ENVIS CENTRE ON ENVIRONMENTAL BIOTECHNOLOGY

SUPPORTED BY MINISTRY OF ENVIRONMENT AND FORESTS
GOVERNMENT OF INDIA

VOLUME-23 ISSN : 0974 2476 DECEMBER, 2013

BIOMIMICRY

NEWS LETTER

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ENVIS Newsletter on Environmental Biotechnology is a half-yearly publication publishes articles related to the thematic area of the ENVIS Centre. Popular or easily intelligible expositions of new or recent developments are welcome

Manuscripts should be typewritten (font should be Times New Roman and font size ought to be 12) on one side of the paper in double spacing with maximum of 6-8 typed pages

Figures and typed table should be in separate pages and provided with title and serial numbers. The exact position for the placement of the figures and tables should be marked in the manuscript.

Articles should be sent to

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EDITORIAL

Biomimicry is an emerging design ethic that consciously observes and emulates nature's forms, processes and systems. It is based on the understanding that for four billion years organisms in nature have been evolving and refining solutions to universal problems, e.g. packaging, adhesion, climate control, benign manufacturing, etc. They achieve these feats within the same context and boundary conditions as humans. Biomimicry is a tool that encourages engineers to consciously emulate these blueprints and recipes to find ways to improve their innovations. It is studying trees to create pumps, or electric eels to produce electricity. In nature, organisms create, manage and process their technologies while enhancing their surrounding habitat and contributing to the continuity of life. Biomimicry uses nature's best ideas as a model, measure and mentor to create sustainable designs and begin to more sustainably converge our way of doings things with the natural world.

In this newsletter (Vol. no. 23). We have attempted to discuss the Biomimicry related issues and its applactions.

(S. C. Santra)

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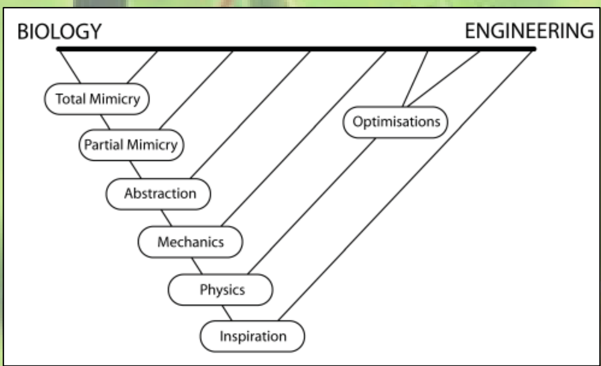
Biomimicry

Introduction

Biomimicry [from bios (life) and mimesis (imitate)] is a new discipline that studies nature's best ideas and then imitates these designs and processes to solve human problems. Sometimes called Biomimetics or Bionics, it's basically biologically inspired engineering. The term biomimetics was introduced in 1950s by an American inventor, engineer and biophysicist Otto Schmitt. By creatively converging technology and the natural world, biomimicry requires a collaboration of engineers and biologists and uses a design methodology that is founded on principles of environmental sustainability.

Janine Benyus (1997) in her book entitled 'Biomimicry: Innovation Inspired by Nature' brought together the recent discoveries in a number of disciplines, from engineering to agriculture, that can be traced to research and investigations into the designs and processes found in nature



The thinking of Biomimicry helps to create various products and processes that are useful for mankind. Those are:

❖ Sustainable

Biomimicry follows Life's principles. Life's principles instruct us to build from the bottom up, self-assemble, optimize rather than maximize, use free energy, cross-pollinate, embrace diversity, adapt and evolve, and use life-friendly materials and processes, engage in symbiotic relationships, and enhance the bio-sphere.

❖ Perform well

In nature, if a design strategy is not effective, its carrier dies. Nature has been vetting strategies for 3.8 billion years. Biomimicry helps to study the successful strategies of the survivors, so it can thrive in the marketplace, just as these strategies have thrived in their habitat.

❖ Save energy

Energy in the natural world is even more expensive than in the human world. Plants have to trap and convert it from sunlight and predators have to hunt and catch it. As a result of the scarcity of energy, life tends to organize extremely energy efficient designs and systems, optimizing energy use at every turn. Emulating these efficiency strategies can dramatically reduce the energy use. Greater efficiency translates to energy cost savings and greater profitability.

❖ Cut material costs

Nature builds to shape, because shape is cheap and material is expensive. By studying the shapes of nature's strategies and how they are built, biomimicry can help to minimize the amount of spends on materials while maximizing the effectiveness of the products patterns and forms to achieve their desired functions.

❖ Redefine and eliminate "waste"

By mimicking how nature transitions materials and nutrients within a habitat, can develop various units and systems to optimally use resources and eliminate unnecessary redundancies. It will drive profitability through cost savings and/or the creation of new profit centers focused on selling the waste.

❖ Heighten existing product categories

Helps to stale product categories in a radically different light. This new sight creates an opportunity for innovation.

❖ Define new product categories and industries

Help to create disruptive technologies that transform to industry or help to build entirely new industries.

