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Insect Architects

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Abstract

Insects are miniature marvels of the earth that represent a staggering 85% of all animal species. Despite their small size and fragile nature, they are creators of various structures that are of great scientific interest. Master engineers of class Insecta include Blattodea (termites), Hymenoptera (bees, wasps and ants), Lepidoptera (moths), Trichoptera (caddis flies) and so on. Among all these insects, the social insects are known to create enormous and complex structures. These insects are the untaught engineers with remarkable intelligence. One can find many successful human creations that have been built inspired from the spectacular building behavior of insects.

Keywords: Architects, Construction, Engineer, Insects

Introduction

Insects constitute earth's most abundant and successful life forms, representing a staggering 85% of all animal species. These widely diverse creatures fascinate humans in innumerable ways with their amazing behaviors and abilities. Despite their small size and fragile nature, they are creators of various structures that are of great scientific interest. Master engineers of Class Insecta include the orders Blattodea, Hymenoptera, Lepidoptera, Trichoptera and so on (Downing, 2008). Among all these insects, the social insects are known to create enormous and complex structures.

Humans have always taken cues from nature to recreate its brilliance. Biomimcry is a term that refers to the human efforts to design and produce structures and systems modeled in nature. There are human creations built inspired from the spectacular building behavior of insects like the East gate Centre in Harare, Zimbabwe that is constructed inspired from the termite mound ventilation system. Some of the important insect architects include the termites, honey bees, weaver ants, paper wasps, potter wasps, acrobat ants, leaf cutter bees, mason bees, stingless bees, caddis flies, bag worms and eastern tent caterpillars.

The Amazing Architecture of Termite Skyscrapers

Termites are formidable architects that can create skyscrapers. Living place of the termite is known as Termitarium, which is not merely the nest, but also the environment they create to live in (Figure 1). Termites construct different kinds of nests depending upon the environmental conditions and locality. These nests can be found constructed above ground

Figure 1: Termite mound

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as mounds, as subterranean (*Coptotermes* sp.) or arboreal (*Nasutitermes* sp.) and can be even found inside the woods of trees or buildings. The nest of a termite is actually a small part of the massive complex structure they build. They use positioning, sun, wind and complex engineering to survive. If their mounds are damaged by some means, they work on repairing it and the structure which took them years to build will be repaired in months.

Termite mounds are constructed using soil, saliva and excreta by a process called bio-cementation by the soil inhabiting termites. It contains structures like royal cell, fungal garden and forage tunnels. The queen and king reside in the royal chamber. Forage tunnels are also seen radiating from different directions through which the workers foray out to collect food. They have multitude of chambers that are linked by apertures and short corridors. These structures provide protection from adverse environmental conditions and predators. Mound walls are extremely porous even though they appear solid and this allows the movement of air. Top of the mound consists of central chimney, which is surrounded by an intricate network of tunnels and passages. Warm air moves through small tunnels and reaches the central chimney and rises up. When the fresh air meets warm air, it cools and sinks down the nest. Hence this ventilation system constantly circulates air and prevents overheating. Base of the mound has several openings that the termites use for entry and exit. The coolest part of the whole structure is the cellar, the ceiling of which is made up of thin plates that absorb moisture from above and provide cooling (Anonymous, 2011). Through this way the thick walls of mounds help in regulating the temperature and humidity inside the nest, thereby maintaining the homeostasis.

Heaven-Instructed Mathematicians

Honey comb structures are built by bees and wasps. It was William Kirby in the year 1852 who labeled honey bees as the heaven instructed mathematicians, owing to their fascinating ability to engineer the comb. Honey bees build combs using bee wax. Bee wax is secreted through a series of glands on the bee's abdomen. The wax is then molded to build the hive (Figure 2). Upper portion of the comb is used for storing the honey and pollen and the lower portion is used for brood rearing. The queen cells are irregular in shape with capping and are located at the bottom edge of the comb. The worker cells and drone cells are located at the surface of the comb. These cells are capped with flat cap and are convex with central hole. Queen cells are largest in size followed by drones and workers. The bee space left in between combs allows easy movement of bees in their nest. The ideal bee space lies between 4.5 mm and 9 mm. If the space is more, the bees fill the space with wax or propolis.

