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Review Article

Biomimetic textiles: An innovative approach towards conserving the future

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ABSTRACT

Superhydrophobicity, self-repair, self-cleaning, energy conservation, dry adhesion, adaptive development, drag reduction, and other natural phenomena have evolved over billions of years to produce more efficient textile solutions than equivalent man-made solutions. Few innovative biomimetic technologies viz., functional surfaces, structural colours, fibre structures, self-healing, thermal insulation, and other characteristics that can be used for prospective textile goods. Biomimetic research is a fast-growing discipline, and exploiting the issue's full potential in the manufacture of unique and sustainable textiles requires a multidisciplinary approach based on a comprehensive knowledge of nature. Biomimicry has the potential to enhance man-made materials and pave the way for the next generation of technological, high-performance materials, including novel materials and characteristics, creative structures and designs, and product and process sustainability. In this study, the potential of a bio-inspired textile structure is explored to the best extent conceivable. The potential use of different biomimetic fabrics was also considered. In essence, this technique can serve as a source of motivation for further material advancement.

Keywords: Biomimicry; innovative textiles; natural approach; biomimetic textiles; next generation technology

INTRODUCTION

Humans have learned from nature in a variety of ways. Bionics in engineering include boat hulls that replicate the thick skin of dolphins. For example, Leonardo da Vinci developed ships and planes by studying fish and birds. The fact that some dolphins and bats have been utilizing sound for communication and object detection for millions of years appears to be tied to the creation of radar (Eadie and Ghosh, 2011). Birds' perfect designs have had a great effect on aviation advancement. Indeed, the Wright brothers, popularly acknowledged as the inventors of the aeroplane, modelled their Kitty Hawk plane's wings after the wings of a vulture. The lives, cultures, and religions of early human civilizations were intimately linked with nature. These pre-industrial communities relied on nature to collect food, create medicine, supply clothes, construct housing, and clean up garbage. On the other hand, today's civilization is reliant on industrial production. Biomimicry will play a key role in accomplishing this objective (Das et al., 2015). The name "biomimetics" is made up of two Greek words: "bios" (which means "life") and "mimesis," which means "to copy" (meaning "to imitate"). The process of imitating, adapting, or extracting technology from nature or biology is referred to as "biomimicry." "The study of the configuration, structure, or purpose of biologically produced substances and materials (such as enzymes or silk) and biological models and methodologies (such as protein synthesis or photosynthesis), particularly for the purpose of synthesizing similar products through artificial mechanisms that mimic natural ones," according to another definition. Textiles have an important role in human culture (Das et al., 2015 and 2017). Humans have been using textiles since prehistoric times. Despite the fact that humans are more intellectual than animals, they have been proven to be insufficiently protected against a number of harmful environmental situations. To defend themselves from the environment or to increase their aesthetic appeal, prehistoric people employed leaves, tree bark, feathers, animal hides, and other materials. Fabrics have existed since the dawn of time (Weerasinghe et al., 2019). Biomimicry's fruits have been adapted and used in textiles to solve a range of problems, including self-repair, self-cleaning, drag reduction, energy conservation, dry adhesion, and superhydrophobicity are examples of biomimicry solutions. Bio-inspired textiles are made from fabrics having functional surfaces, architectural colours, self-healing, and thermal insulation qualities.

This review looked at the use of biomimetics in textiles to the fullest degree possible. The investigation begins with a broad overview, then continues on to biomimetic surfaces and applications, as well as current and future biomimetic textile endeavors.

Applications of biomimetic in textiles

Fibre and spinning

Because of their fibrous nature, fibres are utilized to strengthen the integrity of natural constructions. Many natural constructions are composite, meaning they are made up of two or more materials, which results in greater qualities than those made up of simply one component. Even from the beginning, man understood from nature that mixing elements might be useful (Chew et al., 2021). The wattle-and-daub (mud and straw) and 'pide' (heather mixed into hard-rammed soil) construction methods precede the Romans' use of reinforced concrete, which predicted the pre-tensioned and post-tensioned reinforced concrete. Spiders and silkworms are natural engineers and product experts. They create and spin silk fibres with unrivalled mechanical qualities using the simplest and greenest approach available (Illner et al., 2019). In order to emulate the intelligence of spiders and silkworms (fig.1) in the design and manufacture of silk strands, a number of artificial spinning methods have been created. The mechanical performance of regenerated silk fibres was greatly enhanced by these bioinspired and biomimetic techniques, allowing for additional fibre functionalization (Das et al., 2017).

