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Biomimicry: The Path towards Sustainable Evolution

Kartikaye Shah,Yashpal Singh Chouhan, Rishabh Varma, Mantu Kumar Gupta

(Department Of Mechanical Engineering, Chandigarh University, Mohali, Punjab.
Email: kartikaye.shah@gmail.com)
(Department Of Mechanical Engineering, Chandigarh University, Mohali, Punjab
Email:ys1998chouhan@gmail.com)
(Department Of Mechanical Engineering, Chandigarh University, Mohali, Punjab
Email:rishabhvarma09@gmail.com)
(Department Of Mechanical Engineering, Chandigarh University, Mohali, Punjab
Email:mantukumar1803@gmail.com)

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Abstract:

An evolution of two centuries has altered the face of the earth from a network of orbiting satellites to self-driving cars. But all this evolution is having a catastrophic impact on Earth's ecosystem because we failed to build our technologies as sustainable as earth. Nature is the supreme architect which has sculpted the earth into a self-sustaining ecosystem with 3.8 billion years of evolution. Nature itself is an ultimate example of a self-sustaining system and the study of acquiring nature's technique in our design is called Biomimicry. This file explains how biomimicry can be the solution against environmental degradation by learning the most natural and sustainable way of executing a task, the advantages of biomimicry in designing, great inventions mimicked from nature, upcycling of waste. The paper also puts up numerous question and tries to answer them:

- What is Biomimicry?
- How human made systems differ from biological systems?
- How does nature inspire Modern Designs?
- How biomimicry contributes towards sustainability?

Keywords- **Biomimicry, design, self-sustaining ecosystem, upcycling, closed loop system, manufacturing, bio-polymers.**

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LITERATURE REVIEW

In this file Biomimicry is classified as the most sustainable source of energy. Many research paper and blogs were referred during the process the most influential being "Biomimicry Level as an approach to architectural sustainability" by Mehran Shahda, Biomimicry as "Innovation: a systematic review" by Negin Imani and researches of Janine Benyus who coined the term 'Biomimicry' who puts her work it her website asknature.org which answers all the questions about what nature can do to help sustain modern technologies. Every innovation was validated with their respective websites and all the statistics are from reliable sources. There were unscripted oral lectures which I received through ASME and TED Talks of Janine Benyus which were also a source of information for this research paper. After going through much of the previously done research it was observed that Biomimicry's contribution in the evolution of is not clearly highlighted .Though its states all the advantages of applying biomimicry to variety of field but in lacks the conclusion of the application biomimicry has helped and will help in the future in order to make

our technologies more sustainable, ecofriendly and how it is the only way we decrease the human impact on earth.

INTRODUCTION:

Biomimicry is a practice of imitating life. It looks to nature to provide inspiration and direction in order to sustainably solve the complex challenges we face in the modern world. From ages we have tried to create things that are inspired from nature such as airplanes, flippers, bullet trains, wind turbines etc. because the designs that pre-exist in nature are the best possible design/systems to perform a particular task.

Human beings are very clever and have dominated all the other species in the world. We have created societies, living structures , wireless technologies but with all the exponential evolution, we have created challenges for our own survival. Phenomenon like pollution, global warming, droughts, depletion of ozone layer, exhaustion of resources such as fresh water and fossil fuels is a path towards a wipe out of Life from earth. Scientists and engineers are working day in and day out to invent new technology to prevent this apocalypse and in that quest they have come back to nature. In this research paper we see the modern technologies which have been inspired by nature and help in a sustainable ecosystem for earth.

WHAT IS BIOMIMICRY?

The word biomimicry is derived from Ancient Greek where "bio" means life and "mimic" means to imitate.This term was first given by a biologist named Janine Benyus in 1997. Biomimicry is an emulation of designs, patterns, systems, and elemental structure that are present in nature in order to solve modern problems. Scuba flippers mimicked from a duck, a B2 stealth Bomber jet inspired from a Falcon, Bullet train with a nose inspired from a kingfisher, modern ball and socket joints in machines which are copied from human skeletons and many more. All these designs helps to improve the efficiency of the function because those designs have already been tested by nature.