The walls of each chamber are designed in a way that a broad hexagon symmetry is formed by cutting at an angle of 120 degrees. Why the hexagonal symmetry? Studies reveal that this symmetry helps the comb to be built using minimum wax in a fixed volume. Wax production in bees is an expensive process. It takes six to eight pounds of honey to produce one pound of wax. Also, large amount of energy is

Figure 2: Honey bees and the constructed comb cells

required to produce the wax comb. The total wax produced in Indian honey bee may account to 1.8 kg, requiring 51,000 kcal of energy (Southwick and Pimental, 1981). The hexagonal symmetry makes the whole construction process more economical resulting in stronger constructions with minimum material and maximum capacity. Closed ends of honeycomb cells also provide greater geometric efficiency. The cell in which honey is stored is angled up at 13 degrees from horizontal so as to prevent the dripping out of honey.

Some Other Skilled Insect Architects

Weaver Ants (*Oecophylla* sp.)

Workers of weaver ants weave elaborate nest out of tree leaves, in the canopy (Devarajan, 2016). The ants divide the process of nest building among the colony members, where a team of ants bend leaves while others stitch it together using larval silk. Leaves for making the nest are brought closer using live ant bridges. Unlike most animals where adults carry out societal duties, in weaver ants both young and adults cooperate and contribute equally for survival. Worker ants pull and hold leaves together, using their strong mandibles and legs while other workers move in to glue the leaves. The gluer ant holds the larva and touches the tip of the leaves with the larva's head onto the leaf surfaces at places it needs the larva to attach the silk and continues it. Water proof silk walls hence created will be strong enough to bind the leaves together and the enclosed space will create the perfect environment for the colony to nest in. The larval silk is reusable. The transpiration will keep the inner cavities created nice and humid. These ants are seen to create many nests in the same fashion in a single tree. Major worker ants forage, maintain, defend and expand the colony whereas minor workers stay within the nests and care for their brood.

Paper Wasps (*Polistes* sp.)

Paper wasps are semi-social insects that construct nests that are sheltered under cave roofs, attics, crawl spaces, *etc*. The construction is made of paper processed by the wasps to form perfect hexagons. The female adult wasps mix saliva and wood fiber to form the paper. Single egg is laid in each cell which hatches in about two to three days. Twelve to eighteen days old larva then spins a cap over top of their cells for pupation and adult wasps emerge cutting the roof of the cells. Paper wasp nests are extremely safe, warm and mathematically perfect.

Potter Wasps (*Eumenes* sp.)

Potter wasp nests are small jug like constructions made of mud mixed with saliva. Jaws are used for mixing the mud with saliva and forelegs to measure the thickness of the nest wall. These wasps take around hundred trips to build a mud pot, taking one to two hours for building the entire nest. The whole process of nest construction involves coiling. The nest has a main body and a bottle neck shaped entrance. The neck of the pot is drawn up smooth and imitates the effect of the potter's wheel. The female lays an egg inside the mud pot and gathers lepidopterous larvae which she stings and places inside and this is aided by the funnel like entrance constructed. The capacity of the nest is high enough to hold even more than 20 caterpillars.

Mason Bees (*Osmia* sp.)

Mason bees create a three-layered nest, made out of flower petals and moist soil. The nests are vase shaped constituting the layers; petals-soil-petals. The inner layer of petals bends towards each other, mud is then smeared and outer petals are folded. At the entrance the inner and outer envelopes adhere, forming a central passageway through which the female imports provision and deposits her egg on the top surface of the provisions. Flower petals maintain the moisture and also protect the nest from floods. Air inside the nest helps it to float in situations of flood and lining of hardened mud protects the nests from attack by natural enemies.

