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BIOMIMICRY: LEARNING FROM NATURE

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ABSTRACT

Biomimicry or **biomimetics** is the imitation of the models, systems and elements of nature for the purpose of solving complex human problems. Living organisms have evolved well-adapted structures and materials over geological time through natural selection. Biomimetics has given rise to new technologies inspired by biological solutions at macro and nanoscales. Humans have looked at nature for answers to problems throughout our existence. Nature has solved engineering problems such as self-healing abilities, environmental exposure tolerance and resistance, hydrophobicity, self-assembly and harnessing solar energy. It means, biomimicry is an old approach, but in the scientific conceptualization is new. Today Biomimicry is widely studied in material science, in automotive industry, in engineering, in architectural design and in climate issues. This paper mainly focuses on the imitation of ideas of nature for the wellfare of mankind.

Keywords: Biomimicry, nature, architecture, design, innovation, technology etc.

1. INTRODUCTION

Biomimicry (from bios, meaning life, and mimesis, meaning to imitate) is a new discipline that studies nature's best ideas and then imitates these designs and processes to solve human problems[1]. It is also known as Biomimetics, Bionics, Bio-inspiration and Biognosis[2]. Biomimicry, defined as a new engineering inspired by Nature, for innovation in different fields, design, transportation and architecture. Imagine it as the combination of biology, nature and architecture into one composition. Biomimetic is involved with artificial mechanisms to produce materials similar to ones that exist in nature[3]. Papanek[4] believes that bionic is more related to 'cybernetics' and Vogel[5] claims that it focuses on artificial intelligence. Bionic design considers taking control of nature[6] and seeks resolving engineering problems using data related to biological functions[7] has also defined a set of dimensions for biomimicry: nature as model, nature as measure and nature as mentor. Some researchers believe that these dimensions form the basis for classifying the different approaches to biomimicry[8]. Janine Benyus argues that looking at nature and imitating its existing models, systems, and process can solve design problems sustainably[9]. Biomimicry is argued to serve two main purposes: innovation and sustainability. Pawlyn suggests biological organisms can be considered as embodying technologies which offer sustainable solutions[10]. Technological innovations and sustainability criteria could be interrelated aspects of biomimicry as Rao explains: "biomimicry uses an ecological standard to judge the sustainability of our innovations[11]".

2. LEVELS OF BIOMIMICRY

By examining the biomimetic ideologies and implementations from other scientists, designers and writers; Maibritt Pedersen Zari[12] was able to break down Biomimicry into three different "categories" or "levels"; Organism, Behaviour and Ecosystem.

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1) **The Level of the Organism:** The organism level corresponds to a biomimetic shape or surface. It is a question of the inspiration from forms found in nature. The organisms in nature and their morphology are perfectly adapted to the environment in which they live.
2) **The Level of Behaviour:** The behaviour level corresponds to the function. It's about observing how nature performs a function.
3) **The Level of Ecosystem:** The ecosystem level corresponds to imitate ecosystems found in nature and considered as a means of increasing the sustainability of an architectural project. It is about understanding, how relationships between species and their environment produce an ecosystem and It is characterized by his organization, hierarchy, interdependence, dynamic, adapted. The world's ecosystems are very complex and those characteristics what keep the planet as a whole in balance.

3. EXAMPLES OF BIOMIMICRY

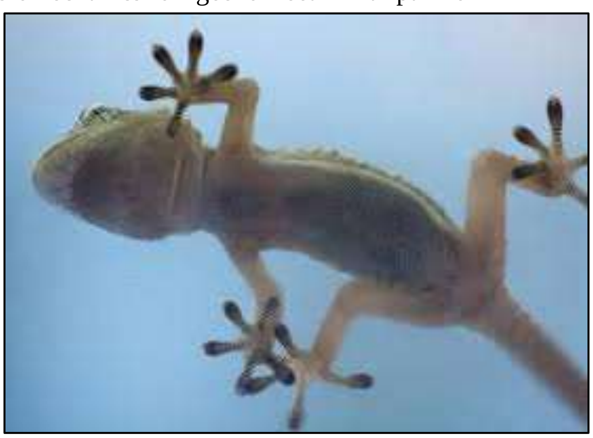
Mother Nature has perfected the biomechanics of everything from tiny leaf cells to whale fins over millennia, adapting their functions to be as efficient and effective as possible for each particular set of circumstances and environments. So it's no surprise that designers, architects and engineers are taking cues from nature when they set out to create buildings, trains, prosthetics, robots and fashionable accessories. There are so many examples of biomimicry in design, engineering, architecture and technology inspired by the sea, plants, insects, animals and other organisms.

