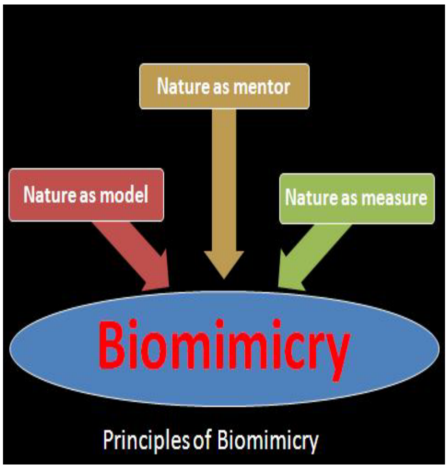
Insects as a muse for innovation of modern technologies

Raghavendra K.V., Omprakash Navik and Bhagyasree, S. N

From time immemorial, several technological advances are inspired by nature. Many a time's biologists find themselves attracted by the graceful perfection of nature. From molecules to organisms, engineers and scientists have frequently been fascinated by nature's skill and have followed natural designs in man-made innovations. The Science behind this is Biomimcry. The Discipline of science, which studies nature's best ideas and exploits those ideas, designs, and processes to solve human problems is known as Biomimicry.

The term "biomimetics" is originated from Greek words "*bios*" (life) and "*mimesis*" (to imitate). We could see Biomimetics in everyday life and often used without our knowledge. The fundamental idea of nature is that, during her past 3.80 billion years of experience and novel developments, she has come out with highly competent systems and processes that can provide solutions to many of the resource efficiency and management problems that we now tackle in our day-to-day life like from knives and axes inspired by the dental structures of extinct animals to the strongest revolutionary carbon nanomaterials. Bio-engineering has always being advanced along with human history. "Flying Machine" by Leonardo da Vinci's (1452–1519) was inspired by a bird is a basic example of biomimicry. The motorized airplane invented by Wright brothers (1867–1948) based on the flight pattern of eagles made to succeeded human flight for the first time in 1903.

A book 'Biomimicry' was published by J M Benyus in 1997, which highlights about biomimicry laying the path to the development of new-age technologies by learning from nature as the foundation for products, instead just using it for raw materials. According to J.M. Benyus, by treating nature as 'model, measure and mentor', many companies, governments, and universities are in a firm position to take benefit of the innovative opportunities provided by the emerging field of 'biomimicry'.



Among the different components of nature, insects are one which motivates human beings in their innovation in one or the other ways. Insects are the brilliant creatures on the earth which are diverse, inventive and resilient which serves as a symbol of everything from beauty and rebirth to epidemic and iniquity. Insects pollinate or devour crops, contribute or cause chaos to technology, inspiring architecture or destroy it and advance human health or act as vectors for transmission of diseases in plants and animals.

Few examples of Insect biomimicry are as follows

1. Insect-inspired sensors for improving the tiny robot's flight

From Micro-roboticists technology, engineers have designed simple sensors based on insect simple eyes called ocelli to improve a miniature flying robot. A team of scientists has published a paper in *Science* journal describing their efforts to create a bee-sized robot, 'dubbed RoboBee'. This 'dubbed RoboBee' (about 100 mg weight) could fly by a preset route on two lightweight wings. In such tiny sized robots, power sources and navigation sensors must remain on-board and connected to the robot *via* thin wires. Neuro-ethological and Neuro-biological research findings on insects can be used to devise and create small robots controlling their navigation based on bio-inspired visual strategies and circuits. The Insect flight concept is also being used in aerospace engineering and mobile robotics.

2. Fog basking beetle to water harvester structure

Desert darkling beetle species (Tenebrionids) can absorb water content from morning fog in the desert to fulfill its water requirement. The body of these beetles is covered with minute bumps, while the shell itself is covered with a waxy substance that is highly hydrophobic. Desert beetle collects water on its back using the hydrophilic spots present on its hydrophobic surface. Designer Kitae Pak has fabricated an award-winning biomimetic device based on the beetle's strategy (Model insect – *Onymacris unguicularis*, Tenebrionidae, Coleoptera), which was made of stainless steel where the beetle-back-shaped dome collects drops of water from fog/air and runs them into a circular reservoir for further consumption. This could perhaps provide enough water per day for the survival of Namibian desert people.

3. Butterfly wings inspired screen display

Butterflies have brilliant colours on their wings and these colours are created through the prism-like, crystalline structure of the surface. Qualcomm, a wireless technology company imitated the butterfly wings in its Mirasol and IMod displays. The same structures that give a vibrancy to butterfly's wings were used to create an "always-on" effect without losing energy for backlighting. These displays are being used in cellular phones and other user interface devices.

4. Algorithms inspired by social insects

Social insect can solve a number of problems that none of the individual insects would be able to solve by itself. Some examples are, finding short paths when foraging for food, duty allocation when assigning work to workers and gathering when organizing brood chambers.

Direct communication: When a scout bee of a colony finds a food source, it communicates the direction and distance of the location of the food to the other bees by performing a characteristic dance. Bee dancing has inspired several important computing algorithms for the formation of the group and task allotment in scheduling theory and computational intelligence.

Insects swarms: Swarm Intelligence is a computational and behavioral symbol for solving scattered problems inspired by biological examples provided by swarming in social insects (ants, termites, bees / wasps), herd, flock and shoal phenomena in vertebrates such as bird flocks, fish and shoals. Therefore, Swarm Intelligence principles have been effectively applied to a sequence of applications including optimization algorithms, communications networks, and robotics.

