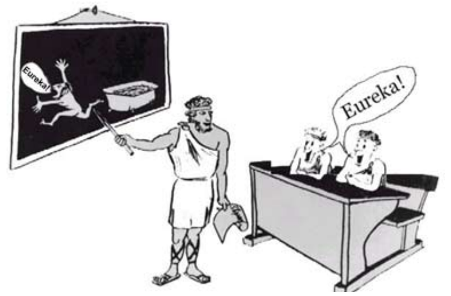

Dr. Abram Teplitskiy

<u>STUDENT'S CORNER #5</u>

<u>BEE</u>
<u>And HONEYCOMB</u>

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On our Student's Corner #4 we considered inventions made by <u>plants</u> – corrugated structures. Now we'll enjoy inventions made by insects, and more specifically by <u>Bees -</u> flying <u>insects</u>, closely related to wasps and ants. They are adapted for feeding on nectar and pollen, the former primarily as an energy source, and the latter primarily for protein and other nutrients. Bees may focus on gathering nectar or on gathering pollen, depending on their greater need at the time. Bees gathering nectar may accomplish pollination, but bees that are deliberately gathering pollen are more efficient pollinators. It is estimated that one third of the human food supply depends on insect pollination, most of this accomplished by bees.

Bees are fuzzy and carry an electrostatic charge, thus aiding in the adherence of pollen. Bees periodically stop foraging and groom themselves to pack the pollen into specialized pollen baskets. Besides collecting pollen for agriculturel purposes, and producing honey for feeding people, another important merit of the bee is *<u>inventing the honeycomb</u>* ,as illustrated in Fig.1.

Fig.1. Bee on Honeycomb.
Courtesy of Igor Endovtsev

Do you see a regular hexagonal structure on the top of this "honey storage?" This is one of the most beautiful structures made by nature.

Mathematicians and architects have wondered about the engineering skills of honeybees for at least 2000 years. In about 70 A.D., for example, Pliny mentioned men devoting lifetimes to the study of the geometry of honeycombs. Later famous scientist Kepler researched the mathematics of the honeycomb.

Bees build the comb for storage of honey to last them through the winter when the flowers they feed on are not available. The honeycomb is vertical with horizontal storage tubes, like a pile of unsharpened lead pencils carefully pressed together. Honeycomb is two faced with different tubes on each side; thus an individual tube goes only half way through the comb. Two of the six sides of the tubes are always vertical and each tube slants slightly downward toward the middle of the comb, which helps prevent the honey from running out as the worker bees fill it. Why did honeybee engineers "choose" six-sided tubes? Why didn't they build cylinders or prisms with triangle, square or other cross sections? The answer is straightforward. Their hexagonal tubes use less wax for the volume of honey they hold. Each wall in the honeycomb serves two tubes, which avoids the wasteful duplication of cylinders and most polygonal prisms. Only triangular or square tubes can also share all walls, but hexagonal tubes still use less wax for the same amount of honey: 18% less than triangular tubes, 7% less than square tubes.

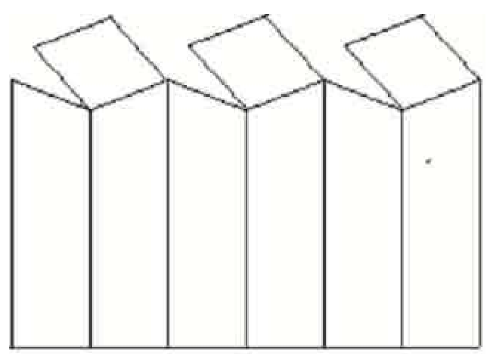


Fig.2. Model of Honeycomb Structure

Courtesy of Free Internet Wikipedia Encyclopedia

Even more remarkable is the way the tubes meet in the middle of the comb. If you removed the honey and the wax where the tubes meet and peered through the holes, you would see that the tubes on opposite sides are offset; the center of a tube on one side is at the corner of tubes from the opposite side. You can demonstrate this by constructing several comb units, as suggested by the accompanying diagram. And the wax that separates the opposite tubes is not a single flat wall. Instead each tube ends in three rhombuses that come to a

point, like a pencil cut with only three knife strokes. The three end walls of one tube serve as single walls for three adjacent tubes from the opposite side of the comb.

