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BIOMIMICRY: Exploring nature's genius for a better tomorrow

As populations expand and pressures on our water increase, scientists have to find new, innovative ways to protect the nation's scarcest natural resource. A new research discipline is illustrating that the secret to a successful survival strategy might lie in nature itself. Article by Lani van Vuuren.

Man has studied nature for hundreds of years. First we tried to tame it, to control it with our structures and machines. In many ways we now seek to protect it against those same structures. Yet our challenges remain – billions of people around the world still lack access to clean water while pollution threatens the supply of those who have access.

In 1997, US biologist Janine Benyus introduced the world to the concept of biomimicry. Since then this new discipline has taken off in leaps and bounds. Biomimicry is described as the practice of learning from and then emulating natural forms, processes and ecosystems to solve human design challenges and create more sustainable designs.

"We are very used to learning about nature," explains biomimicrySA founder, Claire Janisch, speaking at an interview earlier this year. "Biomimicry turns this around and asks what can we learn from nature and how can we take that learning and apply it to our own designs so that we ourselves start to emulate that genius we see in nature?"

There are three types of biomimicry – one is copying form and shape, another is copying a process, like photosynthesis in a leaf, while the third is mimicking at an ecosystem level, such as building a nature-inspired city.

The core idea is that nature, imaginative by necessity, has already solved many of the problems we are grappling with. Animals, plants and microbes are the consummate engineers, physicists, chemists and engineers. They have found what works, what is appropriate, and most important, what lasts here on Earth.

By looking to nature's examples we can begin to create innovative and progressive solutions to the design, engineering and other challenges we now face: in energy, food production, climate control, transportation, water supply and more. The vision of the biomimicry movement is to create products, processes, organisations and policies – new ways of living – that are well adapted to life on earth over the long haul. An important note on biomimicry is that it uses the recipes from organisms – not the organisms themselves.

BIOMIMICRY'S POTENTIAL FOR WATER

Realising the potential of this new discipline for water, the Water Research Commission (WRC) initiated a five-year project to demonstrate the biomimicry methodology in a South African setting. The project, being undertaken by Golder Associates Africa, together with Cape Peninsula University of Technology, the University of the Witwatersrand and biomimicrySA, will be completed next year.

Traditionally, we have thought in very linear ways when looking to solve our water problems, look at a typical wastewater treatment chain: wastewater goes in through concrete structures, gets treated, then flows out again, explains WRC Research Manager, Dr Valerie Naidoo. "The biomimicry methodology challenges us to think more three-dimensionally. Instead of fighting against nature we are now looking to it for innovations, using nature's own principles to come up with solutions to our challenges."

Since this is the WRC's first foray into this field, for now the project is focused only on biomimicry and wetland design. Researchers are looking to nature for innovative ways of enhancing constructed wetlands and rehabilitating existing wetlands. "Wetlands serve as natural filters, removing pollution from waters flowing through them. The economic value of this natural filter is immense, reducing the full cost of downstream (potentially high energy) treatment systems and water purification, notes Dr Naidoo. If successful, this methodology can then be implemented on other systems and processes where appropriate.

The study is looking to exploit knowledge on how nature cleans water to better engineer constructed wetlands to meet the challenges of current and emerging pollutants and pathogens. The core project team comprises engineers and scientists with expertise in various sectors. During the duration of the project experts have been consulted and invited to participate in workshops and seminars in order to incorporate their knowledge and delivery a novel approach to constructed wetland designs for water treatment.

"This project is really exciting as it is not an easy methodology to apply. We are asking researchers to stop thinking about innovation in a traditional sort of way and enter a more creative, multidisciplinary space," says Dr Naidoo. "This project is only the start of what we hope will be a new wave of creativity to enter the South African water space."

To date, the team has had a mixed reaction from colleagues, with some researchers not seeming very keen on giving up their conventional way of thinking and others seeing the potential of biomimicry. Perhaps the true worth of biomimicry will not be in solving just the water sector problems but in contributing to economic growth and the knowledge economy through the development of innovative products and processes for the marketplace, notes Dr Naidoo.

HOW DOES BIOMIMICRY THINKING WORK?

Golder environmental engineer, Priyal Dama Fakir, explains in a Water Institute of Southern Africa conference paper what the key steps in

The mouth of the humpback whale has an excellent water filtering mechanism.

Wikipedia

the biomimicry innovation methodology are. The first step is to **identify** the core problem that needs to be solved, asking questions such as: What do I want to achieve? and What do I want my design to do?

The next step is to **interpret** or to 'biologise' the question. "As an example, consider a design problem where the designer is required to treat water containing high concentrations of sulphate. Typical questions would be: How does nature remove sulphates from water? How does nature survive under high sulphate conditions? What natural processes require high sulphate conditions?," explains Dama Fakir. One also needs to understand the overall context of the solution being investigated.

The third step is to **discover** – actually finding solutions in nature. This means brainstorming between designers and biologists, identifying nature's models which meet the functions indentified, and selecting the champions by considering the context and identifying the organisms whose survival are dependent on the function.

The next step is to **abstract** or understand the principles and context and select a shortlist of champions. Key here is to look for repeated successes and the principles that achieve this.