❖ Drive revenue

Help to create whole new growth areas, reignite stale product categories and attract both customers who care about innovation and sustainability.

❖ Build your brand

Creating biomimetic products and processes will help both innovative and proactive about the environment.

There are **12 Methods** by Which Nature can inform the Development of Technology: (Benyus, 2004)

1. **Self Assembly** – The ability of an organism to direct its own process of development.

2. **Chemistry in Water** – Nature produces all of its compounds in normal environmental conditions without a necessity for extreme temperatures or harsh chemicals.

3. **Solar Transformations** – Many organisms respond actively to the sun to maximize their energy absorption

4. **The Power of Shape** – Nature uses many structurally efficient non-orthogonal forms with which to create its structures.

5. **Materials as Systems** – Nature builds from small to large with a corresponding scaling of function in relation to the materials and components involved for particular functions.

6. **Natural selection as an innovative engine** Environmental forces that act on an organism and affect its fitness will direct the development of future organisms.

7. **Material Recycling** – Create structures using materials that are non-toxic and can be fully recycled at the end of their life.

8. **Ecosystems that Grow Food** – Systems are created that have a net surplus of production without a corresponding drawdown of environmental resources.

9. **Energy savvy movement and transport** – Locomotion and internal circulation systems have adapted to require a minimal investment of energy for their purpose.

10. **Resilience and Healing** – Living organisms have the ability to absorb and rebound from impacts and can repair themselves if damage is incurred.

11. **Sensing and Responding** – A series of feedback systems within an organism allow it to sense a variety of environmental factors acting on it and to respond to these in a suitable manner.

12. **Life creates conditions conducive to life** – The waste products and various byproducts of growth and sustenance create materials that are beneficial to the growth of other organisms.

Biomimicry used the Nature's ideas as **Model**, **Measure** & **Mentor** (Fig. 1)

➢ Nature as model

Biomimicry is a science that studies Nature's models and then imitates or takes inspiration from these designs and processes to solve human problems. It focuses on the physical characteristics of natural designs, such as copying the hooks of burdock burrs to make Velcro, or creating wind turbine blades that mimic the shape of a humpback whale's fins. At this level, engineers simply utilize the billion years of evolved efficiencies of nature's physical designs. Biomimicry models in nature are found at three levels: **Form, Process** and **System**.

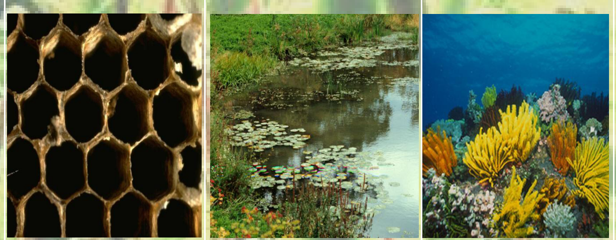


Fig: 1 Biomimicry in nature

- **Nature as measure**

Biomimicry uses an ecological standard to judge "rightness" of our innovations. In the process of evolution, nature has learned: What works? What is appropriate? What lasts?

Is a unique design tool because it avoids trial and error metrics for determining how well a technology will adapt or interfere with nature. Instead, it uses a set of principles, strategies and laws that commonly exist in nature as a template for design.

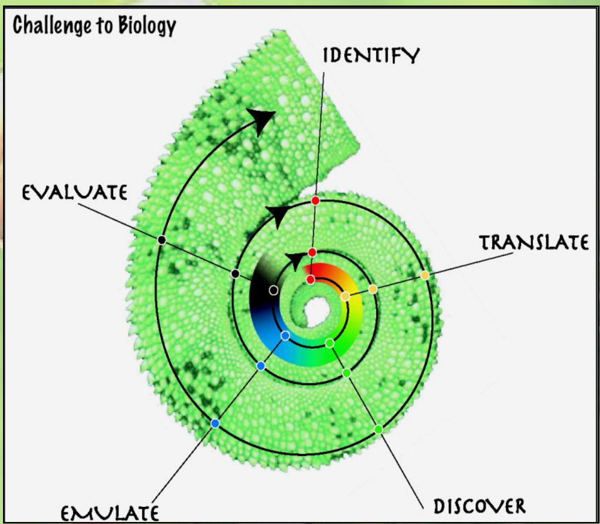


Fig: 2 Biomimicry & design

- **Nature as mentor**

Biomimicry is a way of viewing and valuing the nature. It introduces an era based not on what we can extract from the natural world, but on what we can learn from it (Benyus, 1997). Biomimicry is not just a design methodology but also a paradigm of sustainability. Its main focus is on finding a balance between our natural and constructed environments. It is a science that unites biologists, ecologists, designers, and engineers in a collaborative effort to make efficient and long-lasting designs. It is not only unites technology and biology, but also economics, industry and environmentalism. But biomimicry is about using the steps of emulating form, process and system in nature to guide engineering designs to become more efficient and more fully integrated with nature. The biomimicry design method that allows engineers to observe nature and amaze at the competency and capabilities of our planet. Through this, engineers may also find a respect for nature, and in turn a desire to protect it (Fig 2).