Plants and Animals have engineered through 3.8 billion years of existence. The one who failed to adapt through evolution , got extinct and those survived have huge amounts of data from years of research and development which we can use in our modern technologies to make them eco-friendly and sustainable.

THE BIOMIMICRY APPROACHES

Biomimicry has the capability to bring our ideology closer to Nature. It inspires us to design sustainable solutions to human problems. Biomimicry links the built environment to the natural world by striving to use mother nature as a model, a standard of measure, and a mentor.

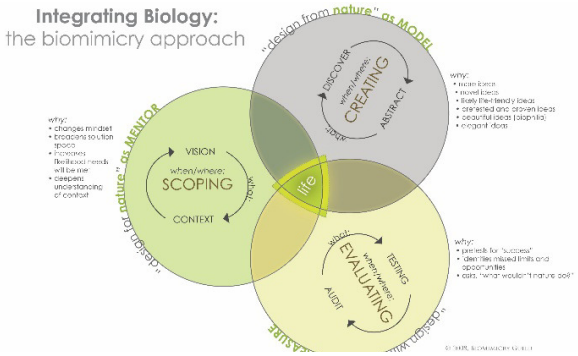

Figure 1: Viewing nature as a design model, measure, and mentor

Nature as a model	Nature as a measure	Nature as a mentor
"Design from nature" Taking inspiration from nature for sustainable designing. e.g- solar cell inspired by leaves.	**"Design with nature"** Making standards to keep a check on the **rightness** of our innovation. Asking "What wouldn't nature do?"	**"Design for nature"** Learning to respect nature and focus on giving it back to nature by learning from it instead of exploiting it.

By looking at this approach we get to know biomimicry in a broader sense. Making designs inspired from nature is just a part of it while it means to make processes as ecological as possible.

HOW HUMAN MADE SYSTEMS DIFFER FROM BIOLOGICAL SYSTEMS?

It has been just a few thousand since humans have started developing systems which solve our problems. We have come a long since the invention of the wheel to interplanetary rockets still there is a lot to learn from nature as it has such complex systems which leaves no waste. biological systems have no end of the cycle like we have in human made systems as everything is in a closed loop. Every system is self-sustaining and unique in its own way. Here are some of the key differences between a human made system and a biological system.

Human made system	Biological system
Simple	complex
resistance to change	Adapted to constant change
Wasteful	Zero waste
Disconnected and mono-functional	Densely connected and integrated
Linear flows of resources	Closed loop flows of resources
Toxins often used in process	No toxins are used
350+polymers are used	5-6 polymer make 90% of the structures
Simple structure	Complex structures
Extractive	Regenerative
Fossil fuel dependent	dependent on solar energy

ADVANTAGES OF BIOMIMICRY

Biomimicry thinking helps create products and processes that are:

1.Sustainable: Biomimicry follows Life's Principles. Life's Principles train us to work from the base up, self-amass, improve as opposed to expand, utilize free energy, cross-fertilize, embrace variety, adjust and advance, and use life-accommodating materials and cycles, take part in cooperative connections, and upgrade the bio-circle. By following the standards life utilizes, you can make items and cycles that are very much adjusted to life on earth.

2. Perform well: In nature, if a plan system isn't compelling, its transporter bites the dust. Nature has been confirming techniques for 3.8 billion years. Biomimicry assists you with contemplating the effective procedures of the survivors, so you can flourish in your commercial center, similarly as these methodologies have flourished in their environment.

3. Saves Energy: Energy in the regular world is considerably more costly than in the human world. Plants need to trap and change over it from daylight and hunters need to chase and catch it. Because of the shortage of energy, life will in general sort out amazingly energy proficient plans and frameworks, streamlining energy use every step of the way. Imitating these proficiency techniques can drastically lessen the energy utilization of your organization. More prominent proficiency means energy cost investment funds and more noteworthy benefit.

4. Cut material costs: Nature works to shape, since shape is modest and material is costly. By considering the designs of nature's procedures and how they are assembled, biomimicry can assist you with limiting the sum your organization spends on materials while boosting the adequacy of your items examples and structures to accomplish their ideal capacities.