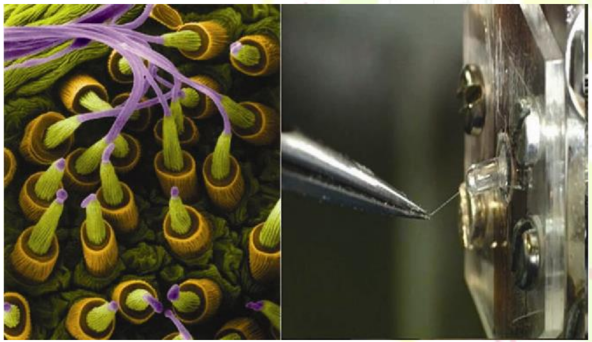

Fig. 1. Biomimicry of spinning (https://animals.howstuffworks.com/arachnids/spider3.htm. Retrieved on 12 Oct, 2021).

Weaving

Weaving is the process of crossing and interlacing threads or continuous strands of any substance into a properly stretched form that may be used to cover the human or other body. The male weaverbird uses fibrous materials to create his nest (fig. 2). They make a robust nest by weaving together the leaves and other nesting materials. Human weavers may be inspired by the baya weaver. The weaverbird nest is usually 15 cm long and 12 cm tall, and it is hanging on a limb. Step by step, the weaverbirds weave the nest's exterior shell (Das et al., 2017 and 2015). The initial attachment, ring, ceiling, egg chamber, antechamber, entrance, and entrance tube construction are all included in this list. The woven design of the entry tube consists of two sets of yarns interlaced at a 45-degree angle, providing the highest resistance to shear stress created when the bird hangs from one side of the entrance at the tube's bottom during nest-building. The weaverbird uses sewing, knotting, and weaving activities throughout the nest-building process. Its operations are therefore analogous to human weaving and knotting procedures. Because the weaving of modern plain fabric is comparable to that of the weaverbird, it is possible that the notions arose by emulating the weaverbird's building process (Zari, 2010).

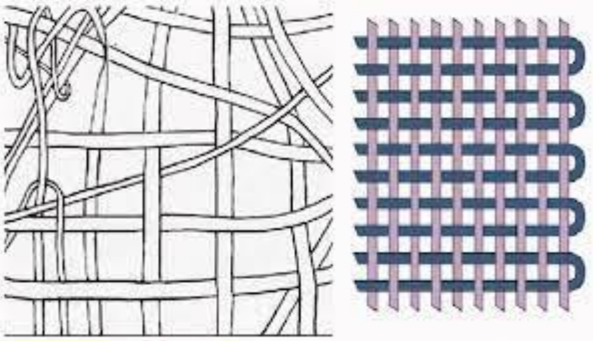

Fig. 2. Biomimicry of weaving (https://textilestudycenter.com/woven-fabric-structure. Retrieved on 13 Oct, 2021)

Hook-and-loop fastener

Hook-and-loop fasteners are made up of two strips, one of which has 'loops' that 'hook' into the other. The hooks catch in the loops when the two parts are pushed together, and the two pieces momentarily connect or bind. Practically every application where a temporary binding is required, hook-and-loop fasteners have been employed. It's very common in apparel, where it may be used to substitute buttons or zippers, as a shoe fastening, and in purses, among other things. In 1964, a Swiss engineer named Georges de Mestral devised the hook-and-loop fastener (Das et al., 2015). This innovation has a background to it. He saw burrs (seeds) of burdock adhering to his clothes and his dog's fur as he returned from a shooting excursion in the Alps with his dog. He looked at the seeds under a microscope and found hundreds of pegs that could be attached to clothes, animal fur, or hair with loops (Figure 3). He was motivated to develop the hook-and-loop fastener as a result of this. If Mestral could find out how to recreate the hooks and loops, he could reversibly bond two materials in a simple method. Some, like Steven Vogel and Werner Nachtigall, regarded this as an important example (Das et al., 2017: Ivani et al., 2015).

