Fish show the way to stay unseen

They have, writes s ananthanarayan, adapted their scales to reflect better and stay out of sight

REFLECTING surfaces have a way of throwing back less or more of the light that falls on them, as the angle of the incident light changes. An object may, thus, sometimes look darker than the background and become easy to spot. This could endanger living things that have adapted to merge and stay unnoticed by enemies and predators. TM Jordan, JC Partridge and NW Roberts at the University of Bristol have found that certain fish have evolved a skin structure that keeps them reflectivity unchanged even when the angle, intensity or other features of light are varying.

Light waves are like the waves that spread out on the surface of a pond or those we see at the seaside. The up and down movement of water causes adjoining water to move down or up, which similarly affects further adjoining water and so on. But while the movement of water is up and down, the movement of the wave is along the horizontal surface of the water, or in the transverse direction. These directions are fixed because it is the weight of water that is causing the wave motion and gravity acts downwards. We could imagine that if gravity were to act not downwards but towards the left, then the surface of water would not be horizontal, but vertical, and the movement of water would be not up and down but right to left and back again. This would be like the water has been tipped and held up on its side and the waves that move forward along the surface would now be in the vertical plane.

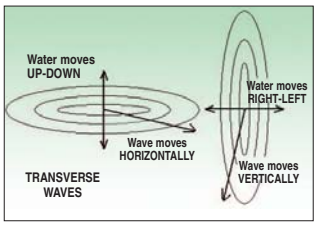
Light waves arise not by the movement of any material thing but by the variation of electric and magnetic fields. These fields are not affected by gravity and there is no associated concept of vertical or horizontal. The change in electric and magnetic fields can, thus, be in all possible planes, horizontal, vertical or turned at any angle, so long as transverse to the direction of the light wave. And in general, light waves consist of field variations in all possible planes.

A shrimp seen through the polarisation-sensitive eyes of a cuttlefish. Above is how it looks to us, and below is an interpretation of how it might look to a colourblind cuttlefish or octopus that sees polarisation angles but not colour. The false colours represent the different polarisation angles as provided in the coloured triangle on the left.

TM Jordan, JC Partridge and NW Roberts.

But when light waves strike a plane surface, like a glass sheet, the surface is in a fixed plane and not in all possible planes. All portions of the light wave are, thus, not oriented in the same plane relative to the surface and the whole wave does not reflect or pass through in the same way.

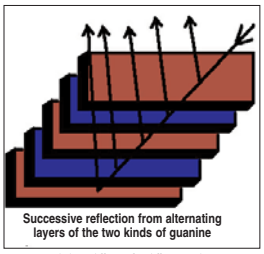
There are materials that affect light waves in different ways, depending on the plane of vibration of the light wave. Thus, they may allow only light that vibrates in a particular plane to pass completely. In this case, light with a different plane would be weakened while light with the plane at right angles would be stopped altogether. The light that comes through would be vibrating all in the same plane, and this is called *polarised light*. Some materials allow all light to pass but affect the speed, depending on the plane of vibration. In these cases, a beam would be split into two, each polarised opposed to the other.



Just like how light passes through a medium depending on its plane of polarisation, the same plane also affects reflection. When a beam of light approaches a transparent surface, we can see that the planes of vibration could be either in the plane perpendicular to the surface or along the plane of the surface. The portion that is along the plane of the surface would not be affected on reflection, but in the case of the plane that is perpendicular, the wave would not stay transverse when the beam changes direction, after reflection. At a particular angle, which depends on the angle at which the light wave enters and passes through the surface, this portion of the wave would be so turned around on reflection that it would not be reflected at all and it would completely pass through. The light actually reflected, at this angle, would be the portion where the plane of vibration is *polarised* along the plane of the surface. Taking into account all parts of waves with vibrations along other directions, the amount of light reflected may be just half of what is normally reflected.

This is the effect of polarisation on reflection, which causes objects to become dimmer when the light comes off them at a particular angle. Certain silvery fish, like sardines, carp and mackerel, have evolved to appear the same colour as the scattered light that comes through seawater around them. This makes them less visible against the background lighting, which helps them stay safe from predators. But if the light that reflects off their bodies was to go dim at certain angles, then they would still stand out against the background and come into view!

Jordan, Partridge and Roberts report in the journal *Nature* that the scales of these fish have evolved a microstructure that takes care of dimming by polarisation on reflection.



Successive reflection from alternating layers of the two kinds of guanine

The fish scales

The skin of fish consists of layers. Under transparent, outer scales is the silvery layer, or *stratum argenteum*, which is made up of many layers of two different transparent materials. The first, *guanine*, has a strong effect on the direction of light that enters and the second, which is *cytoplasm*, has a lesser effect. Guanine has yet another property — its effect on light is different for different polarisations. The guanine layer, thus, continuously splits the light that enters into beams with opposite polarisation. The Bristol group reports that there is yet another feature of guanine — there are two kinds of guanine, one that splits light beams in one way and the other that splits them the other way!