5.Build your brand: Making biomimetic items and cycles will help your organization become known as both creative and proactive about the climate.

HOW DOES NATURE INSPIRE MODERN DESIGNS?

There are numerous examples of exceptional designs which came out of nature which would've asked for years of research and development for achieving the same result without nature's inspiration. Some of them are listed below:

1. Impeller Inspired from Calla Lily

The spiral shape exists everywhere we see in the nature, from pattern in flowers and sea shells to the vortex of a whirlpool. Spiral is a shape in nature which concentrates energy to a single point which makes it very efficient. People at PAX Walter technologies saw the spiral shape of calla lily and got inspired to implement this geometry into the impellers. The bio mimicked impeller design is so efficient that a 6 inch tall impeller can circulate millions of gallons of liquid in the tank.

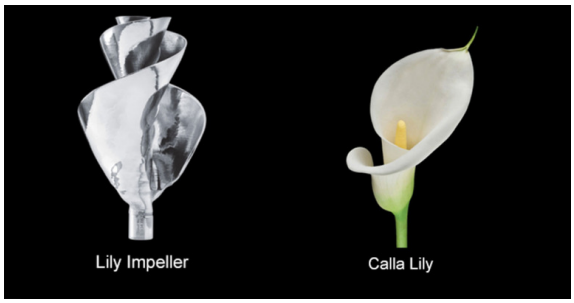

Figure 2 : Impeller inspired by Calla Lily

Due to its small size it takes less raw material and machine for manufacturing, due to its small size motor consumes less power. This is an example of how efficient nature is, we just need learn and implement the most out of it.

2. Velcro inspired from Cocklebur Seeds.

The invention of Velcro is one of the greatest example of biomimicry. The idea of Velcro came in the mind of a swissengineer ,George De Mestral who was walking his dog in the woods while he noticed the Cocklebur seeds got stuck on its fur. The burr seeds had hook like structures at the end which helped the seeds to stick firmly with the animal fur for pollination.

Figure 3:Velcro inspired from Cocklebur

This led to the invention of Velcro which is now used in every bag, clothing, shoes and all sorts of different devices and accessories which are to be temporarily attached to each other repetitively.

3. Innovations from the Structure Shark Skin

The skin structure of shark has recently been one of the most eye catching structure in the design industry. Unlike other water creatures like whales and dolphins who tend to have a tendency to grow algae or barnacles on their skin the sharks despite their slow speed have no bacterial growth. This is due to a distinct structure of their skin which does not let the bacteria sit on their skin thus keeping the shark's skin bacteria free. These structures were observed by researcher and scientists andthey used it in making surfaces anti-bacterial.

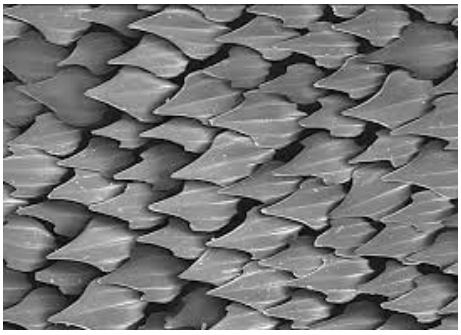

Figure 4 : microscopic view of shark scales

A company call Sharklet technologies which observed the problem of "antimicrobial resistance" which causes death of almost 35,000 death in the US alone(AR Threat Report US,2019).They are creating medical devices with the similar nanostructure as that of shark's which showed a significant loss in bacteria sticking with the surface. This was due to the high surface energy of the shark skin texture which does not allow the bacteria to sit on the surface.