Now it is time to **emulate** – to actually mimic the innovation discovered. The last step is to **evaluate** your innovation again life's principles and identify areas of improvement to the design. These principles include being resource efficient, using life-friendly chemistry, integrating development and growth, being locally attuned and positive, adapting to changing conditions and evolving to survive.

EXAMPLES FROM NATURE

The WRC study has come up with a tool to guide a whole host of potential innovations. Nature is full of examples of sufficient and efficient ways to treat water. Take the mangrove, for example. Remarkably tough, mangroves can live in water up to 100 times saltier than most other plants can tolerate. This is because of the ability of these estuarine plants to filter out the salt as the water enters their roots.

Mangroves can tolerate extremely salty water due to their desalinisation abilities.

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Some species of mangroves excrete the salt through glands in their leaves. Others concentrate the salt in older leaves or bark. When the leaves drop or the bark sheds, the stored salt goes with them.

The ability to filter water is also found among animals. Flamingos have bills lined with numerous complex rows of lamellae, which filter out the various small crustaceans, algae and unicellular organisms on which the birds feed. The feeding process requires a series of tongue movements and opening and closing of the beak, which allows food items to be filtered by the lamellae and eventual ingestions.

Unwanted items, such as mud and water are pushed out by the tongue. Swinging the head to and fro allows water to enter the beak. Acting as a pump the tongue moves back and forth sucking the water in and forcing it out.

Looking to an example from the sea, Baleen whales, which feed on krill, have no teeth. Instead, they have developed a keratinous row of fibres, known as a ballen, to filter out organisms from seawater. The keratin sheath of each baleen plate encapsulates hair-like strands that become evident as the sheath is worn down and splits open.

Upon closing its mouth, the whale's lower jaws distends, creating pressure against the baleen. This forces water through the keratin fibres, but retains all organic material. Once material is forced out the whale's tongue rises and sweeps the organic material off the baleen and swallows it.

The principles of Baleen whale filtration have been emulated in existing biomimetic technology, called Baleen filters. Water runs through the filter, causing visible solids and particles to remain behind in the filter. Hereafter, a second high-pressure, low-volume spray of water dislodges the solids and carries it away.

Among nature's genius that has been most successfully emulated are aquaporins. An aquaporin is a membrane protein that allows water to pass through cell walls. These proteins contain pores in the shape of an hour glass, made of crystalline material and are used to transport water in and out of cells. Aquaporins transport the water through membrane at a rate much faster than diffusion.

A Danish firm, also called Aquaporin, has mimicked this by using a forward osmotic system incorporating aquaporins to increase the water transport rate. Aquaporins are embedded into artificial membranes simulating the natural behaviour of biological membranes. Since aquaporins are ubiquitous among all living organisms they can easily be produced.

Several other successful innovations have been identified during the WRC study which could potentially be mimicked to produce sustainable water treatment technologies. It is hoped that some innovations can be tested at lab scale and could lead to new solutions for the water sector and beyond.

It is hoped that this WRC project on biomimicry will be the start of a new way of approaching South Africa's water challenges. As we look to learn from nature's genius, may it also awaken the genius in ourselves. ❑

The WRC project is looking to nature to improve the functioning of constructed wetlands.

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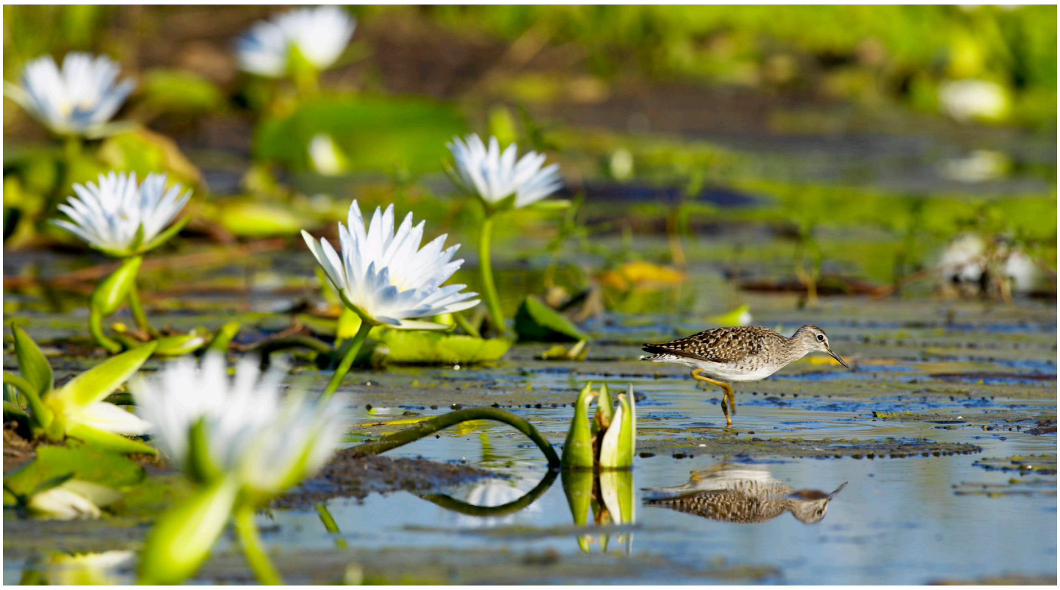

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