vessels by using natural physical forces. For that cause, researchers and engineers are building big polymer nets that on their surface the dew drops are concentrated and flowing down. These methods are also used to produce water in isolated areas and are popular amongst Survivalism Movement members that are building shelters to help them survive the apocalypse. But the efficiency of this method is low and there is a need to cover large areas with nets in order to produce a relatively low amount of water.

When birds are singing, the squirrels feel safe to look for their next acorn.

Life is truly powerful than everything: How does germs survive in a depth of 250 meters in the Dead Sea?

Chance of life: For the first time an earth-like plant was found – its atmosphere contains water molecules.

Energy map on the back

Alongside the scientific trials to perfect the methods used by past cultures to "Harvest the fog", there are those who turn to nature in order to find inspiration for more effective methods to collect the morning dew for drinking purposes. One of the specialist researchers in this area is Dr. Bat-El Pinchasic from Tel-Aviv University. Her laboratory which was established only a year ago at the engineering faculty, is dealing with biomimetics: A research branch that turns to nature in order to find creative solutions to human problems.

"Water are in the air and condenses on surfaces, but what is the problem? They are not concentrated in one place and hence it is difficult to collect significant amount of them", says Dr. Pinchasic. In order to build dew collection devices, she and her students are investigating how beetles and lizards that live in desert area are collecting drinking water from air.

Horned Iguana, spraying blood from her eyes to confuse predators. Photographed by LM Otero / AP.

"Beetles and lizards have mechanisms that encourage water condensation on their bodies and systems that directs the water towards one direction – the mouth", says Dr. Pinchasic. "In this way the small drops are turned into a critical amount for drinking".

"These animals have mechanisms that encourage water condensation on their bodies", explains Dr. Pinchasic, "And also systems that directs the water towards one direction – the mouth. In that manner the water is flowing spontaneously or with the help of the wind in a certain direction. This directionality is important to make the small drops into a critical quantity that can be used for drinking".

The Namib Desert Beetle has an "Area Energy Map" on its body, that helps the water to condensate on its back and then flow to its mouth. Area Energy Map is a pattern of different areas. Part of them are hydrophobic (water repellents, like Teflon), and others are hydrophilic (water pulling). The beetle back contains hydrophilic bumps surrounded by hydrophobic areas. The water Concentrates on the bumps and when the beetle raises its rear side, the droplets concentrated reaches critical size and them easily rolls down towards the mouth.

Another method that is investigated by Dr. Pinchasic characterizes a lizard called Texan Horned Iguana. This lizard is known by its startling habit to spray blood from its eyes in order to confuse predators, but on its body exists a sophisticated mechanism for collecting water from air. A system of canals on its back that encourage water condensation and their flow towards the mouth, even without the help of the wind.

The scales of the horned iguana are covered with hydrophilic material that encourages condensation and what enables water concentrating and collecting is the unique geometry on the iguana's back. Very thin canals that are notched in the Iguana's back armor creates the capillary effect – the tendency of fluid to flow upstream in thin pipes without an external driving force. The capillary force depends on the balance between the internal forces that attracts the molecules together and the external forces that attracts the molecules to the material in which the pipe is made of. These forces are the same forces allowing plants to carry up water from the soil to the leaves. These forces perform one-directional canals on the iguana's back that supplies the desert reptile the necessary drinking water.

Dr. Bat-El Pinchasic. "Insects are walking on walls, flying, diving and walking under the water. There are plenty of mechanisms that we can learn from" Photograph: Jonathan Birenbaum.

"In the laboratory we are trying not only to imitate the mechanisms, but first of all to understand the physical and chemical principles behind them", says Dr. Pinchasic. "Our target is to expand the mechanisms in order to make the water collection efficient or to use them for other fluids and find applications beyond what exists in nature". In her laboratory, the mathematic models behind the natural mechanisms are investigated and smart material are produced, most of them by using 3D printers.

"Our first target is to increase efficiency – collect more water in less time", says Dr. Pinchasic. "Some applications use polymer nets to collect water from the air but do not use smart materials. We are trying to find a smart material that will perform it in an effective way". Thanks to the potential of this method that is aspiring to find in nature an inspiration to a more effective water technologies, Dr. Pinchasic has recently received the Young Grant from the Israel Science Foundation)ISF).