In about 1720, Miraldi measured the corner angles of these end walls and found them to be about 70° and 110°. Koenig and Maclaurin used calculus to determine that these were angles that give the maximum volume for this configuration. And finally, though the engineers found that the bees used minimal material to build their honeycomb, the honeycomb has exceptionally high strength. This advantage laid the road for the wide spreading honeycomb principle in different branches of industry, including space, aviation, oil, etc. Members of our Student Corner could use the above honeycomb design to build their own honeycombs and provide their own experiments and results.

While waiting for information from our readers, we'll describe some applications of honeycomb structures. Fig. 3 shows a structure of honeycomb panel with conformable surface. A self-adhering spacer block of a panel of honeycomb material is adopted to be conformable to the shape of an object that it confronts.

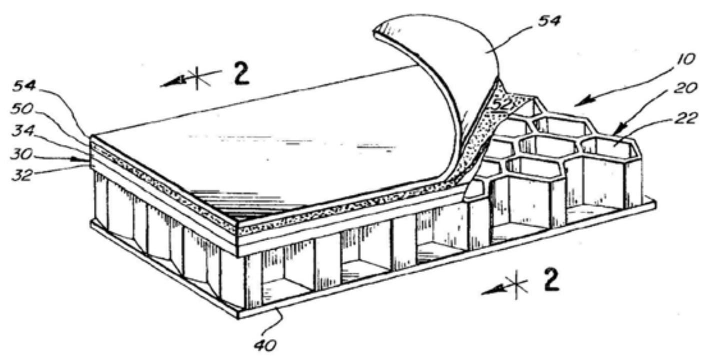
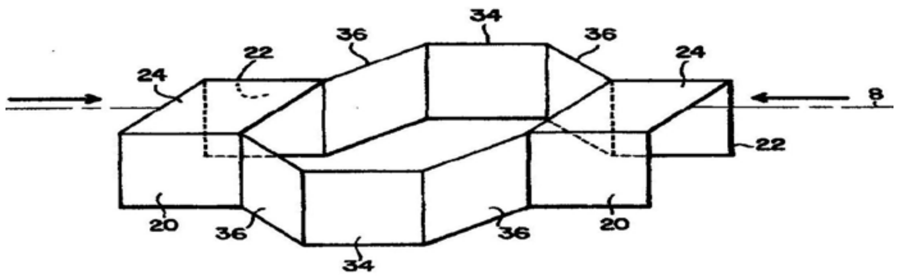


Fig.3. Conformable Honeycomb panel

Public Domain 3 US Patent #4,382,106

In the top part of the next picture (Fig.4) you can see the structure of what we can call an elementary unit of a honeycomb.

Fig. 4A Elementary Unit of a Honeycomb



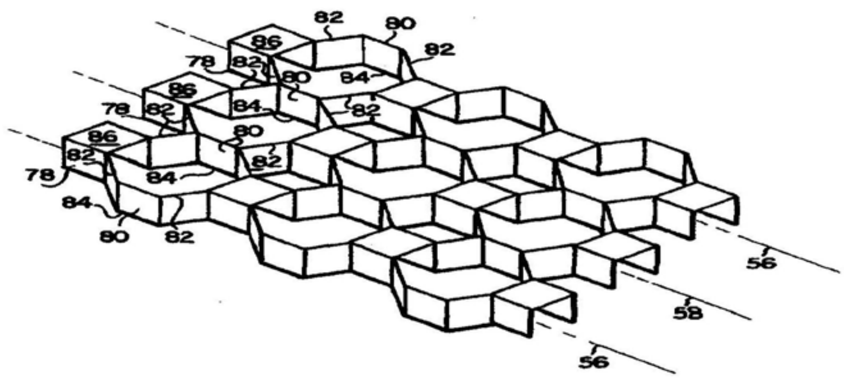


Fig. 4.B Multiple Units of a Honeycomb

Public Domain – US Patent #5,389,059

A honeycomb, shown in Fig 4.A, is formed from a flat sheet by folding it vertically into three sections (flaps 20, 24, & 22), then folding the ends down (folds between flaps 20 & 36 and 22 & 36). The rectangle shape is cut away and the folds between 34 & 36 can be added. In Fig.4.B, the pattern is repeated 9 times sharing flap 34. Try to make several honeycomb units from Fig.4.A and connect them, as in Fig.4.B, to build different structures. Any feedback from your experiment may appear in a subsequent Student Corner.