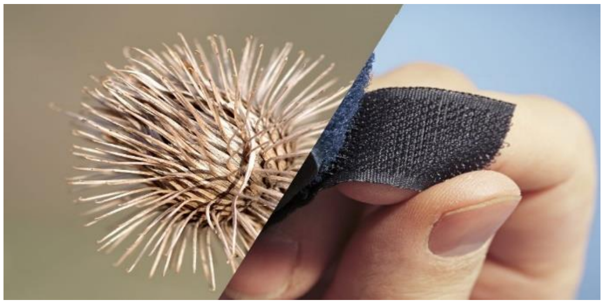

Fig. 3. Biomimicry of Velcro (https://www.microphotonics.com/biomimicry-burr-invention-velcro. Retrieved on 13 Oct, 2021)

Camouflage

Predator and prey play a deadly game of hide-and-seek in nature. In order to live, they both try to hide their identities or visibility from each other. Some creatures have evolved specific skills to hide their existence in their surroundings by having unique body colours, textures, and patterns. Camouflage is the art of blending in with your surroundings. As a result, camouflage is crucial in the battle for survival of living organisms (Dumanli and Savin, 2016). Camouflage may be accomplished in a number of different ways. They differ depending on the species. The most prevalent ways are (i) crypsis, in which the animal merges into the backdrop; (ii) disruptive colouring; (iii) self-decoration using natural materials such as twigs, sand, or shell fragments; (iv) shifting skin pattern and colour; and (v) mimesis. However, changing the colour of the skin is the most popular concealment technique. Concealment is influenced by the colour scheme, texture, and patterning of the skin. Species migration, on the other hand, renders most concealment methods ineffectual. As a result, 'active' camouflage is more effective than passive camouflage. Color shift and counter illumination are used by some animals to produce active camouflage. This sort of camouflage may be seen in the coleoid cephalopods (chamellion, octopus, squid, cuttlefish).

Lotus effect

In terms of textile material use, the natural lotus effect is advantageous (fig. 4). This might be utilized to make umbrellas, rainwear, carpets, upholstery, protective apparel, sportswear, vehicle interior textiles, and even self-cleaning clothes if it can be recreated in textile materials. The static contact angle is the key characteristic that describes surface wetting. It is defined as the angle formed by a liquid with a solid (Li et al., 2010).

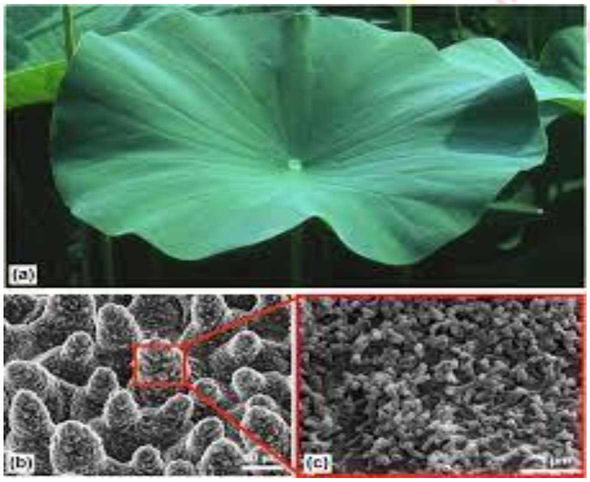

Fig. 4. Biomimicry of superhydrophobic surface (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3148040. Retrieved on 12 Oct, 2021)

Several factors influence the contact angle, including surface energy, surface roughness, and cleanliness. If the static contact angle is $0^\circ \leq \theta \leq 90^\circ$, the liquid wets the surface; if the liquid does not wet the surface, the contact angle is $90^\circ \leq \theta \leq 180^\circ$. Hydrophilic surfaces are generated by polar molecules with a high surface energy, whereas hydrophobic surfaces are formed by non-polar molecules with a low surface energy (Deng and Lee, 2010). Super hydrophilic surfaces have a contact angle of less than 10 degrees, whereas super hydrophobic surfaces have a contact angle of between 150 and 180 degrees. Two elements govern the wettability of a surface: (i) the surface free energy and (ii) the surface roughness.