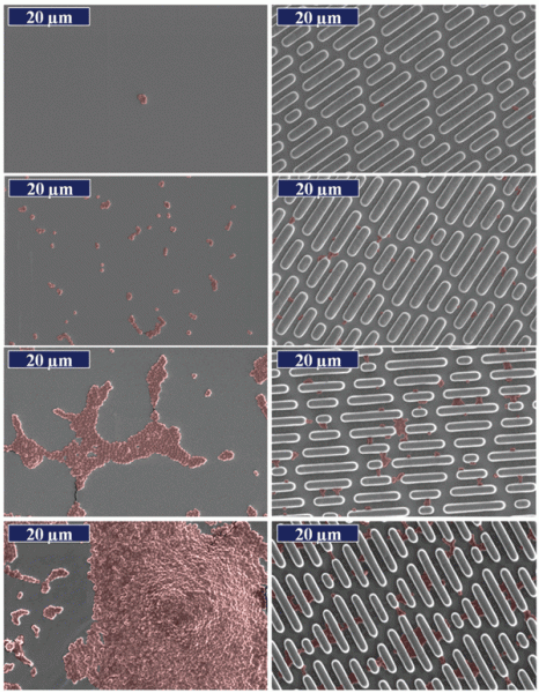

Figure 5: plain surface vs shark textured surface

The figure above shows the difference between a plain surface and a textured surface inspired by a shark's skin and the difference in bacteria accumulation is evident. This innovation can be very useful in times like today when the world is suffering from a pandemic and innovations like these can prevent the virus and bacteria from sticking to surfaces.

4. Drag Efficient windmills from Humpback whales

Humpback whales are among the largest mammals on earth weighing around 30,000kg .Despite their enormous size they easily maneuver around in the ocean very swiftly. This was observed by a marine biologist Frank Fish and he noticed the bumps(also known as 'Tubercles') on the fins of the whale. This was observed to give a 20% drag efficiency while swimming, it also helps the whale change its direction veryeasily.

Figure 6: Tubercles on Humpback whales fin.

Frank Fish along with 2 other people started a company called Whale power which are making energy efficient windmills which are able to generate 15% more energy by decreasing drag.

Figure 7: wind turbine and a pc fan

They are in true sense used biomimicry in order to create a source of sustainable energy. They also work with other companies and help in making new concept designs of efficient water turbines, fans and even airplane wings.

5. Bullet trains inspired from Kingfisher

Figure 8: Bullet train inspired by kingfisher

In 199 Japan Shinkansen Bullet train was set for a launch but it had a major problem. The train was really fast around 270 kmph due to which whenever it existed a tunnel, it made a loud sonic boom which disturbed the residents living nearby. The challenge was to make the train quieter without compromising on the speed ,that's where the kingfisher came into play. EjiNakatsu , the General manager was an avid

bird watcher and he observed that the kingfisher never left a splash whenever it dived inside the water. This was due to the design of its beak which had a very aerodynamic shape. This inspired the engineer to implement the same design principle on the nose of the train. He also designed the pantograph as the shape of an owl's wing span and the supporting shaft in the shape of Adelie penguin which made the pantograph more aerodynamic.

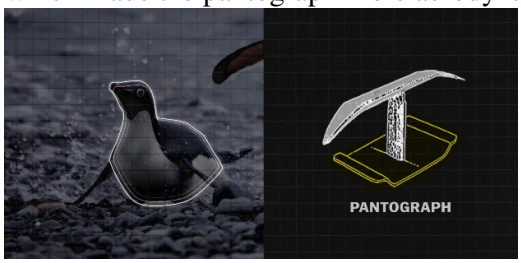

Figure 9: pantograph of train mimicked from Adelie penguin

All these changes when applied to redesigned Bullet Train, it became 10% faster, uses 15% less electricity and remained well under the 70db limit in the residential area. This train was one of the greatest example of how powerful natures design can be. While a team of experienced scientists and engineer failed to design a fast and quiet train, the answer existed in the nature itself. The Shinkansen bullet train then became the inspiration for all the bullet train around the world.

6. Air purifiers inspired from Butterflies

Every year millions die from diseases caused by air pollution traditionally catalytic converters have been used outside to clean toxic fumes and these contain catalysts materials that accelerate chemical reaction without being degraded themselves however many catalysts contain expensive metals and require high temperatures to work, ruling them out for indoor use inside air purification systems can be used but they tend to used expensive filters and many are unable to capture the smaller particles which pose a threat to health, so it may come as a surprise that a family of butterflies has inspired a particularly creative solution this global problem.