Biomimicry and Biotechnology

Biomimicry is the name coined for this approach in which industrial production systems imitate nature. Industrial biotechnology is that set of technologies that come from adapting and modifying the biological organisms, processes, products, and systems found in nature over millions of years for the purpose of producing goods and services. For example, all energy in natural ecosystems is renewable and is initially captured from sunlight through photosynthesis. Also, all bio-organic chemicals and materials are renewable, biodegradable and recycled. There is no such thing as "waste" – the by-products of one organism are the nutrients for another. Most, if not all, metabolic processes are catalysed by enzymes and are highly specific and efficient. Increased efficiency allows for greater use of renewable resources without leading to their depletion, degradation of the environment and a negative impact on quality of life. Biotechnology can become an important tool for decoupling economic growth from degradation of the environment and the quality of life (Fig 3).

Fig: 3 Application of Biomimicry

Design of Biomimicry

- **Looking to biology**

The approach where designers look to the living world for solutions, requires designers to identify problems and biologists to then match these to organisms that have solved similar issues. This approach is effectively led by designers identifying initial goals and parameters for the design.

- **Biology influencing design**

When biological knowledge influences human design, the collaborative design process is initially dependant on people having knowledge of relevant biological or ecological research rather than on determined human design problems. An example is the scientific analysis of the lotus flower emerging clean from swampy waters, which led to many design innovations. including Sto's Lotusan paint which enables buildings to be self cleaning (Fig 4).

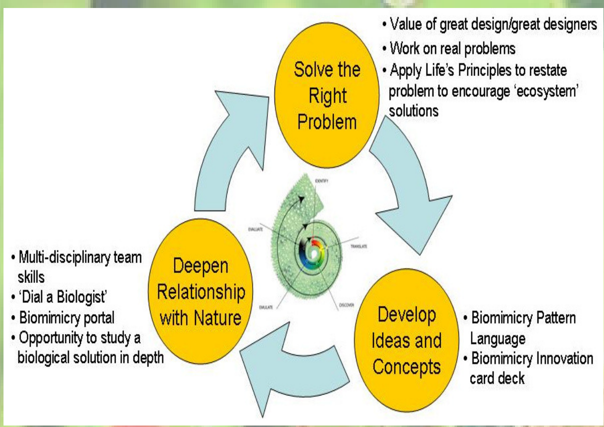


Fig: 4 Step in Biomimicry application and design

Applications of Biomimicking and case study

Biomimicry today operates at three levels: materials, machines, and processes.

A. Materials

Chemists and physicists have spent centuries studying natural structures. One of the great works of Renaissance science was Robert Hooke's 1665 *Micrographia*. But until recently, scientists had a much harder time replicating those structures. Now, though, scientists working in *materials biomimicry* and using nanotechnology has made it possible to understand natural materials in far greater detail, and to design synthetic versions of them.

a. a. Enlightenment and the Lotus

The lotus flower has provided one of the more recent commercial successes. Its remarkable ability to stay clean even in muddy flats attracted the attention of engineers working on self cleaning surfaces. Electron microscopy reveals that the lotus remains clean because of tiny indentations that trap air and prevent water or dirt from its surface. British and German scientists have created a transparent material that is used as a coating on windows (Fig 5)

Fig: 5 Transparent surface coating of building

b. Spinning Webs

Scientists are also closing in on a suggestion of Hooke's to create a synthetic analog to spider's silk. It's long been known that a spider's web consists of several different kinds of silk—the children's classic *Charlotte's Web* discusses them—but recently scientists have begun to unravel how spiders vary the chemical composition of their silk to produce different properties. No company has yet successfully manufactured artificial silk, but several are trying, and no wonder: spider's silk is stronger than steel by weight, and rivals expensive fabrics like Kevlar in its ability to deform and absorb energy, and has serious potential for use in surgery, prosthetics, and defence (Fig 6).

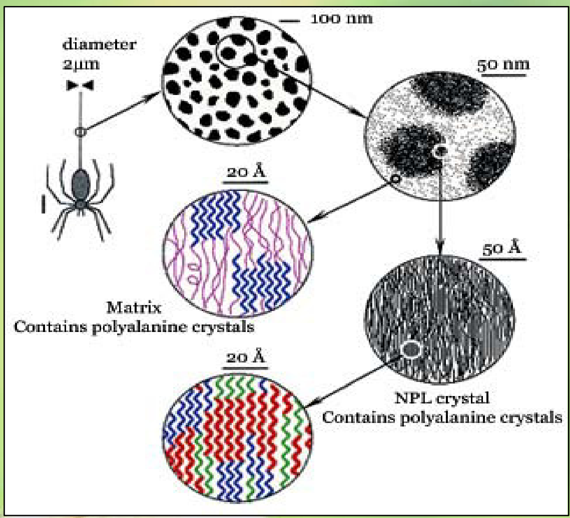


Fig: 6 Spinning web design

c. Hanging Around

Spiders hang around on their webs; but thanks to the nanoengineering on their feet, geckos can hang around on just about any surface. This talent has made geckos one of the most popular laboratory animals in biomimicry research. Scientists have found that geckos have microscopic cilia on their feet that attach to surfaces forces long known to chemists and physicists, but not often encountered, much less exploited, by engineers. Scientists are now trying to create a synthetic gecko tape that can be applied and removed as easily as a Post-It, but adheres without adhesives or chemicals (Fig 7)