1) Kingfisher-Inspired Bullet Train

The fastest train in the world at speeds of up to 200 miles per hour, ***Japan's Shinkansen Bullet Train*** was a marvel of modern technology. But there was one major problem after its initial debut: noise. Each time the train emerged from the tunnel, it caused a change in air pressure that caused thunder-like sounds that were a nuisance from a quarter of a mile away. The train's chief engineer, a bird-watcher, had an idea: taking inspiration from the shape of a bird's beak to make it more aerodynamic. The resulting design was based on the narrow profile of a ***kingfisher's beak,*** resulting in a quieter train that also consumes 15% less electricity and goes 10% faster than before.

2) Gecko Climbing Feet

How do geckos climb up vertical surfaces without falling off? The secret lies within tiny little hairs covering their toes. Researchers have managed to mimic the biomechanics of gecko feet in a pair of ***climbing pads*** capable of supporting a human's weight. Each pad is covered with adhesive tiles bearing sawtooth-shaped polymer structures about the width of a human hair that create an adhesion force when they're pulled on.



3) Baobab Tree Inspired Treehouses

The beautiful Embryo Treehouse by Antony Gibbon Designs aims to look like a part of the tree that it uses for support, wrapping around the trunk like a natural growth. The shape of this beautiful treehouse closely resembles that of the baobab tree, which has a massive, swollen-looking trunk. Not only does it honor nature in its appearance, it also has a very small impact on its forest environment, attaching with a set of braces so the tree can continue to grow.


4) Armadillo Backpack

The hide of an armadillo is rigid yet flexible, offering protection but enabling the animals to remain nimble. This backpack from Cylus and others in the Pangolin collection take cues from the scaled mammals of the Manidae family, joining sections of recycled rubber inner tubes around a central axis to make them durable and adaptable.


5) Survivor Locating Spider

The ability to squeeze through tight spaces and turn on a dime makes the spider an ideal model for life-saving robots that could make their way through rubble after a disaster to locate survivors. Normally, seeing a gigantic arthropod making its way toward you would be terrifying, but in this case, it would be a relief. Researchers at Germany's Frauenhofer Institute say this robot can be cheaply reproduced using 3D printers. "This high-tech assistant is still a prototype, but future plans envision its use as an exploratory tool in environments that are too hazardous for humans, or too difficult to get to. After natural catastrophes and industrial or reactor accidents, or in fire department sorties, it can help responders, for instance by broadcasting live images or tracking down hazards or leaking gas".

6) Biomimicry Heliotrope Follows the Movements of the Sun

Did you know that sunflowers turn themselves throughout the day to follow the movement of the sun? This lighting device by designer Jonathan Ota copies that phenomenon with silvery artificial flowers with LED light bulbs in the center. Powered by solar panels, the flowers are fitted with tiny pistons that use evaporation of alcohol to move the petals, closing them up during the day and opening them at night.

7) Tree-Climbing Robot Mimics Inch Worms

The Treebot uses tactile sensors to find its way up a tree trunk in the same way that inchworms do, feeling around to determine where it should grasp for the best grip. It can even haul loads up sharply inclined branches. Say the creators, "The objective of the development of Treebot is to assist or replace human being in performing forestry tasks on trees. Although the information obtained by tactile sensors is not rich, it is reliable. Furthermore, the processing of tactile information is much simpler than that of visual information".

8) Bird Skull Shoe

The aesthetics and shape of a bird skull inspired this highly unusual, lightweight, sculptural shoe design by Mariek Ratsma. The Dutch designer collaborated with architect Kostika Spaho to create 'Biomimicry Shoe,' which offers lots of support with less material for "optimal efficiency, strength and elegance".

