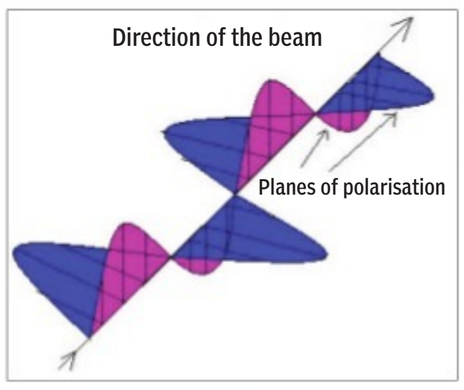
Manipulating light waves to multiply

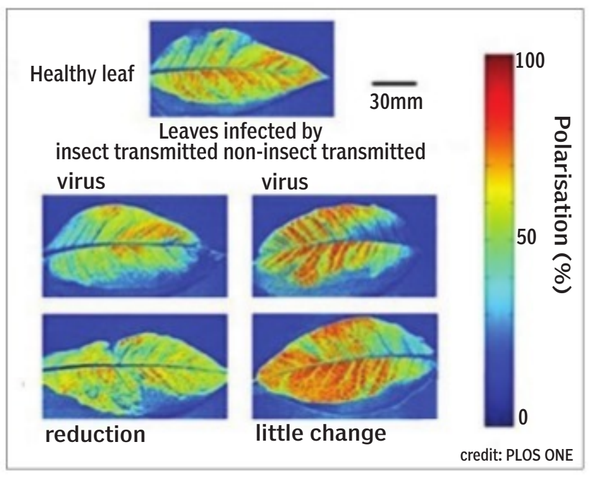
VIRUSES HAVE BEEN FOUND TO DIVERT PLANT MACHINERY TO THEIR OWN USE, WRITES **S ANANTHANARAYANAN**

The plant's arsenal for making the best of the environment includes a range of physical phenomena. From quantum efficiency in light gathering for photosynthesis to sophisticated hydraulics in moving the sap in the stem, evolution has helped the plant to adapt and optimise the use of energy. Manipulating the wave properties of light to create all colours of the rainbow is one such adaptation. And another is to use the property of polarisation of light to attract insects and birds.

Daniel J Maxwell, Julian C Partridge, Nicholas W Roberts, Neil Boonham and Gary D Foster of the School of Biological Sciences, University of Bristol, and also from York and Perth in Australia, report in the journal *PLOS ONE* an analytical detective story of how viruses that affect plants have adapted to get the plants that they infect to modify the plant's own architecture to help the virus spread from host to host.

That animals and insects can sense features of light that humans cannot is now well documented. Light itself is a wave that carries energy. At the level of photosensitive cells of the eyes, light behaves like a particle and transfers a packet or lump-sum of energy to the cells. This is the action of light that humans are able to sense and it serves to make out shapes and colours. But apart from a straight line path and a frequency or colour, the light wave has another dimension, of the plane of vibration of its electromagnetic composition. Thus, if a beam of light is moving from left to right parallel to this sheet of paper, the electric vibration is either in and out of the plane of the paper or up and down within the plane of the paper, or in any other plane, so long as the plane is perpendicular to the direction of the beam.





Sunlight, which arises from thermal emission of very hot gasses in the sun, consists of waves in all possible planes of vibration. On reflection, however, there is a selection of the plane of vibration and the scattered light from the blue sky and particularly diffused light at sunrise or at dusk is markedly polarised. As humans have evolved to rely on position and colour for navigation and hunting, and benefit by maximum sensitivity, the cells in the human eye respond equally to light waves of all planes of polarisation. This, however, is not true of animals, birds or insects, which need to navigate without fixed markers and also to be sensitive to detect prey or food that is not always distinctly visible. Being able to detect the plane of polarisation helps know the position of the sun even when it is hidden behind clouds and also to locate specific reflecting surfaces. Examples are waterbodies as habitats or suitable egg-laying sites.

Plants have evolved to capitalise on a brace of features to attract the right kind of carriers of pollen to help them procreate and flourish. The bright colours of flowers, the scent and the nectar are all means of attracting bees, the main agent, and also butterflies and many other creatures to the plant. While the colours on the surface of petals are found to arise partly from pigments, they are also sensitive because of surface geometry, which causes interference of waves and suppression or enhancement of specific colours. In addition, studies have shown that the smoothness of petal and leaf surfaces promotes the selection of particular planes of polarisation which also influences insects whose eyes are sensitive to such changes. Some of the same researchers at the University of Bristol, in fact, have documented how the bumblebee makes good use of polarised light while foraging.