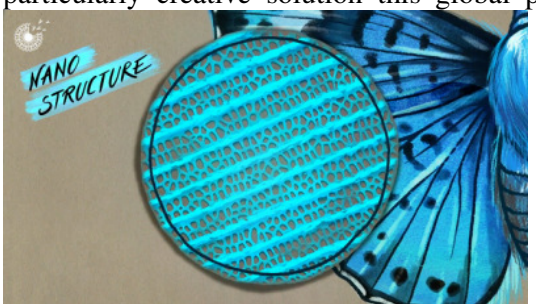

Figure 10: Nanostructures of metalmark butterfly

They may not realize it but the Metalmark family of butterflies are masters of nanotechnology the wings of these butterflies are made from nanostructure that manipulate lights but also allows them to be strong, lightweight and waterproof and a team at metalmark innovations has found a way to create a lab-based version of these nanostructures this has allowed them to produce low-cost catalysts capable of cleaning of both outdoor and indoor air by placing tiny particles of catalytic metals within the butterfly-inspired lattice, the team were able to maximize the amount of catalyst exposed to polluted air whilst massively reducing the amount of materials required this also allows them to reduce the operating temperatures which produces a cost effective air purification system that is also capable of targeting the very small pollutant particles which pose a threat to health not bad for a pair of butterfly wings

LEVELS OF BIOMIMICRY

There are three levels of Biomimicry- Nature is the inspiration for the formation ,mimicry of how an organism behaves and ecosystem. The first level refers to a specific organism like a plant or animal and may involve mimicking part of or the whole organism. The second level refers to mimicking behaviour, and may include translating an aspect of how an organism behaves, or relates to a larger context. The third level is the mimicking of whole ecosystems and the common principles that allow them to successfully function.

Levels of Biomimicry		
Organism level- Taking inspiration a single organism	Behaviour level- Studying the behavior of organism	Ecosystem level- simulating nature as a complete system.

FIRST LEVEL OF BIOMIMICRY- ORGANISM LEVEL

With the evolution of billions of years, each organism has perfected itself in order to survive in its natural habitat and has developed distinct sets of features which are studied by engineer , architect and scientist in order to make sustainable designs. The First level of biomimicry is mimicking the structure and special features of a particular as animal in order to innovate new technologies. The bullet train inspired from a kingfisher, water repellent Lotus leaves mimicked into water repelling paint , a robotic arm ispired from an elephants trunk are just a few examples of first level of biomimicry.

Ultra-Strong 3D material inspired by Mantis Shrimp.

This shrimp help us design the stronger and more lightweight materials and can be used as ultra-strong 3D printed material. A decade ago, researchers from California University had begun to unravel the mystery of the shrimp success. They discovered that the material that makes up the clubs was arranged internally in a spial like structure knowing as a helicoid.

Figure 11: Mantis shrimp

This is an amazing shock absorbing structure, formed from sheets of parallel fibres which are stacked and rotated and allowing to dissipate energy efficiently and now by reverse engineering this natural architecture the company helicoid industries have been able to incorporate it into the modern design of the composite materials.

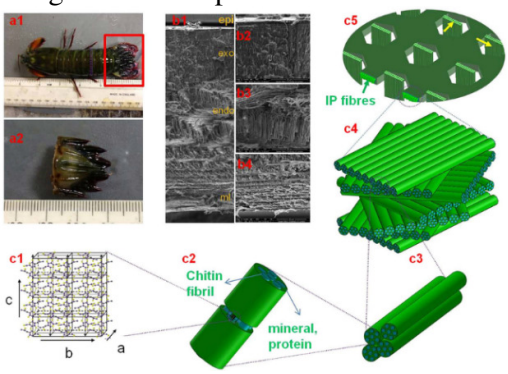

Figure 12: helicoid structure of clubs of mantis shrimp

The benefits of using helicoid is that they have a very small surface area and are formed from a far less material than solid by using them in composites helicoid industries can massively reduce the amount of raw materials used in production, making them lighter with a smaller environmental footprint all without sacrificing strength.There plan is to use them in natural structures into materials to build things like wind turbines, cars, sporting goods and airplanes and this enhanced design would allow for more fuel-efficient vehicles as well as allowing for longer and stronger turbine blades increasing their overall energy output.