9) Tentacle Inspired Prosthetic Arm

Why would a prosthetic arm for humans take its shape from the appendage of another creature? For Kaylene Kau, designer of this fascinating concept, it comes down to study of the way prosthetics are actually used. Says Kau, "Through extensive research, I found that the prosthetic functioned as an assistant to the dominant functioning hand. The prosthetic needed to be both flexible and adjustable in order to accommodate a variety of different grips". Tentacles provided an ideal model, gripping objects with a simple curling motion.

10) Lotus Inspired Hydrophobia

Water spilled on a lotus leaf, does not wet its surface but simply beads up and rolls off, cleaning its surface from accumulated dust and dirt in the process. This effect is known as ***"superhydrophobicity",*** which researchers have mimicked to create ***water-repellent and self-cleaning materials and fabrics.*** This high repellence is due to the nanostructure of the plane, where micro-protrusions coated in waxy hydrophobic materials repel the water. This is also a self-cleaning mechanism as dirt particles also stick to the water molecule. Copying this process, CeNano developed ***nanotol -*** a hydrophobic (water-repelling), lipophobic (fat-repelling) and oleophobic (oil-repelling) sealant that can be sprayed to substances to create their own superhydrophobicity.

11) Humpback Whale and Wind Turbines

The humpback whale weighs an astonishing 36 tonnes, yet it is one of the most elegant swimmers, divers and jumpers in the sea. As first researched by Frank Fish, a biomechanic, these aerodynamic abilities are greatly attributed to the bumpy protrusions on the front of its fins, called ***tubercles***. Similar to the processes of aircraft wings, whales use their fins at different steepening angles to increase their lift. Too much tilt though, and the opposite will occur and they'll stall - a loss of lift due to current turbulence and the formation of eddies in the water. By comparing bumpy blades to smooth-edged ones, Fish and colleagues found that stalling occurs at a much higher angle with tubercles - an increase by nearly

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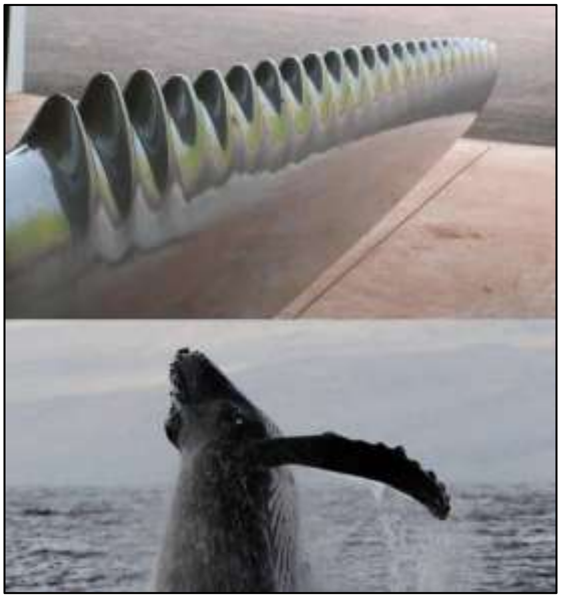
40 percent, in fact. They deduced this higher angle proficiency was beneficial for the whale in allowing it to manoeuvre in tight circles, hence how they circle and entrap their prey in a 'net' of bubbles. Further testing by Fish also revealed that serrated-edge wind turbines proved to be more efficient and quieter than the typical smooth blades. This led to the formation of ***Whale Power tubercle technology***, a company developing a range of tubercle technology products, with a range of blade applications, including wind turbines, hydroelectric turbines, irrigation pumps and ventilation pumps.



12) Box Fish and Bionic Car

Despite the cumbersome appearance of the boxfish, it has a low flow resistance and a drag coefficient of an astounding 0.06. In comparison, penguins swimming through water have a coefficient of 0.19. In 2005, inspired by the great structural strength and low mass of the boxfish, Mercedes Benz developed the Bionic Car, which reported to reduce drag, have great rigidity, low weight and a significantly lower fuel consumption than traditional cars. Of course just because something seems like the perfect design in the natural world, doesn't necessarily mean it works out that way in industrial design. You might have noticed the distinct lack of Bionic Car-shaped vehicles on the road, which is probably because a 2015 study found that the shape of the boxfish didn't reduce drag at all and actually made it more unstable - great for a box fish with 50 million years of evolution to perfect the art of being a boxfish, less good for a people carrier.

