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Insect Hydrophobicity for Mankind

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SUMMARY

Insects, the most dominant group of living organisms on the planet earth, exhibit hydrophobicity and super hydrophobicity at varied level. Insect hydrophobicity is manifested morphologically and exploited for their survival. It involves deeper physics (hydrodynamics) and chemistry proving how beautifully insects were created. Insect hydrophobicity also has a plethora of biomimetic applications benefitting the mankind for better existence.

INTRODUCTION

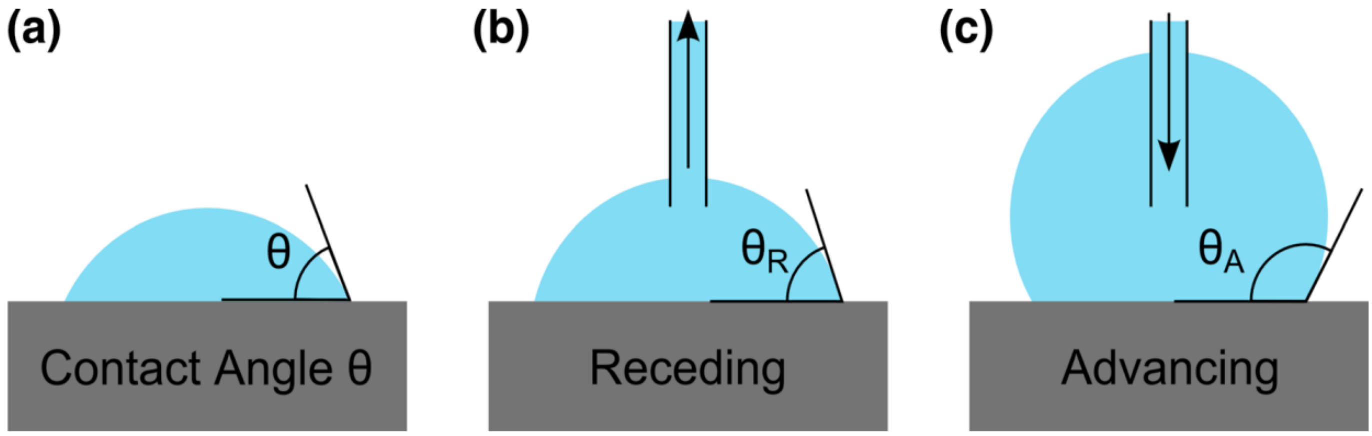
Nature has been performing the law of "natural selection and survival of the fittest" since its very inception. The harmonization and unification between structures and functions in all the natural creatures have been perfectly achieved together during several billion years of evolution and natural selection, simultaneously motivating scientists to study nature and then imitate nature to develop the bioinspired functional materials. In 1997, the first report of super hydrophobic self-cleaning property of the Lotus flower, *Nelumbo nucifera*, and its patenting in 1998 marked the beginning of the realization of biomimetic hydrophobic surfaces globally. Scientists from around the world started exploring the hydrophobic surfaces which was supported by the advent of scanning electron microscope.

Physics behind hydrophobicity:

Hydrophobicity is determined by the surface structures and chemistry *i.e.*, higher entropy and lower surface free energy. It is decided by the contact angle between water droplet and the solid surface that ranges from 0°-180°. Surface with contact angles >90°, 90°-150° and >150° are defined as hydrophilic, hydrophobic and super hydrophobic surfaces, respectively. This property has been well explained with the wettability models *viz*., Cassie-baxter state where the droplets sit on top of a rough surface and wenzel wetting where the droplets interact between and on the rough surface.

How do insects manifest hydrophobicity?

By using hierarchical roughness structures or by coating their bodies with wax or protein components Eg:- Cicada, Morpho Butterfly, Water strider Or both



Why do insects need this property?

To avoid contamination using self-cleaning properties; reduce the risk of predation; increase mobility in extreme conditions; mitigate the risk of surface tension, so they do not get stuck or do not sink in water; adapt with the environment for better survival and to prevent pathogen attack *i.e.*, bacteria, fungi etc.