According to Dr. Pinchasic, same methods for spontaneous manipulations of water inspired by nature can be used for other liquids. For example: The smart surfaces that she is building can be used for liquids separation and purification. Building a device in which each fluid is tilted and is flowing in different trenches and to separate in this manner between petroleum and water for example.

Another option is to use condensation for building cheap and effective sensors for air pollution measurements. "Sometimes, the pollution amount in the air is very small and is hard to detect. But when a polluted air condenses, the concentration of the pollutants is higher in the droplets and furthermore, the droplets can be concentrated at the sampling point", says the researcher that her laboratory opened only six months ago. "Our methods can be used to develop cheap and effective sensing devices to track environmental pollution".

Besides water collecting, Dr, Pinchasic's laboratory also examines how different species of insects are dealing with marine environment in order to find inspiration for new technologies. " Insects are walking on walls, flying, diving and walking on surfaces under the water. This is the most diversified group of species and there are plenty of mechanisms that we can learn from" In Dr. Pinchasic's laboratory they also build robots that imitates insects in nature. For example, using 3D printing technology she is working on creating under-water robots' swarms with artificial intelligence.

For a clean tomorrow

There are plenty of researchers in the biomimetics area that are searching inspiration in animals in order to build advanced robots. For example, robots that flies like a dragonfly or durable and flexible as cockroaches. This month, researchers from Amory University in USA presented synthetic skin which changes its color, inspired by the camouflage techniques of the chameleon.

Biomimetics researchers refer also to the flora in search for inspiration sources for smart materials that will improve the life of humankind. For example, in the Nano-technology laboratory of Dr. Gay Machrez in the Vulcani Institute, they are investigating hydrophobic surfaces inspired by nature. His developments are not based on beetles or lizards but on plants samples.

"Lotus leaves and the peach peel are super hydrophobic – the water does not wet the leaves", says Dr. Machrez. "In that manner the plants have a self-cleaning characteristic, the condensed droplets are immediately flowing down, thus cleaning the dirt from the leaf or the fruit".

In order to imitate this attribute, Dr. Machrez laboratory is using advanced tools from the nano-technology field, which enables identical behavior of the material. "We have developed coating which is based on nano-particles and provides control on surface geometry in a nano-metric and micro-metric levels", he says. "This combination creates super-hydrophobic behavior"

The emphasis on his scientific work, explains Dr. Machrez, is on developing methods that will allow the use of smart material in a cheap and a commercial way. The advantages of the smart coating lie in its high durability but also in its ease of production and low process costs. His laboratory is working in cooperation with Israeli plastic industrial companies in favor of producing self-cleaning surfaces in the nearest future. Because the laboratory belongs to the Vulcani Institute, the research orientation is mainly towards agriculture and the development is relevant for greenhouse surfaces with a self-cleaning ability, which will improve the sunlight level in the greenhouse.

"In the future", says Dr. Machrez, "The ability to produce super-hydrophobic surfaces easily and with cheap costs, opens a variety of options, starting with roofs and coating that are self-cleaning, through showers and products to the automobile industry and food coverages that contains the moisture and preserve the contents for a longer period and even ketchup bottles made of "Ketchup-phobic" plastic which will allow the user to empty the bottle content up to the last drop without a struggle and suspicious sounds.

Another biomimetic development in Dr. Mechraz laboratory is a sensor to monitor the maturing of fruits and vegetables. When fruits mature, they release a vegetal hormone called Ethylene. Monitoring this hormone can make the marketing of fruits and vegetables to be more efficient. Farmers and vegetable marketers do not have the ability to monitor the concentration of Ethylene on air in real-time and with enough accuracy, but the plants have dedicated receptors that react to this hormone. Dr. Mechraz is trying to build, using nanoparticles, a sensor that will imitate these receptors and will react to a change in ethylene concentration in the air. "The idea is to build something similar to what exist in nature – only simpler", he explains.

Another research is dealing with plastic recycling. According to Dr. Mechraz the method he is developing will allow to return used material to the production lines without a significant change in the new product. "The secret is on mixing – if the material will be well mixed, the used plastic bag will hardly be noticed in the product".

In order to achieve perfect mixing of plastic, a compatibilizer material need to be used – such material must have good interaction with all the mixed materials. For that reason, the Vulcanic Institute is developing these days unique nanoparticles that will help to coordinate between various polymers. "If we will succeed on developing a material that can bring those mixing capabilities do different plastic types, we can create a revolution in plastics recycling: Plastic companies will be able to recycle their own products". In favor of a cleaner future.