13) Velcro

George de Mestral was inspired to invent Velcro after noticing how easy it was for burrs to stick to his dog's hair. Upon studying them under a microscope, he noticed the simple design of tiny hooks at the end of the burr's spines. These were able to catch anything with a loop, such as fur and fabric and he went on to replicate this synthetically. His two-part velcro fastening system uses a strip of loosely looping nylon opposite a strip of tiny hooks, and has since been prolific in its range of applications and popularity.

14) Birds and Flight

Perhaps one of the most famous examples of biomimicry is evident in the history of human flight. ***Leonardo da Vinci*** is largely recognised as a key instigator in its development, as he made the first real studies on birds and human flight in the 1480s. His original design, called the Ornithopter, was never created, but was a principal in showing how man could potentially fly. Several designers and engineers worked on this bird-inspired concept in the following years, for instance Otto Lilienthal completed more than 2,500 flights in a glider, but it was not until 1903 that the ***Wright brothers flew the first powered, heavier-than-air machine in a controlled and sustainable flight.*** This technology went on to define the aerial developments of 20th century and the technology seen in the air today.

15) Bird-Safe Glass

It is estimated that 100 million birds die every year as a result of flying into glass and the reason is obvious - they simply do not recognise the transparent structure as a physical barrier. To address this problem, a company developed biomimetic ***Ornilux Birdsafe Glass***, drawing inspiration from the UV reflective strands in spider webs, which birds see and therefore avoid. This is a clear mutual benefit for both species, and so Ornilux sought to replicate this with their criss-crossing UV glass.

16) Shark Skin Coat

By examining the biological processes of shark skin, NASA scientists were able to copy the microscopic patterns of dentricles to create a ***'riblets' film***. Comparable to shark skin dentricles, this film reduces drag and deters microorganisms (such as algae) attaching to the surface. This was highly advantageous to marine vessels, such as the sailboat Stars & Stripes, which was coated with NASA riblets and won the 1987 America's Cup in the process. However, the environmental benefits of riblets are broad in reducing friction as it conserves energy and money. This has led to its further development and utilisation in coatings for ship's hulls, submarines, aircraft and even swimwear for humans. There is also a huge financial incentive, as reducing drag can save thousands of pounds. For instance, researchers estimate that a 1 per cent drag reduction can save one aircraft an approximate 25,000 gallons of fuel per year.

17) Biomimetic Architecture

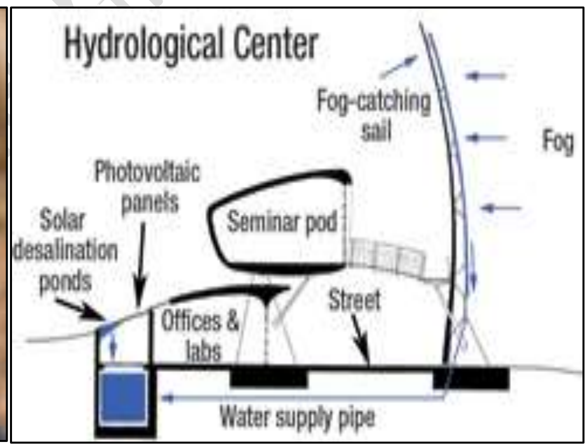
We generally think of termites as destroying buildings, not helping design them. But the ***Eastgate Building, an office complex in Harare, Zimbabwe, has an internal climate control system originally inspired by the structure of termite mounds.*** Further research is revealing more about the relationship between mound structure and internal temperature and could influence additional building designs as our understanding grows. The Eastgate Centre in Harare, Zimbabwe, exemplifies biomimicry at an incredible scale. The green architecture is the country's largest office and shopping complex, and uses no conventional air-conditioning or heating, yet it stays a regulated temperature all year. The architect Mick Pearce was inspired by termite mounds to create the building, as they demonstrate an ingenious structure that self-cools. This is due to their ventilation system, involving a process of opening and closing vents throughout the mound that regulate the convection currents of air. The Eastgate Centre uses a similar process, as it draws air in and warms/cools it with the building mass. This is dependent on which medium is hotter - the building or the air. The innovative building is quoted to consume 10 per cent less energy than same-sized conventional buildings.