SECOND LEVEL OF BIOMIMICRY- BEHAVIOR LEVEL

The second level of biomimicry studies how an organism or a group of organism interact with their environment. The behavioral study of organisms and of how the organism deals with problems is the behavioral level of biomimicry. A termite mound inspiring the ventilation system of a building sand a desert beetles ability to collect fog as droplets inspiring fog harvesting are the examples of second level of biomimicry.

Building inspired from Termite Hills

The East Gate Complex designed by Mick Pace, recreating termite hills by employing negative

ventilation technology, control climate and make warm equilibrium environment. Termites that are found in Zimbabwe orchestrate hills that are kept exactly at 87 F, whereas climate outside range over 35 F to 104 F. These termites are able to accomplish this by opening and closing warming and cooling vents periodically whole day.

Figure 13:Eastgate building inspired from termite hill

The Eastern Gate building which was planned by designer Mick Pace virtual design for termite hills, uses 10% less energy than customary structure, therefore which results in lease to lessen by 20% than rest of the building Mick Pearce said during meeting- "I entertainingly enough invested a ton of energy contemplating termite homes and justifying that they're clever than us in controlling common habitat which is permeable.

These extraordinary hills which they work in nature are not like palaces we construct to flaunt; in fact, they are like lungs. The sole purpose of these to lengthen the structure. The termite hill is like body of an organism and termites are like blood cells moving inside the body. They built these structures and respirate. They allow flow of air through their overlay

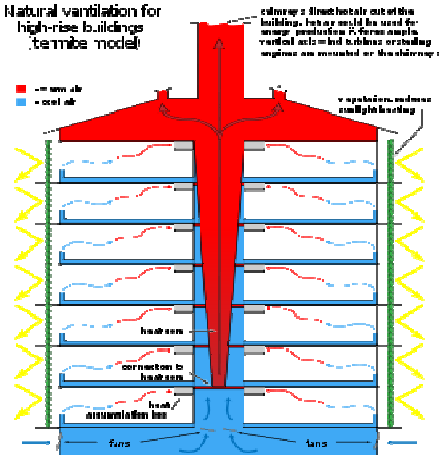

Figure 14: structure of Eastgate

THIRD LEVEL OF BIOMIMICRY - ECOSYSTEM LEVEL

Mimicking the ecosystem is the fundamental goal in biomimicry, often termed as Eco-mimicry means to make our human habitats sustainable by getting inspired by nature. Ecosystem is self-sufficient and restorative, here are some key features of an ecosystem:

- Ecosystems are dependent on contemporary sunlight.
- Ecosystems optimize the system rather than its components.
- Ecosystems are attuned to and dependant on local conditions.
- Ecosystems are diverse in components, relationships and information.
- Ecosystems create conditions favorable to sustained life.
- Ecosystems adapt and evolve at different levels and at different rates.

All these characteristics must be kept in mind while constructing a man-made ecosystem. We are not technologically advanced enough to imitate the whole natural ecosystem but there are some advancements which have mimicked nature to an ecosystem level.

CALIFORNIA ACADEMY MUSEUM GREEN ROOF

Figure 15:California academy museum green roof

This structure receives leed rating which is platinum rating in layman term. The structure planned by designer Renzo Piano. The vital highlight of the exhibition is green rooftop which impersonates the inclining rows of encompassing scene. A part of rooftop will be available to guests. The new academic building will have a planetarium, aquarium and presentation rooms. All this will be available to the people by 2008. Beside its extraordinary rooftop, the structure in itself is an accomplishment of green structure institution, it has utilized day lighting, water biofuels and effective use of energy.

Figure 16: Diagram of the California green roof museum.

The Success in Achieving Design Sustainability

The actual rooftop is assessed to forestall roughly 2,000,000 gallons of water from turning out to be storm-water spillover, Storage arrangement of ice for cooling, Agriculture Inclined plane without slide, took a patent called "biotray".