Daniel Maxwell, Gary Foster, Julian Partridge, Neil Boonham and Nicholas Roberts

Entry of the virus

While insect visitors to plants perform a useful function of promoting cross-pollination and prosperity, varieties of insects are also the agents that transfer and promote the proliferation of pathogens and diseases that affect plants. An important instance is the transmission of viruses, which is the reason for the loss of valuable food crops, by insects. The current study of the Bristol group was to investigate the manner in which viruses, whose transmission is through insects that are sensitive to polarisation of light may use this sensitivity to their advantage.

The *PLOS ONE* paper notes that a large number of viruses are transmitted by insects like aphids, whiteflies and thrips. What is more, the paper says, the viruses themselves are not passively moved about by the insects, but they influence the insect and virus host interaction in such a way that the insect finds the host attractive, which favours transmission of the virus.

There are different ways in which the virus affects the plant so that the insects that transmit the virus come and stay, the paper says. One way is by inducing vapours and odours, a common signalling mechanism among insects. Another is to affect the nutritional quality of the host, and there have been studies that have found that insects feed differently on virus-infected plants as against healthy ones. But an area that has not received attention is the effect that viruses have on the surface of leaves of infected plants. Modified leaf surfaces would have a different feel and changes in the surface hairs could affect how the insect is able to move. And then, changes in the surface waxes could change the colour and way the leaf looks, and a particular effect, which has not been studied so far, the paper says, is how changes in the surface could affect the polariSation of light on reflection from the leaf.

There is evidence, the paper says, that insects that transmit plant viruses have the machinery to sense polarisation of light, which suggests that effects of the viruses on the polarising capacity of leaves could be an agency to attract virus-transmitting insects.

Sifting the evidence

The researchers note that the reflectivity of leaves is because of waxes on the surface and changing the composition of the waxes would affect the level of polariSation on reflection. The various components of waxes, in turn, arise because of particular molecules called Very Long Chain Fatty Acids that are found in the outer layer of leaves. And the formation of these molecules is controlled by a group of genes called CER genes in the plant cells. Instances of a virus affecting the waxiness of leaves should then be reflected in the activity of the corresponding genes, the researchers observe. The group, hence, studied the effect of both insect-transmitted viruses as well as viruses transmitted by other means on the reflecting-polarising effect, the waxy surfaces and the expression of the CER gene in common plants.

The main effect of infection by insect-transmitted viruses is found to be reduced polarisation of light on reflection by leaves, an effect not found on infection by other viruses. As infected leaves are found to be more attractive to virus-transmitting insects, it looks like viruses are adapted to benefit by modifying the reflectivity of host leaves. Although the actual polarisation sensitivity of aphids and whiteflies has not been verified, the class of insects does have the necessary eye structure, the researchers say. Even if this were not the case, they say, reduced polarisation would have the effect of emphasising pigmentation of the leaf and make it more attractive. There is also the possibility that reduced polarisation has the effect of discouraging predators of the insects, which would effectively enhance virus transmission, they add.

The study went on to consider the kind of waxes that formed on the leaves, the level of expression of the relevant genes and also hairiness of the leaf surface, which would affect reflectivity. While insect-transmitted viruses were found to have different effects on leaves, it was also seen that the differences were adapted according to the hosts. But the idea that viruses that depend on insects for their transmission affect the host in ways to attract the insects, in different ways, is borne out. This is not only insight into the complex web of interrelations in the natural world but also direction to find ways of controlling the spread of viruses that affect plants that have economical value.