18) Nicer Needle from Mosquito

Have you ever noticed a mosquito bite (or two or three) that seemingly appeared out of nowhere? It turns out that the tip of the mosquito's mouth is composed of several moving parts that work into skin with the minimum of fuss and the minimum of pain. So, this is used for the making of needle.

19) Namibian Beetle and Water Collection

One of the most interesting insects studied and mimicked in design is the Namibian beetle; also known as the ***African Stenocara beetle***. The beetle lives in a desolate desert that rarely sees any rainfall. Since the area is dry for the majority of the year, many animals have to find alternative ways to survive and obtain an adequate water source, but not the Stenocara beetle. Even though there is less than one inch of rainfall per year, there is frequently fog in the morning; and the beetle instinctually knows how to take advantage of the situation. The intricate design of the beetle's shell provides the beetle with the essential nutrients and water necessary to survive in such a climate. There are bumps on the beetle's shell which are hydrophilic (water-attracting) along with alternate parts to its shell which are hydrophobic (water-repelling). The hydrophobic parts to the shell act like channels or groves for water and moisture. During the hot day the beetle is exposed to the radiating sun and its black shell absorbs a lot of the heat. When nightfall approaches, it comes out from below the ground and climbs to the top of a mound and waits for the morning to come. Because the beetle's temperature is a lot warmer than its surroundings, it is a beacon for moisture. When the morning fog rolls in, water droplets from the fog are combined and collected on the beetle's shell. As the water droplets form, because of the shape of the bumps, the water droplets stay in tight spherical beads which make them more mobile and easier to channel towards the beetle's mouth. When the water droplets have formed, the beetle tilts its back and the droplets run down the channels or hydrophobic groves and into its mouth. After it has had its desired amount of water, it runs back underground and starts the process all over again. So how can this be applied in architectural design? Matthew Parkes' of KSS Architects has used the design of the Stenocara beetle to design a Hydrological Center for the University of Namibia.



20) Cactus and Temperature Regulation

Another organism that has adapted to arid, dry climates is the cactus, which has also been mimicked in design. What makes the cactus so unique is the technology it uses in order to survive. The signature characteristic of a cactus is the spines that encompass the entire plant. But these spines serve more than just one purpose. The obvious purpose for the spines is for protection. It makes it very dangerous and difficult for herbivorous animals to eat the plant. They also serve to channel the rain water down to the base of the plant where it gets collected and stored. Being that most cacti live in areas that receive very little rainfall, it is crucial that it takes advantage of capturing water when the opportunity presents itself. But the most important function that the spines serve is to help shade the plant from the intense sun. By having so many spines throughout the exterior skin, it shades the plant enough to keep the internal temperature low enough to where the water that the plant stores does not evaporate. This is key for surviving in such an extreme climate. So how can these technologies influence the design of a building? Aesthetics Architects in Thailand designed a building in Qatar that uses these technologies to create a unique sustainable

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solution to a complex problem. The new Minister of Municipal Affairs and Agriculture office (MMAA) in Qatar is going to be a first of its kind. Aesthetics Architects was looking for inspiration to design a building that would be situated in the hot, dry climate of Qatar, an area that only receives approximately 3.2 inches of rainfall annually. They decided to investigate the cactus for ideas on a building solution.


MMAA Building Cactus plant

21) Namaqua Chameleon Inspired Adaptive Fritting and Solar Collection

The Namaqua Chameleon has a very unique adaptation that allows this reptile to survive in a very intense climate. The chameleon is found in the Namib Desert located just north of South Africa. The average temperature in Namibia during the months of November-March is roughly 90°F. At night however, the temperature can drop to as low as 45°F. The sun in this area is very extreme and many organisms have developed adaptations in order to cope with the sudden fluctuation in temperature change. In order to regulate its body temperature, the Namaqua Chameleon has the ability to change the color of its skin depending on where the sun is. Where ever the sun is shining, the chameleon changes that half of its skin to a darker color to absorb heat, while the other side turns to a lighter color to minimize the heat from escaping its body. The engineers at Hoberman Associates have developed a unique technology that functions in the same way as the Namaqua Chameleon's skin. The technology is called ***Adaptive Fritting***. ***Standard fritted glass*** usually has a pattern or design that is typically displayed as a decorative feature or to control the transparency through the wall. Adaptive Fritting is an innovative way to apply operable thermal regulation and complete user control to a fritted glass system. In standard fritted glass the pattern is stationary. With Adaptive Fritting, the graphic pattern is used to not only control transparency and light that enters a space, but it also can control heat gain.