This structure of the fish skin, thus, contains many layers of transparent material that reflect or transmit light with a different extent of deviation and, again, causing beams of different polarisation to diverge or converge. The result is that even if light were to strike the exterior of the fish at an angle where the reflected light is strongly polarised, and hence weaker, the light that is transmitted through the outer layer is deviated and rechannelled so that it is again soon reflected just like at the outermost layer, and the extent of reflection is not materially affected by the degree of polarisation or the angle from which the illumination comes.

Fish have, thus, evolved to counteract a natural phenomenon of polarisation of light and preserve their camouflage and security. But of interest to human researchers is the scale structure that helps them do this. Similar, angle and frequency independent, multi-layer reflecting surfaces are used in applications like optical fibres, LED reflectors or channels for microwaves. The construction of these devices has involved using different materials to build the layers. The fish scale structure has the different layers made of the same material, which provides the advantages of uniform mechanical and heat-conducting properties. Using the same design, using polymers or a honeycomb that contains liquid crystal whose properties can be controlled electronically could lead to advances in optical devices used in industry.

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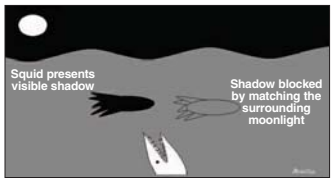
One good deed...

ANOTHER instance of an optical means of concealment is that of the *Hawaiian Bobtail Squid* or *Flashlight Squid*. While foraging at night in the shallow Pacific Ocean (and some parts of the Indian Ocean), it presents a silhouette or shadow against the moonlight or starlight,to predators below, and becomes a sitting duck target. The squid has evolved to carry a light emitting apparatus that senses the light coming from above and beams light downwards, with just the right intensity and colours to merge with the surroundings and become invisible.



The light-emitting arrangement is a colony of light-emitting bacteria, called *Vibrio Fischeri*, which live off the sugar and amino acid nutrients from the squid and repay their host by getting luminescent when required.

What is good insulation?

Many architects use imported, expensive and environmentally inappropriate material, writes avikal somvanshi

THE walls and roof of a building should be built in a way that its indoor temperature is not disturbed and the extreme heat or cold outside does not intrude, say architects. But this basic wisdom is now in market overdrive as a large number of insulation products have flooded in. This market, expected to be worth Rs 3,550 crore ($670 million) by 2015, is booming at an unprecedented rate of 20 per cent a year, according to a report by the Tata Strategy Management Group and the Federation of Indian Chambers of Commerce and Industry released in October this year.

Poorly insulated buildings are difficult to aircondition and lead to high energy loss. The market is, therefore, abuzz with products that can be padded to the walls to improve thermal insulation. These include hazardous materials like mineral wool, rock wool, vermiculite, foams, expanded polystyrene and extruded polystyrene. The market is also agog with technologies like vacuum and gas insulations. But this pushes for more airconditioners when the need is to improve the design and make buildings naturally comfortable.

The push comes from energy regulations for buildings. The energy conservation building code that the Bureau of Energy Efficiency has prescribed calls for the minimum thermal resistance, called R-value, for walls and roofs. "Going by this, a conventional wall would require a 75 mm thick glass wool pad. This is a lot," says Kolkata-based architect Laurent Fournier. He finds fixing one value wrong because weather conditions across the country are different. High R-value, he says, does not mean high comfort.

In non-airconditioned buildings, techniques like shading and ventilation play a major role in improving a building's comfort value. But R-value has become the new mantra, with green rating agencies like Leadership in Energy and Environmental Design, Green Rating for Integrated Habitat Assessment and Bee's star rating vouching for higher insulation.

India finds itself disadvantaged because imported, expensive and environmentally inappropriate material is being shoved in. Worse, dependence on these products has deflected the market's attention from creative cooling designs. "For high-level insulation efficiency, inner walls must be separated from the exterior surface, which is exposed to weather conditions, just like a Thermos flask," says Richa Joshi, architect planner.

Traditionally, in hot-dry and composite climates of north India, buildings had thick mud or stone walls with roofs of mud and grass sandwiched between timber and terracotta tiles to keep the heat out. These are still effective in the cool interiors of the *havelis* of Rajasthan.

In hot and humid climates, architects make use of natural ventilation with light construction and high roof of organic material like thatch, *keeth* (interwoven coconut leaves) or plain terracotta tiles. These can be seen in the houses of Kerala and Tamil Nadu.

The thermal performance of modern buildings can be improved with intelligent architecture. Replacing conventional material like brick and concrete with autoclaved aerated concrete blocks, hollow blocks or other material with inherent higher R-values can also improve buildings' insulation. Designs like filler slabs, double roofs, cavity walls, composite walls and shadings also help insulate houses.