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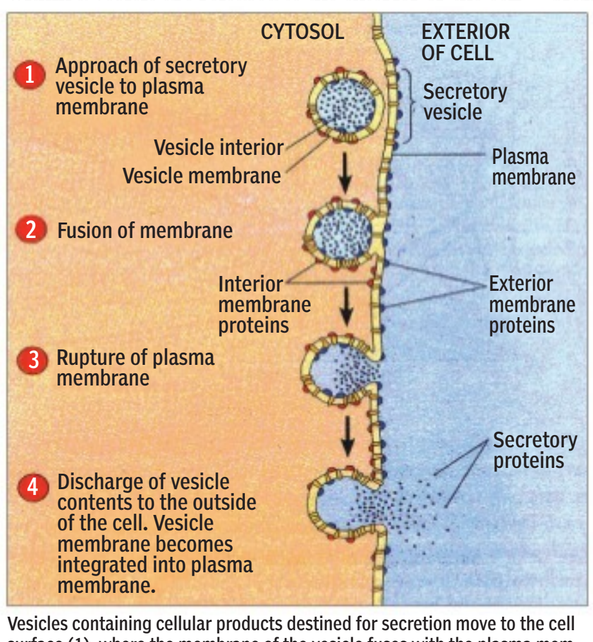
PROTEIN LOCOMOTORS

TAPAN KUMAR MAITRA EXPLAINS THE PROCESSES BY WHICH MATERIALS ARE TRANSPORTED ACROSS THE PLASMA MEMBRANE

The two methods of transporting macromolecules and other substances across the plasma membrane are exocytosis, by which secretory granules release their contents to the exterior of the cell, and endocytosis, by which cells internalise materials that were previously outside them. Both processes are unique to eukaryotic cells.

First let's consider exocytosis, because it is the final step in a secretory pathway that began with the ER and the Golgi complex. In it, proteins sequestered within a vesicle are released to the exterior of the cell as a membrane fuses with the plasma membrane and a variety of proteins is exported from both animal and plant cells through the process. Animal cells secrete peptide and protein hormones, mucus, milk proteins and digestive enzymes in this manner. On the other hand, fungal and bacterial cells secrete proteins associated with the cell wall, including both enzymes and structural proteins.



Vesicles containing cellular products destined for secretion move to the cell surface (1), where the membrane of the vesicle fuses with the plasma membrane (2). The plasma membrane pulls apart, discharging the vesicle contents to the exterior of the cell (3). In the process, the membrane of the vesicle becomes integrated into the plasma membrane, with the inner (lumenal) surface of the vesicle becoming the outer (extracellular) surface of the plasma membrane (4). Glycoproteins and glycolipids that remain anchored to the plasma membrane will face the extracellular space.

The mechanism underlying the movement of exocytic vesicles to the cell surface is not yet clear but current evidence points to the involvement of microtubules in both exocytic and endocytic vesicle movement. For example, in some cells vesicles appear to move from the Golgi complex to the plasma membrane along "tracks" of microtubules that are oriented parallel to the direction of movement. Moreover, it stops when the cells are treated with colchicines, which is a plant alkaloid that binds to tubulin monomers and prevents their assembly into microtubules.

Most eukaryotic cells carry out one or more forms of endocytosis. A small segment of the plasma membrane progressively folds inward, and then pinches off to form an endocytic vesicle containing ingested substances or particles. By this, materials that were previously outside the cell are brought into it. Endocytosis is important for several cellular processes, including ingestion of essential nutrients and defence against micro-organisms.

In terms of membrane flow, exocytosis and endocytosis clearly have opposite effects. Whereas exocytosis adds lipids and proteins to the plasma membrane as vesicles fuse with it, endocytosis internalises portions of the plasma membrane. Thus, the steady-state composition of the plasma membrane is a consequence of the balance between the two processes. Through endocytosis and retrograde transport, the cell can recycle molecules essential for exocytosis by recovering lipids and proteins that are deposited in the plasma membrane by secretory vesicles. The magnitude of the resulting membrane exchange is impressive. For example, the secretory cells in the pancreas recycle an amount of membrane equal to the whole surface area of the cell within about 90 minutes. Cultured macrophages (large white blood cells) are even faster, replacing an amount of membrane equivalent to the entire plasma membrane within about 30 minutes.

The term endocytosis encompasses several processes that differ in the nature of the material ingested and the mechanism employed. In each case, however, the membrane of an endocytic vesicle isolates the internalised substances from the cytosol. Most endocytic vesicles develop into early endosomes that fuse with vesicles from the TGN, acquiring digestive enzymes and maturing to form new lysosomes. A distinction is usually made between *phagocytosis* (Greek for "cellular eating") and *pinocytosis* ("cellular drinking"). Pinocytosis is then subdivided into receptor-mediated endocytosis, also called clathrin-dependent and clathrin-independent endocytosis.