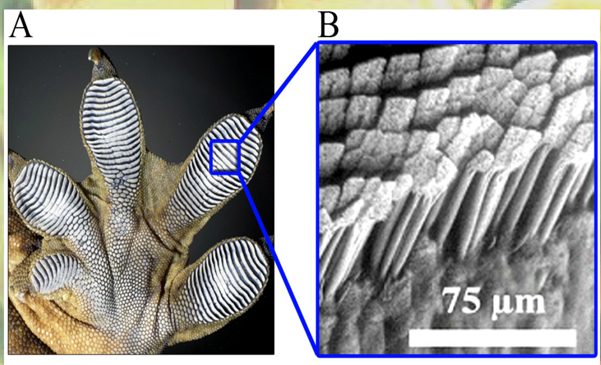


Fig: 7 Synthetic gecko tape

d. Muscle Strength

Finally, shellfish turn out to be some of Nature's most accomplished materials scientists. They can create exceptionally durable shells from a few basic materials, most notably calcium carbonate and proteins. An abalone shell, for example, consists of many alternating layers of calcium and organic polymer, a combination that gives it both strength and the flexibility necessary to form curved shapes; moreover, the polymers orient the calcium molecules in ways that maximize their strength. Other shellfish generate strong adhesives that they use to attach themselves to rocks and reefs; scientists have customized soy proteins to create an adhesive similar to the glue that blue mussels use to bind themselves to rocks. Not only is this cheap— soy is already extensively farmed in the United States, Europe, and Asia—it can also replace more toxic adhesives used in plywood and housing material (Fig 8)

Fig: 8 Calcium carbonate deposition layer

B. Mechanics

While chemists and physicists work at the molecular level with designs first developed by living forms, civil engineers, mechanical engineers and roboticists working in *mechanical biomimicry* are looking to birds, insects, and other animals to improve the design of largerscale devices, like aircraft wings, rotors, and space probes.

a. Improving Wings and Rotors

Mechanical and aerospace engineers are studying birds and insects for clues about how to make vehicles quieter and more efficient. Scientists at NASA's Langley Research Center are working on aircraft wing designs that generate very little noise, thanks to a serrated trailing edge similar to the trailing feathers that make an owl's flight nearly silent. Biologically inspired rotor blades may also appear on wind turbines. Engineers in Britain are working on a radical new turbine blade design based on sycamore seeds, which could dramatically increase the amount of energy generated by wind farms

b. Biorobotics and Microrobotics

Scientists have been working for decades on replicating human locomotion, for the purpose of creating humanoid robots (Sony's Asimo is a good current example), but more recently scientists have begun looking at other animals. A research group of engineers and physiologists at UC Berkeley, Stanford, Johns Hopkins, and Harvard has developed robot cockroaches; they're still larger than even the largest cockroaches, but their legs move in the same scurrying pattern (Fig 9).

Fig: 9 Biorobotics

C. Process

Natural forms are providing scientists with design templates and inspiration at the nanometer scale (in the case of new materials) and centimeter scale (in the case of insects). Process biomimicry applies emerging research on natural processes to innovative designs in architecture, resource conservation, and management. It looks not to spider's webs, but energy and food webs, to understand how to create lighter, more efficient, and sustainable (or self-sustaining) technologies and systems.

a. Architecture

Architects have always designed buildings that fit their environments, by adjusting their height and scale, or by using local materials. In the early 20th century, Frank Lloyd Wright's low, sweeping Prairie Style homes were designed to mimic the plains of the Midwest; at the same time, his California counterpart Julia Morgan used local materials to create a distinctive West Coast style of modern architecture.

In the 1960s, a handful of architects began exploring designs that were more resource and energy efficient, and avoided chemically treated finishes and furnishings. Such tactics are now mainstream, thanks to concerns about energy costs and "sick-building syndrome."

Architects are now moving to design systems that copy natural processes, or draw on their environments in clever ways. Arup Associates' Plantation Place has a ventilation system inspired by human lungs. Located in the center of the City of London, Plantation Place's air supply is drawn from the top of the building, passes through a garden terrace, and then circulates throughout the building: they designed the system after site planners discovered that the air at the top of the building would be considerably cleaner than that at street level. The Commerzbank Tower in Frankfurt. Most famously, the Eastgate Centre in Harare, Zimbabwe (fig. 10b) stays cool from cross breezes generated a ventilation system inspired by giant termite mounds. The ultimate aim of such designs is to create buildings that are designed to function like living organisms. Specifically adapted to place and able to draw all of their requirements for energy and water from the surrounding.