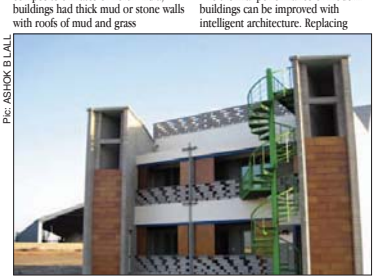
"Some of our traditional insulation systems like cavity walls may be low on R-value but have lesser embodied energy and are long-lasting compared to high- performance insulation products," says Deependra Prasad, an architect based in Delhi.

Synthetic insulation products like glasswool and rockwool are carcinogens, says Fournier. "Thermocol (polystyrene) is worse as it is less stable than glass and other wools, and releases gases. I prefer to keep these out of my and my client's houses," he says. The US Department of Health and Human Services admits that enough research on health hazards from synthetic insulation products has not been done yet.

"Dependence on import and expensive technology transfer should be minimised," says Delhi-based architect Ashok B Lall.

"Efforts are required to reduce the use of resource-guzzling airconditioners through good insulation, and not use insulation as an excuse to increase the numbers of air-conditioners," he adds.

CSE/Down To Earth Feature Service



Pic: ASHOK B LALL

Cavities in the walls insulate an apartment in Bellary, Karnataka.

Should you gaze into the eyes of a Zombie?

rachel nuwer reports on how a father-son team got to work

THE dungeon is pitch black — until the dungeon master blazes a torch, confirming your worst fears. A Beholder monster lurches at you, its eyeballs wriggling on tentacular stems. As you prepare to wield your Vorpal sword, where do you focus your gaze: at the monster's head or at its tentacle eyes? Such a quandary from the role-playing game *Dungeons & Dragons* may seem like a meaningless trifle, but it holds within it the answer to a scientific question. In fact, a father-son team has used images of such monsters to show that most people will look to another creature's eyes, no matter where they are located on the body.

"*Dungeons & Dragons* monsters have eyes all over the place," says Julian Levy, a ninth grader at Lord Byng Secondary School in Vancouver, British Columbia. Two years ago, his knowledge of the role-playing game led him to a unique solution for solving a basic scientific question: Do people focus their gaze on another person's eyes or on the centre of the head, where the eyes just happen to be located?

"We were eating dinner and my dad was talking about how, after publishing a paper about gaze tracking, a reviewer said that you could never prove whether people are looking at the eyes or the centre of the face," Levy recalls. So he piped up with an idea, offering *Dungeons & Dragons* characters as an experimental solution. Because many characters have eyes located on their hands, torso, or other areas of the body, a researcher could track viewers' gazes to see what part of the characters they focus on first.

Levy's father, cognitive scientist Alan Kingstone of the University of British Columbia, loved it. The father-son team got to work, with Kingstone recruiting university students for the experiment and Levy combing the Web for the best examples of *D&D* beings. He selected 36 photos of *Dungeon & Dragon* humans, humanoids (non-humans that still have eyes in the middle of their faces), and monsters (creatures with eyes positioned elsewhere). Levy set up eye-tracker equipment called Eyelink 1000 for 22 student participants, who viewed each of the character photos for five seconds.

Kingstone and co-author Tom Foulsham at the University of Essex in Colchester, England, analysed the eye-tracking data, as they reported in *Biology Letters*. They found that participants first tended to look at the middle of the image, but then tended to fixate on the eyes, regardless of whether the eyes were on the head or elsewhere.

"This paper makes the point explicitly that no, these brain areas are really interested in processing the eyes, not the centre of the head," Kingstone says. The human brain's preference for eyes may have evolved as a way for people to communicate quickly and quietly and to convey simple information about a person's age, health, and emotions, he hypothesises.

"At first blush, these sorts of reactions can seem trivial: OK, so we're slightly more likely to look at the eye region, big deal," says Stephen Shepherd, a neurobiologist at Rockefeller University in New York who was not involved in the research. "But these mechanisms are likely foundational to behaviours like eye contact and gaze following, which humans and other primates use to threaten one another, to flirt, and to share experiences and attitudes," he says.

In addition to answering questions in basic biology, the study's findings may prove useful for children with autism, who often struggle in making eye contact with others. Their therapy includes training that teaches them that skill. Now, researchers may be able to apply the new investigative technique as a first step for clarifying whether children with autism seek out the eyes or whether they focus solely on the head.

However, the study used only two-dimensional images that do not gaze back at the viewer, whereas real-world eye contact is "a much more sophisticated dance", Kingstone notes. "Because there's just so much more going on with the eyes in real life, this would never cut it for teaching natural-looking behaviour."

This is adapted from *ScienceNow*, the online daily news service of the journal *Science*