5. Flea's Jumping Joints

Resilin, a cuticular protein that makes up the joints of many insects, including fleas. The effectiveness of resilin is significantly higher than synthetic rubber or natural rubber harvested from rubber trees. It helps fleas to store sufficient kinetic energy to jump up to 100 times their body length in a single leap. It is the most efficient elastic protein and its synthesized form can be used to improve everything from the responsiveness of human heart valves to the bounciness of sports shoes. This resilin influences CSIRO scientists to develop a rubber with 98% resiliency.

6. Social insects to learn teamwork in humans

As a result of co-evolution from past millions years, social insects (ants, bees, wasps, termites, *etc*.) have evolved as 'super-organisms' (A super-organism is an aggregate of individual organisms that behaves like a unified organism). These are exceptionally qualified to inform human design. Members of a super-organism have highly specialized social cooperative instincts, division of labour, and are unable to survive away from their super-organism for very long. They have evolved firmly integrated societies comprising millions of members in a colony and solve many problems inherent to social organization. Individual social insects exhibit comparatively simple behaviours, but together, colonies can perform complex tasks such as direction-finding, assigning labour and resources and constructing nests/mounds that provide physical and social services. Unlike most human operations, social insects complete such works without a supervisor and this is possible because of stigmergy, a form of indirect communication through alteration of the environment. 'Social Biomimicry' provided a forum for exchange between biologists, designers, engineers, computer scientists, architects, and business people.

7. Building with termites

The termite mound above ground level consists of porous but very hard material, with a series of channels for ventilation. Cool air is sucked upwards from subterranean channels, cooling the mushroom-shaped nest below the mound. During the night the air stream is reversed and regenerates the reservoir of cool air. Even termites construct deep channels to the groundwater to gain additional cooling in the mounds through evaporation. Termites even construct their asymmetrical flat-shaped mound with the long axis in east-west direction to avoid the direct heat in the summer. The simple reason behind this effort is to control humidity and temperature, to provide a stable environment for the termites, their offspring and the symbiotic fungi (fungal garden) in the nest. The termite mounds serve as a role model for an effective passive ventilation system for the control of the internal climate. Efforts have been made to translate this principle in architecture leads to the world's first all-natural cooling structure such as Eastgate Centre, in Harare, Zimbabwe, built-in 1996 by Mike Pearce. The roof and lower floor of this building are porous which leads to natural ventilation, similar to that of termite's nest. Hot air escapes through the roof, and the inflow of cold air from the bottom ventilates the building. Hence, the energy consumption rate of this building is 10percent and an internal temperature of 24°C is maintained even when the external temperature is higher than 38°C.

8. Moth eye surface, the role model for anti-reflection nanostructures

Microscopically tiny grating narrower than the wavelength of light coats the eye surfaces of moths. This structure influences the reflection and refraction of light and this delivers good night-vision and because with their eyes hardly reflecting anything, the available light and good camouflage are efficiently used. A phenomenon known as Areflexia is observed in moth's eyes, which reflect all wavelengths of light beyond the visible light spectrum to block them. The projections on moths' eyes, spaced at a distance of 200 nm, absorb most visible light rays, as they are shorter than most wavelengths of light. The refraction of the light rays entering the eyes will be increased, considerably decreasing reflection. This allows the moth to avoid its enemies and to find its host in the dark. This know-how is being used in national security agencies and also it is used in solar cell light-emitting diodes.

9. Insect navigation system

Many insect species complete their extraordinary navigation tasks. In their daily foraging trips, social insects like bees or ants cover distances of several kilometers and accurately and back to their nests. Besides methods like path integration (estimating distance and direction to the goal by constantly integrating distance and direction of movement) and systematic search (steering in pre-programmed patterns), they resort to visual homing strategies, also referred to as landmark navigation. Knowledge of the mechanisms used by insects for visual navigation can be used as a guideline for developing navigation methods for mobile robots. Since an insect brain contains only about one million neurons in total, evolution has found thrifty solutions for the problem of visual homing. These solutions are probably far away from the classical approaches to robot navigation which is usually based on complex processes of landmark recognition, computation of the position in maps of the environment, and planning of movements.

References

Abbott K R, Dukas R. 2009. Honeybees consider flower danger in their waggle dance. Animal Behaviour 78: 633– 635.

Bonabeau E, Dorigo M, Theraulaz G. 1999. *Swarm Intelligence: From Natural to Artificial Systems*. Oxford University Press. 320pp.

French J R, Ahmed B M. 2010. The challenge of biomimetic design for carbon-neutral buildings using termite engineering. Insect Science 17(2):154–162.

Hargroves K, Smith M. Innovation inspired by nature: biomimicry. ECOS (129):27–29.

Jakab P L. *Visions of a Flying Machine: The Wright Brothers and the Process of Invention*. Smithsonian Institution Press; 1990.

Rind F C. 2005. Bio-inspired sensors. in. "Methods in Insect Sensory Neuroscience". ed. by T. A. Christensen. CRC Press. pp. 213-235.

Shimomura M. 2010. New Trends in Next Generation Biomimetic Material Technology: Learning from Biodiversity. NISTEP Science & Technology Foresight Center; 2010 Oct 1.

AUTHORS

Raghavendra K.V. (Corresponding author)- ICAR – National Research Centre for Integrated Pest Management, New Delhi - 110012 E-mail: raghavendra.kv@icar.gov

Omprakash Navik - ICAR – National Bureau of Agricultural Insect Resources, Bengaluru, Karnataka - 560024

Bhagyasree, S.N. - ICAR –Indian Agricultural Research Institute, New Delhi -110012

Cartoon by Ashirwad Tripathy (ashirwadaspire351@gmail.com)