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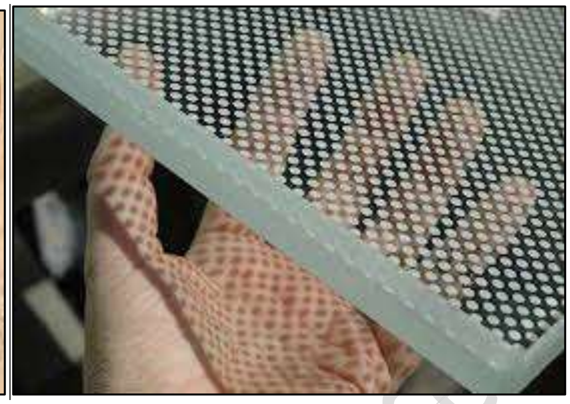

22) Peacock Feather Inspired Colour Fabric Dyes

The beauty of peacocks, with their dazzling multi-coloured feathers, has always provided inspiration to poets and artists in their creative work. Now peacock feathers have inspired a team of Chinese scientists to develop a new way to colour fabrics without the use of traditional dyes that enter streams and rivers, causing environmental pollution. An added advantage: these colours don't fade easily. The non-polluting greener method to colour textiles using "3-dimensional colloidal crystals" has been described by Bingtao Tang and colleagues at China's Dalian University of Technology in the American Chemical Society (ACS) journal Applied Materials & Interfaces. Traditional dyes and pigments used on textile fabrics are chemical colours that produce their visual effect by selectively absorbing and reflecting specific wavelengths of visible light. On the other hand, the colours of peacock feathers (or butterfly wings) result from physical interactions of visible light with "microstructures" on the feathers that are periodic at the scale of the wavelength of light. According to the report, the Chinese researchers wanted to find a way to colour voile, or semi-transparent, textiles by creating the "microstructures" akin to those on peacock feathers.


4. CRITICISM AGAINST BIOMIMICRY

Steven Vogels' book, Cats' Paws and Catapults, is a piece of literature that brings to reality some of the negative arguments towards Biomimicry. He refers to this as "*naïve Biomimicry*". What he refers to as naïve is scientists and inventors that were using the exact same technology found in nature and without any adjustments, turning it into something at human scale. By implementing designs in this way, the majority of the designs were unsuccessful. In his book he uses several good examples that showcase this argument. These examples mostly focus on locomotion by both air and water. One of his best examples is regarding air travel and the design of the airplane. Designers such as the Wright brothers spent much of their time observing birds and their ability to glide through the air. Although this is a good place to start, it actually led them in the wrong direction. The size to weight ratio of birds is much different than that required of an aircraft. Also birds are much smaller than people, and so the characteristics of their flight technology are different than that required for humans. In order for something that is heavier and larger in size to stay in the air, it must be moving at a faster rate, hence the introduction of jet engines and high powered propellers. Birds on the other hand don't need this type of propulsion because they are so much smaller. This was one of the reasons why there were so many failed attempts. But finally after many revisions, the airplane grew from just a one seated aircraft, to a vehicle that transports hundreds of people at a time across the world. Along with these examples he does discuss successful projects as well which makes his book a viable source to uncovering both the positive and negative arguments directed towards the understanding of Biomimicry.

5. CONCLUSION

It is evident from the research conducted that nature plays a substantial role in increasing creativity and innovation as well as assisting in people's general wellbeing. The research suggests there will be an increase in the role of Biophilic Design and Biomimicry in the future design of educational learning spaces and the development of curriculum that connects students to the real world. With that in mind it is highly likely there will be an increase in the uptake of these two "new" sciences in the next 5-10 years as educators become more aware of the inherent value of the natural world to learners of all ages.

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