Fig: 10 Commercial building.

b. Natural Resource Management

The African desert has produced other insects whose survival strategies are now inspiring architectural designs. The Namib desert beetle (*Onymacris unguicularis*) has become a model for water collection. The beetle's habitat is one of the driest parts of the world, and the only moisture comes from morning fog. The Stenocara beetle is a master water collector. The small black bug lives in a harsh, dry desert environment and is able to survive thanks to the unique design of its shell. The Stenocara's back is covered in small, smooth bumps that serve as collection points for condensed water or fog. The entire shell is covered in a slick, Teflon-like wax and is channeled so that condensed water from morning fog is funneled into the beetle's mouth. It's brilliant in its simplicity (Fig 11).

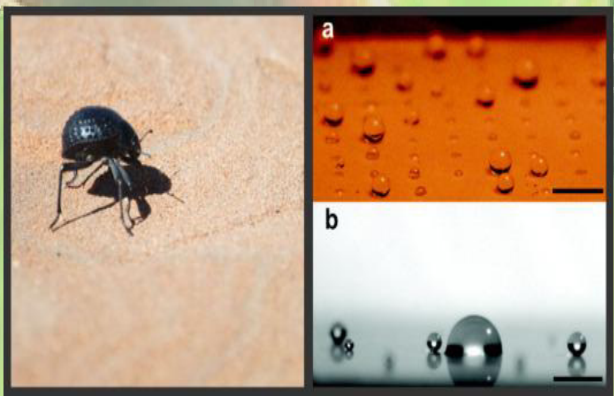


Fig: 11 Water collections by desert beetle.

c. Human Resource Management

Finally, ideas from research in animal communication and behavior are being taken up in management and organizational design. Appeals to Nature are nothing new in organizations, of course; what is new is the push to move beyond metaphor into organizational design. Thus monarchists looked a beehive and saw absolute rule; today, biologists see a model of self-organization and swarming behavior. Students of netwar and smart mobs have already drawn parallels between pack and swarm behavior in the animal and human world; now software developers and project managers are starting to apply lessons from large-scale biological cooperative ventures to the design of distributed, collaborative tools and projects. The hope, as management theorist Ken Thompson puts it, is that by "looking at Nature's most successful biological teams," we can "uncover the secrets of extended cooperation and effective collaboration."

Selected examples of Biomimicry:

- **Secrets of the sandcastle worm: A powerful medical adhesive**

The sandcastle worm makes a protective home out of beads of zirconium oxide in a lab. At the University of Utah, scientists have created a synthetic version of this glue for possible use in repairing fractured bones (Fig 12).

- **Honey bees: Panelite Clear Shade Insulating Glass**

Just as the hub of a bee hive is the honeycomb, the hub of New York-based Panelite's Clear Shade insulating glass unit is its "tubular polycarbonate" core. Modeled after the hexagonal structure of a honeycomb, Clear Shade's core limits sunlight coming through glass thereby reducing heat gains as well as energy costs. Because light rays can only make it through when they hit the glass perpendicularly, the sun is most obscured when it is highest in the sky. At midday, Clear Shade has a low shading coeffcient and a low solar heat gain coefficient—which Panelite touts as "four times better than a typical insulating glass unit (Fig 13).

Fig: 12 Secretion Fig: 13 Honey bee
comb of sandcastle

- **Humpback Whales: Efficient Wind Power**

Whales have been swimming around the ocean for a long time, and evolution has crafted them into a super-efficient form of life. They are able to dive hundreds of feet below the surface and stay there for hours. They sustain their massive size by feeding animals smaller than the eye can see, and they power their movement with über-efficient fins and a tail (Fig 14).

In 2004, scientists at Duke University, West Chester University and the U.S. Naval Academy discovered that the bumps at the front edge of a whale fin greatly increase its efficiency, reducing drag by 32 percent and increasing lift by 8 percent. Companies like Whale Power are borrowing this concept and creating wind turbine blades that greatly boost the amount of energy created per turbine. Other companies are applying the idea to cooling fans, airplane wings and propellers.

Fig: 14 Humpback whale

- **Termites: Sustainable Buildings**

Termite dens look otherworldly, but they are surprisingly comfortable places to live. While the temperature outside swings wildly throughout the day from lows in the 30s to highs over 100, the inside of a termite den holds steady at a comfortable (to a termite) 87 degrees (Fig 15).

Mick Pearce, architect of Eastgate Centre in Harare, Zimbabwe, studied the cooling chimneys and tunnels of termite dens. He applied those lessons to the 333,000 square-foot Eastgate Centre, which uses 90 percent less energy to heat and cool than traditional buildings. The building has large chimneys that naturally draw in cool air at night to lower the temperature of the floor slabs, just like termite dens. During the day, these slabs retain the coolness, greatly reducing the need for supplemental air conditioning.