- Plants convert CO2 into O2.
- On the roof, posts are set up to observe the air, temperature, rain, wind and notify the negative automated system to ventilation

A similar Green building has been made in Dehradun ,India By ONGC which provides a sustainable office space.

Figure 17: UurjaBhawan, Dehradun.

HOW BIOMIMICRY CONTRIBUTES TOWARDS SUSTAINABILITY?

With all the above examples we earn how diverse the effect of biomimicry can be. It has application varying across different application. Be it production of energy or be it waste management, nature has the most efficient and sustainable way to perform a task. The earth's ecosystem on its own was a fully self-sustaining and it did not require any help from humans , but due to extensive exploitation of earth resources and generation toxic non-biodegradable material is making it unsuitable for life. Global warming , air pollution , water pollution , Radioactive waste dumping are just a few reasons which are contributing in making earth inhabitable. Biomimicry is the method adopted by scientist in order to cope with these problems and they have found the answer from the nature:

Alternative to plastic: Over 380 million tons of plastic are produced every year for use in a wide variety of applications.At least 8 million tons of plastic end up in our oceans every year, and make up 80% of all marine debris from surface waters to

deep-sea sediments. Scientists have come with new technologies which guarantees to replace plastic as the new polymers promise to hold all the properties of a plastic but are bio degradable.

There is a type of plastic which is inspired by the waterproof covering membrane of the fruits and vegetables and is used to store water instead of water bottles.

Figure 18: Water Blobs

These small water blobs invented by Skipping Rocks Lab are edible with their covering as it is made up of a seaweed extract. Many such bio-plastics are emerging which have the potential to eliminate plastics in order make earth more sustainable

Absorption of Carbon dioxide: Nature uses Carbon dioxide as a building block where organism emit carbon dioxide while plants sequester that Co2 in order to use carbon as its building block and emitting back oxygen back into nature. Concrete is recently the 2nd biggest source of carbon footprint on the planet emiting around 1 ton of co2 for every ton of concrete produce and this concrete jungle is increasing the co2 levels exponentially.

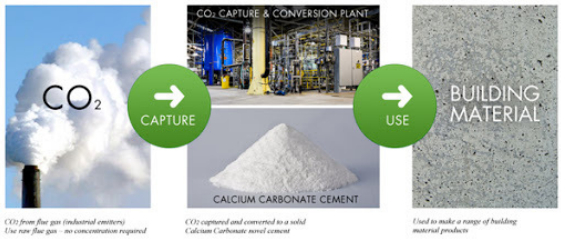

Figure 19: sequestering CO2 in forming concrete.

A researcher from Stanford devised a method to make concrete with the help of CO2 and sea water just like the corals form their exoskeleton. He opened up a company named Calera which sequesters 0.5 tons of Co2 for the manufacturing of every ton of concrete and if it could replace the conventional concrete it will help in making environment much more sustainable.

All these invention are not only inspired from nature but also contribute in saving of ecosystem from collapsing. These are great innovations but we need to come up with some innovative ideas which focus on certain problems and solve them with help of biomimicry. Some of the aspects we should focus upon while innovation are mentioned below:

1. Ways to cut down on existing non-biodegradable waste.
2. Way to make our waste management system more efficient.
3. Ways to keep control over our toxic emission.
4. Ways to decrease carbon footprint.

In order to save the Earth from an undoable damage we have to learn from the nature itself and create a symbiotic relation with nature.

CONCLUSION

- This paper stated how biomimicry can be such an advanced and infinite field for gaining knowledge about sustainable designs and function.
- It shows the advantage of biomimicry over mainstream designs and examples to show its diverse field of application and how they have contributed to sustainability directly or indirectly.
- With all the brilliant designs and processes devised from biomimicry , the file justifies how biomimicry plays a major role in showing a sustainable and efficient path towards evolution.
- We still have a lot to learn from nature as there are organism which have already solved problems which researchers still struggle to solve and we canaddress those problems just by brainstorming on ideas inspired from nature.

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