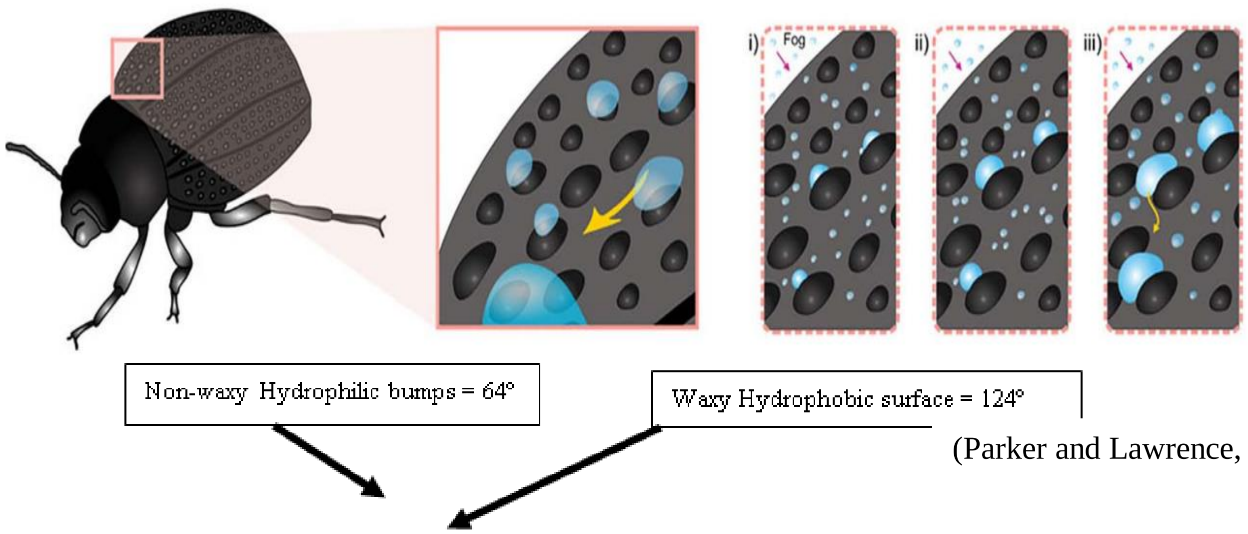
Water strider: *Gerris remigis* has remarkable non-wetting legs that enable them to stand effortlessly and move quickly on water, owing to the special hierarchical structure of the legs, which are covered by large numbers of oriented tiny hairs (microsetae) with fine nanogrooves. The strider generates its thrust by rowing, using its legs as oars and its menisci as blades with a contact angle of 167°. The self-removal of water against wenzel wetting has many practical applications, such as self-cleaning surfaces, antidew materials, dropwise condensers, and microfluidic devices (Gao and Jiang, 2004).

Leaf hoppers: Rakitov and Gorb (2013) reported that brochosomes turn the leaf hopper integument to superhydrophobic state. Brochosome intact integument had a contact angle of 164.8° while the bared leafhopper integument had 103°-129°. The Cassie-baxter wetting due to brochosomes establishes superhydrophobicity and self-cleaning effect. As they are easily erodible, they can additionally reduce the risk of the leafhopper from being captured by arthropod predators relying in their capture mechanisms on adhesion preventing contamination and disabling the adhesive surface.

The backswimmer: *Notonecta glauca* when examined for the hydrophobicity, reported higher air film persistence for 130 days with a drag reduction of five m/sec superior to Kariba weed, *Salvinia molesta*. The combination of these two abilities makes these hierarchically structured surfaces extremely interesting for biomimetic applications such as low friction fluid transport or drag reduction on ship hulls (Ditsche-Kuru *et al.*, 2011).

Collembola: Gundersen *et al.* (2015) reported the effect of changing seasons on the hydrophobicity of the littoral collembola, *Cryptopygus clavatus* that spends its summer submerged and grazing on algae under water, while the winter are spent on dry land. A shift in contact angle from 166° to 140° was seen from winter to summers, respectively due to the wax layer alteration. These switching hydrophobic properties help in evolutionary understanding of how animals adapt to their environment.

Namib desert beetle: A unique combination of hydrophobicity and hydrophilicity was reported in the Namib desert beetle, *Stenocara garacilipes* by Parker and Lawrence (2001). The alternating hydrophilic bumps on hydrophobic dorsal back capture moisture from the fog-laden wind of Namib desert giving a morning drink to the beetle. A plethora of beetle-inspired biomimetics has been designed since its discovery *viz.*, global frog harvester, water trapping tents, air dew harvester, self-filling water bottle/ dew banks, biosensing, antiicing technology etc thus, believed to be the solution for drought, ground water depletion, municipal water shortages and contaminated fresh water supplies.



(Parker and Lawrence, 2001)

Schematic of the fog-harvesting process in *Stenocara gracilipes*

CONCLUSION

Owing to its role in improving survival, flight, protection and evolution of insects, the insect hydrophobicity can be considered as the eleventh reason for entomarchy *i.e.*, insect dominace. Further, through the scientists' continuous efforts, the promotion of insect-inspired hydrophobic\wettable surfaces towards real-world applications would be realized. Since, nature is the house of secrets, we must try to decode the properties that the master, "*insect*" have surpassed through the journey of evolution.

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