Fig: 15 Termite den

- **Sea Shells: Flow Without Friction**

Nature moves water and air using a logarithmic or exponentially growing spiral, as commonly seen in seashells. This pattern shows up everywhere in Nature: in the curled up trunks of elephants and tails of chameleons, in the pattern of swirling galaxies in outer space and kelp in ocean surf, and in the shape of the cochlea of our inner ears and our own skin pores. Inspired by the way Nature moves water and air, PAX Scientific Inc. applied this fundamental geometry to the shape of human-made rotary devices for the first time, in fans, mixers, propellers, turbines and pumps. Depending on application, the resulting designs reduce energy usage by a staggering 10-85% over conventional rotors, and noise by up to 75% (Fig 16).

Fig: 16 Sea shell

➢ Trees and Bones: Industrial design to Optimize Strength & Materials

Engineers have incorporated these and other lessons learned from how trees and bones optimize their strength and minimize their use of materials into software design programs, such as Claus Matteck's "Soft Kill Option" software, which are revolutionizing industrial design. Using these programs to design cars, for example, has resulted in new vehicle designs that are as crash-safe as conventional cars, yet up to 30% lighter (Fig 17).

Fig: 17 Trees & Body

➢ Prairies: Agriculture & Food Sustainably

The modern agricultural practices of humankind are also enormously productive, but only in the short term: the irrigation, fertilizer, and pesticide inputs upon which modern food crops depend both deplete and pollute increasingly rare water and soil resources (Fig 18).

The Land Institute has been working successfully to revolutionize the conceptual foundations of modern agriculture by using natural prairies as a model: they have been demonstrating that using deep-rooted plants which survive year-to-year (perennials) in agricultural systems which mimic stable natural ecosystems – rather than the weedy crops common to many modern agricultural systems – can produce equivalent yields of grain and maintain and even improve the water and soil resources upon which all future agriculture depends.

Fig: 18 Prairies agriculture

➢ Human Lungs: Climate change & Carbon Sequestration

Studying the way human lungs work is inspiring new technologies that remove carbon dioxide(CO_2) from sources like flue stacks, preventing this greenhouse gas from reaching our atmosphere and warming the planet. Our lungs have 3 major adaptations which give them their CO_2 removal effectiveness: a super thin membrane, allowing CO_2 to travel across and out quickly (about one 1000th of the period at the end of this sentence), an enormous surface area (if a human laid flat the lungs' gas exchange surface, it would be 70 times the body surface area – about the size of a volley ball court), and specialized chemical translators, namely carbonic anhydrase, which allows CO_2 to be removed from our bloodstream thousands of times faster. In tests by a company called Carbozyme Inc., human-made filters inspired by the way our lungs work removed over 90% of the CO_2 travelling through flue stacks. Meanwhile, other technologies such as mollusks have successfully transformed CO_2 into limestone, which can be stored or used as a building supply (Fig 19).

Fig: 19 Human lungs

➢ Lotus Plants: Natural Cleaning without Cleaners

The lotus flower is sort of like the sharkskin of dry land. The flower's micro-rough surface naturally repels dust and dirt particles, keeping its petals sparkling clean. If you've ever looked at a lotus leaf under a microscope, you've seen a sea of tiny nail-like protuberances that can fend off specks of dust. When water rolls over a lotus leaf, it collects anything on the surface, leaving a clean and healthy leaf behind (Fig 20).

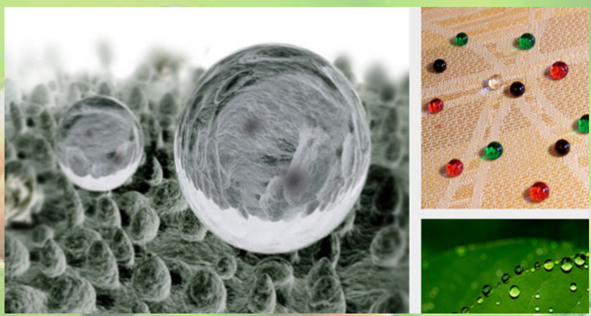


Fig: 20 Lotus plant

➢ Kingfishers: Transportation Efficiency

The Shinkansen Bullet Train of the West Japan Railway Company is the fastest train in the world, traveling 200 miles per hour. Noise. Air pressure changes produced large thunder claps every time the train emerged from a tunnel, causing residents one-quarter a mile away to complain. Eiji Nakatsu, the train's chief engineer and an avid bird-watcher, asked himself, "Is there something in Nature that travels quickly and smoothly between two very different mediums?" Modeling the front-end of the train after the beak of kingfishers, which dive from the air into bodies of water with very little splash to catch fish, resulted not only in a quieter train, but 15% less electricity use even while the train travels 10% faster (Fig 21).

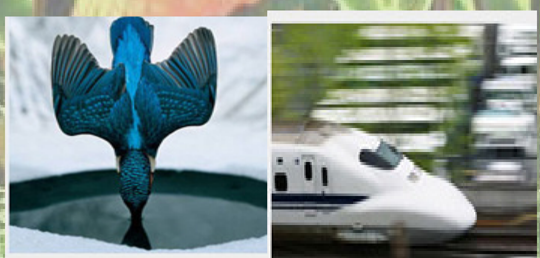


Fig: 21 Kingfisher body

➢ Chimpanzees: Medicine to Heal

By observing how chimps and other species cope with illness, researchers have acquired leads on plants with promising medical applications to human health. Trees from the Vernonia genus, for example, which chimpanzees regularly seek out when ill, have been found to contain chemical compounds that show promise in treating parasites such as pinworm, hookworm, and giardia in humans (Fig. 22).