Now let's analyze applications of honeycomb structures in different branches of industry. In Fig.5 you can see a <u>solar battery module</u> based on honeycomb structure.

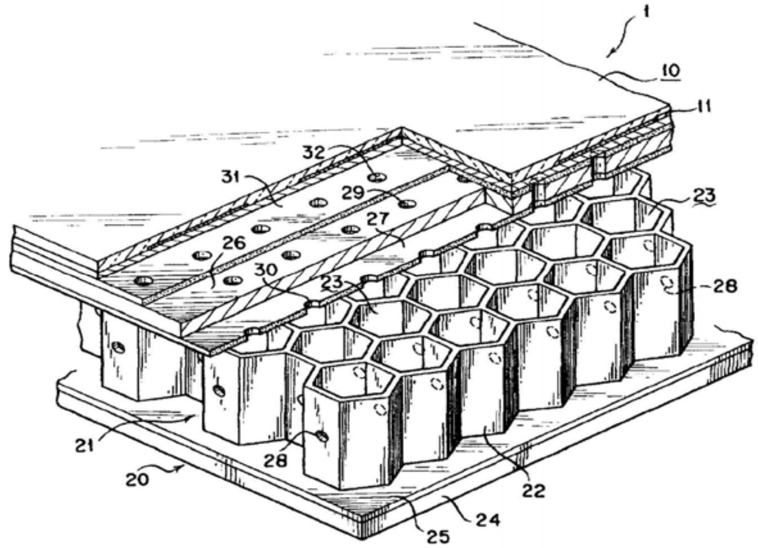


Fig.5. Solar Battery Model Based on Honeycomb

Public Domain # US Patent # 6,051,774

A solar battery model having component members joined uniformly and sustaining no distortion in the surface are disclosed. The solar battery module comprises a solar battery unit and a honeycomb structure. The honeycomb structure comprises a honeycomb core possessed of a plurality of cells and a first surface panel and a second surface panel joined to opposite opening sides of the honeycomb core. The second surface panel has a hole centered over each cell in the honeycomb core. The honeycomb walls are made of porous material. The solar battery unit elements are mounted on the second surface panel of the honeycomb structure through applications of heat and pressure, causing the air to flow into the cavities of the honeycomb structure.

Our last example of honeycomb structure usage which you may be more familiar with is shown in the Fig. 6.

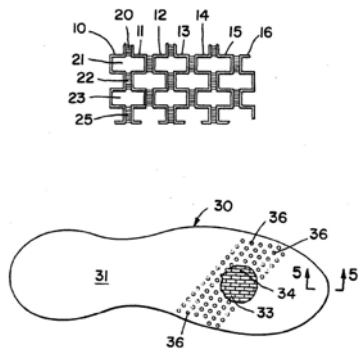


Fig. 6. Honeycomb Based Insole

Public Domain # US Patent # 4,485,568

A shoe insole has an upper elastomer foam pad supported by an over expanded honeycomb structure. It is expanded laterally into rectangular shaped cells. The shorter walls of the rectangle are doubled, and stretched across the sole. This covers more surface area with less material, cutting the manufacturer's costs, which makes it more economical for the consumer.

If you discover a good use for the honeycomb structure in your experiments, please send Student Corner a report of your findings.

Happy inventing!

<u>Editorial staff for this article:</u> Leora, Micaiah (13), and Hosannah (11) Slocum. The Slocum Family is pleased to be involved with the TRIZ Journal and have incorporated these editorial activities into their home school education program.