Leaf Cutter Bees (*Megachile* sp.)

These bees build small nests in dry ground soft and rotted wood, thick-stemmed or pithy plants, in cavities found on woods and soil burrows. After finding a spot suitable for nest, they collect leaves. Leaves are cut in the form of discs and are used to line the cells forming a cigar shaped nest. They then provide each leaf-lined cell with a mixture of nectar and pollen. The female then lays an egg and seals the cell using leaves. A series of closely packed cells are produced in a sequence (Michener, 1953). A completely constructed nest tunnel may contain a dozen or more cells forming a tube 4 to 8 inches long. The entrance of the nest is also covered with cut leaves. The young bees develop and remain within the cells and emerge the next season.

Stingless Bees (*Trigona* sp.)

Stingless bees also called dammer bees construct nests in tree cavities, cracks and crevices of walls, termite mounds *etc*. Nests consists of external tube, internal tunnel, resin dumps, waste dumps, food pots for storing pollen and honey, brood pots and nest envelops like involucrum and batumen. Entrance tube is made out of cerumen, which is bee wax mixed with various type of plant resin. Pollen pots are built closer to the entrance and honey pots on the outer parts of the nests. Pollen and nectar are placed in a cell, within which an egg is laid, and the cell is sealed until the adult bee emerges after pupation.

Organ Pipe Mud Dauber (*Trypoxylon* sp.)

Mud-dauber wasps build nests on smooth vertical surfaces mainly on cliffs and walls where there is an easy access to mud. The nests are built by female wasps in the shape of a pipe and it contains brood chambers. The consistency of the mud is tested by the females and the tested mud if found suitable is scooped out using jaws. The nest is built in the form of strips forming an inverted V shaped striped appearance on the outside but smooth on the inside. The nest with multiple cells is fortified with paralyzed spiders. The female then lays an egg in each cell and leaves the nest; once the eggs hatch, the larvae feed on the spiders.

Caddis Fly (*Order: Trichoptera*)

Caddis fly larvae build thick tubular casing to escape from predators. This portable waterproof case is constructed using twigs, roots of aquatic plants, snail shells *etc.* which are bound together using the silk producing a composite particle of reduced density and relatively large volume. The sticky band that holds the case can stretch like a rubber band but does not snap back soon. This prevents jerky movements making the case resilient for the protection of vulnerable larva. Hard protective covering thus made not only provides protection from predators, but also provides oxygen at times of shortage.

Bagworm Moth (*Family: Psychidae*)

The bagworm moth caterpillar weaves a silk cocoon around itself, inside which it will live. Silk cocoon is reinforced using twigs, leaves and other plant materials. Log cabins are constructed by bag worms by cutting the twigs at equal size and stacking them up. The portable log cabin is provided with openings at top and bottom. Bottom opening of case is used by the caterpillar to feed, expel waste and also for the emergence of adult. These nests are naturally camouflaged.

Eastern Tent Caterpillar (*Malacosoma* sp.)

As the name suggests, caterpillars of eastern tent moth build tent like structures attached to tree branches and gradually enlarge the web. Numerous caterpillars gather and spin silk that forms the tent, except for the last instars. Often, there will only be one tent per plant. This tent helps in thermoregulation thereby improving overall metabolism of the larvae.

Conclusion

Insects are miniature marvels that can create complex and interesting structures without the benefit of the opposable thumbs. They constitute many of the amazing master builders of the animal kingdom. There are human creations built inspired from the spectacular building behavior of insects. The engineering abilities of a honey bee are profound and it is quite impressive how these tiny insects work out the design of perfect comb cells. Termite mounds are proving to be an innovative source of inspiration to architects. If termites were the size of humans, they could create structures taller than humans could. Insects other than social insects also create intelligent nests. These insects are the untaught engineers with remarkable intelligence many of which rival humans for their engineering ingenuity.

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