Fig: 22 Chimpanzees

➢ Dolphins: Warn People about Tsunamis

Tsunami waves dozens of feet high when they reach shore may only be tens of centimeters high as they travel through the deep ocean. In order to reliably detect them and warn people before they reach land, sensitive pressure sensors must be located underneath passing waves in waters as deep as 6000 meters. The data must then be transmitted up to a buoy at the ocean's surface, where it is relayed to a satellite for distribution to an early warning center. Transmitting data through miles of water has proven difficult, however: sound waves, while unique in being able to travel long distances through water, reverberate and destructively interfere with one another as they travel, compromising the accuracy of information. Unless, that is, you are a dolphin. Dolphins are able to recognize the calls of specific individuals ("signature whistles") up to 25 kilometers away, demonstrating their ability to communicate and process sound information accurately despite the challenging medium of water. By employing several frequencies in each transmission, dolphins have found a way to cope with the sound scattering behavior of their high frequency, rapid transmissions, and still get their message reliably heard. Emulating dolphins' unique frequency-modulating acoustics, a company called EvoLogics has developed a high-performance underwater modem for data transmission, which is currently employed in the tsunami early warning system throughout the Indian Ocean (Fig 23).

Fig: 23 Dolphin

- **Sharkskin: Swimsuit**

Sharkskin-inspired swimsuits received a lot of media attention during the 2008 Summer Olympics when the spotlight was shining on Michael Phelps (Fig 24).

Seen under an electron microscope, sharkskin is made up of countless overlapping scales called dermal denticles (or "little skin teeth"). The denticles have grooves running down their length in alignment with water flow. These grooves disrupt the formation of eddies, or turbulent swirls of slower water, making the water pass by faster. The rough shape also discourages parasitic growth such as algae and barnacles.

Fig: 24 Shark skin

- **Burr: Velcro**

Velcro is widely known example of biomimicry. You may have worn shoes with velcro straps as a youngster and you can certainly look forward to wearing the same kind of shoes in retirement (Fig 25).

Velcro was invented by Swiss engineer George de Mestral in 1941 after he removed burrs from his dog and decided to take a closer look at how they worked. The small hooks found at the end of the burr needles inspired him to create the now ubiquitous Velcro.

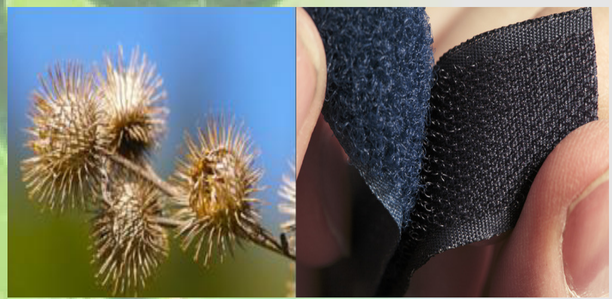


Fig: 25 Burr

- **Birds: Jets**

Birds have been able to boost the distance they're able to fly by more than 70 percent though the use of the V-shape. Scientists have discovered that when a flocks takes on the familiar V-formation, when one bird flaps its wings it creates a small updraft that lifts the bird behind. As each bird passes, they add their own energy to the stroke helping all the birds maintain flight. By rotating their order through the stack, they spread out the exertion (Fig 26).

Fig: 26 Birds flight

- **Cacti: Ideas for desert living**

They manage to stay cool in a broiling climate. Look at the building on the left and you can see some of the ideas that make cacti a cool model for building design (Fig 27).

See the fuzzy objects sticking out from the building? Those mimic cactus spikes and form a thicket of shade down the side of the structure. The swollen shape, with a wider middle, leaves the lower part in shade during the hottest part of the day when the sun is directly overhead.

Cacti also seal up during the day, and do their breathing at night, when the desert cools. These ideas — from the shape to the spikes to air systems that refresh at night — are being used in scorching climates to help buildings keep cool.

In the Middle East, a new government building in Doha, Qatar will sprout a cactus form.

Fig: 27 Cactus design

➢ Pine cones: Open and Shut Case

Pine cones care about the weather. Female cones harbor seeds and male cones shelter pollen. Wind blows pollen from the male over to the seeds to make new pine trees. When it's wet and rainy pine cones close up so their seed and pollen won't wash away. When it's dry outside they open up. Dry air makes good weather for pollen to travel, and it's the right climate for launching fertile seeds that will fly lighter and further (Fig 28).

All of this is automatic and uses no energy from the tree. There are complex tiny composite fibers in the cones that twist one way when dry, and the other when wet to open and close the cone.