Other application

Biomimicry research may be used in a range of industries, from examining how spiders weave their silk to make stronger, lighter fabrics to investigating how shark skin decreases drag while swimming. The prospective applications of current biomimicry research are quite promising. Advances in material development are being paved by the exploration of numerous fields of biological discoveries (Hosseini et al., 2010). In the subject of functional clothing, biomimicry can be a revolutionary approach for designing novel multifunctional clothes. Clothing that is functional serves a number of purposes, from aesthetics to basic weather protection. Bio-inspired functionalized textiles include polar bear-inspired winter clothing or solar-thermal applications, lotus leaf-inspired self-cleaning fabrics, rose petal-inspired superhydrophobic surfaces, butterfly wing-inspired structural colours, shark skin-inspired drag-reducing fabrics, and antimicrobial surfaces, to name a few (Li et al., 2010). In the subject of functional clothing, biomimicry can be a revolutionary approach for designing novel multifunctional clothes. Clothing that is functional serves a number of purposes, from aesthetics to basic weather protection (Dara et al., 2020).

Advantages

Biomimicry is based on natural phenomena. To make ourselves, to refine rather than exploit, to utilize free energy, to cross-pollinate, to nurture sustainability, to grow and extend, to employ eco-friendly items and activities, to participate in symbiotic connections, and to construct the biosphere from the ground up are all life principles. Contributing to the creation of materials and technologies that are more appropriate for life on Earth. When a manufacturing strategy fails in nature, the carrier dies. For 3.8 billion years, evolution has been putting tactics to the test (Akpa, 2017; Hosseini et al., 2010). Biomimicry aims to learn from survivors' successful techniques so that we can succeed in the world as they have in their natural environment. Because form is cheap and material is expensive, nature enables creation. Biomimicry aids firms in lowering product prices by studying the mechanics of natural approaches and how they are developed, as well as maximizing the efficiency of product forms and kinds to achieve their intended tasks. Biomimicry allows us to take a fresh look at old product categories. This new vision paves the way for advancement. Biomimicry can help you develop innovative technologies that are transforming your business or even help you start a completely new one (Ivani et al., 2015). Biomimicry will help in the creation of whole new sectors of expansion, the revival of stale product categories, and the recruitment of both creative and ecologically conscientious customers. The firm would be recognized as both innovative and ecologically sensitive if it created biomimetic items and processes. It is unlikely to contemplate rethinking all goods, processes, and structures using nature as a blueprint, test, and guidance in various areas (Kolle and Lee, 2018). Everything in nature is interrelated, and when humans try to replicate nature's inventiveness, they recognize the finest methods to harness inherent interconnectedness. Mechanisms of biomimicry are fundamentally transdisciplinary and mutual (Lurie-Luke, 2014).

CONCLUSION

Textile designers can draw inspiration from the natural environment, which is rich in patterns, motifs, and colour combinations. Biomimicry has clearly revolutionized the textile sector and is currently functioning as a driver for further material creation. From unique textiles and characteristics to revolutionary systems and designs, as well as product and process conservation, biomimicry has the potential to advance man-made technologies and pave the way for the next generation of technical, high-performance materials. These approaches have had an influence on various parts of society, such as arts, popular culture, and design, in addition to being adopted by humans, most notably by the military and hunters. Nature is a big technological book that contains a wide range of complex strategies for employing fibre as a construction material. The impact of biomimicry on the textile industry is evident, and it is currently acting as a source of inspiration for continuous material development.

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