Inventors are copying the moisture-controlled structure for human uses. They are testing buildings that can seal up when it's hot and sticky and cool themselves when it's dry. They are testing clothing with tiny structures that open or seal depending on the weather. When you are hot they breathe, and when you are cool they close up to keep you warm.

Fig: 28 Pine cone

➢ Leaf Power: Solar energy storage

Plants can take that cascade of light and store it so it can supply the power needs of most of the natural world. They can store solar energy because they generate an electric current when struck by sunlight that kicks off their energy-making process (Fig 29).

It's simple, and we've studied it under the name photosynthesis. But no one really knows how it works. What's the trigger? MIT researchers have developed a new catalyst, consisting of cobalt metal, phosphate and an electrode. When the catalyst is placed in water and electricity runs through the electrode, oxygen gas is produced. When another catalyst is used to produce hydrogen gas, the oxygen and hydrogen can be combined inside a fuel cell, creating carbon-free electricity to power a house or an electric car, day or night.

A system to fuel your personal electrical needs from water and sunlight could turn us all into power plants.

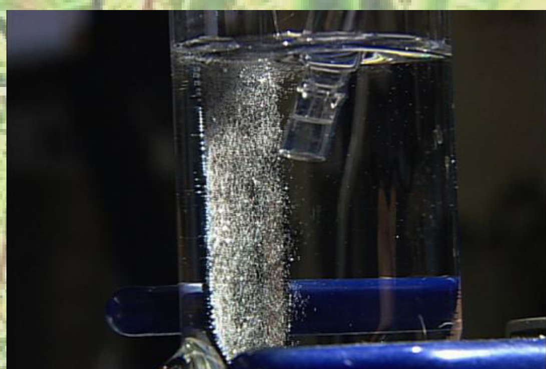


Fig: 29 Leaf Power

➢ Apostle bird's mud nest: Construction

The mud nest of the apostle bird is a sturdy home high in the trees, built using a jiggled-mud construction technique. Closely related to the magpie lark are two other Australian birds of the open forest, the apostle bird and white-winged chough. They build substantially larger nests, weighing up to five pounds, located as much as fifty feet above the ground. But even these scaled-up versions of the adobe cup with their inch-thick walls are manufactured with the same jiggled-mud strategy that seems to be universal among birds that build with wet earth. But then vibration is a key feature in the insertion of twigs and grasses into conventional nests, so this may be a bit of behavioral recycling (Fig 30).

Fig: 30 Bird's mud nest

Example inventions based on/or inspired by animals:

- Airplanes modeled after **birds** (wing and body shapes, falcon beak)
- Morphing airplane wings that change shape according to the speed and length of a flight, inspired by **birds** that have differently-shaped wings depending on how fast they fly
- Boat hulls designed after the shapes of **Fish**
- Torpedoes that swim like **tuna**
- Submarine and boats hull material that imitates **dolphin** and **shark** skin membranes
- Radar and sonar navigation technology and medical imaging inspired by the echo-location abilities of **bats**
- Adhesives for microelectronics and space applications inspired by the powerful adhesion abilities of **geckos** and **lizards**
- Water filters designed like **animal cell membranes** to let certain things pass through while others are kept out
- Running shoes with technology learned from studying the mechanics of **animal feet**
- Super strong and waterproof silk fibers made without toxic chemicals by **spiders**
- Ceramics and windshields, after the mother of pearl material made by **abalone mussels**
- Underwater glue for slippery surfaces, as made by **mussels**
- Anti-reflective, anti-glare film used for flat panel displays, touch screens, lamps, and phone and PDA lenses replicates the nano-structures found in the eyes of night flying **moths**
- A better ice pick for mountain climbers designed after the **woodpecker**.
- Glow sticks made with light-up chemicals, just like **fireflies**
- Very efficient pumps and exhaust fans applying the spiraling geometric pattern found in **nautilus sea shells**, galaxies and whirlpools

Example inventions based on/or inspired by plants

- Hook and loop material (Velcro) inspired by **cockleburs**
- Solar cells inspired by **plant leaves**
- maximize A wind-driven planetary rover design that drag, learned from the **tumble weed**
- Reduced-drag propeller designs inspired by the spiral shape of **kelp**, which moves with the current rather than fight it, so much less energy is required to move water or ship
- Self-cleaning exterior paint, tiles, window glass and umbrella fabric inspired by the slick leaves of the **lotus flower plant** and its natural ability to wash away dirt particles in the rain
- Filter and clean water like a **marsh**

FORTHCOMING EVENTS		
Events	**Date**	**Place & Correspondence**
5th International Conference on Environmental Science and Development-ICESD- 2014	19-20 Feb, 2014, Singapore	Singapore http://www.icesd.org
Waste Management, Recycling, Environment (Save the Planet)	5-7 March 2014 Sofia, Bulgaria	Sofia, Bulgaria http://www.eco.viaexpo.com/en/pages/waste-management-recycling-exhibition
7th International Conference on Design and Nature	9 - 11 July, 2014,UK	Opatija, Croatia wessex.ac.uk/design2014

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