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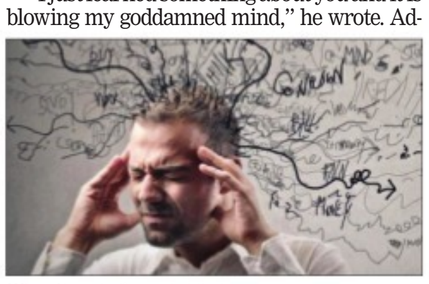
Living with aphantasia

ANDREW GRIFFIN REPORTS ON A 'MIND-BLOWING' POST WRITTEN BY SOFTWARE ENGINEER BLAKE ROSS ABOUT BEING UNABLE TO IMAGINE THINGS

Many people are not able to visualise things — and might not even realise it. A new post from celebrated software engineer and Mozilla founder Blake Ross, sharing the reality of living with aphantasia, is bringing to public awareness a hypothetical but apparently surprisingly common problem that leaves people unable to imagine visual images. He described accidentally stumbling over a description of the problem.

"I just learned something about you and it is blowing my goddamned mind," he wrote. Admitting that though he had simply stumbled over the realisation, it was "as close an honest-to-goodness revelation as I will ever live in the flesh". The post continues, "Here it is: You can visualise things in your mind. I have never visualised anything in my entire life. I can't 'see' my father's face or a bouncing blue ball, my childhood bedroom or the run I went on 10 minutes ago. I thought 'counting sheep' was a metaphor. I'm 30 years old and I never knew a human could do any of this."



When the mind's eye is blind.

Ross described how he accidentally heard about the condition and realised that it applied to him. Straight away, he began chatting to friends to see if it was unusual not to be able to visualise things. But all of those friends reported that they could "see things" if they were instructed to, when he told them to imagine a beach. But the idea of a "mental picture" like that made no sense to him, he wrote. "The very foundation of the question does not compute in my brain," he wrote. "It's like asking me if the number seven has any stubble, or if the puppy is on a leash. What puppy?"

Ross did manage to find two people who described having the problem — engineers from Facebook, where he used to be head of product — and said that the feeling of doing so was one of "transcendent warmth". He then went on to detail a list of common questions that had been asked of him. Many people noted that it was especially surprising that Ross had been the one to point out that he had it — especially given the pioneering work Mozilla has done.

Ross's post has since been shared thousands of times, and liked by thousands more, including Mark Zuckerberg. It has also been shared on Twitter, where many posting it are indicating that they too have just realised that they are unable to visualise things. Ross recommends they email Professor Adam Zeman, who has been responsible for much of the research about aphantasia and who inadvertently helped him find out what was affecting him.

The idea of aphantasia has been part of medical literature for over a century — first proposed by Francis Galton in 1880 — but what exactly causes it has gone mostly unstudied since. This despite a survey in the 20th century that showed that 2.5 per cent of people might be affected by the condition. Most of the work on aphantasia is the work of one team led by Zeman from the University of Exeter's Medical School.

That began in 2005 when a 65-year-old retired building inspector visited Professor Zeman who realised that he appeared to have developed what is now known as aphantasia, following minor surgery. The man, known as MX, seemed otherwise as expected, but couldn't conjure images within his mind.

It was a *New York Times* article on that topic that Ross stumbled over, which described the case of MX and how he had lost the ability to form mental images. "What do you mean 'lost' his ability?" Ross describes himself thinking. "Shouldn't we be amazed he ever had that ability?"

Ross wasn't alone in undergoing that experience, according to that same article in the *New York Times*. Its author, Carl Zimmer, had written another piece about MX in 2010 — and soon after that was published, he began receiving emails from readers who appeared to have the same thing. Zimmer then started forwarding those emails to Professor Zeman, who said that he and his colleagues had also been hearing from people who described having the same condition. They used those emails to undertake a survey of the 21 people who reported the condition to find out whether it was consistent and how people managed to work around it.

THE INDEPENDENT

PLUS POINTS

Growing new limbs

A team of scientists from the University of Kentucky has built on a 2012 study that found that certain species of mice and rabbits could regenerate damaged skin, rather than just rebuilding it with scar tissue. Over the course of their study, the Kentucky team found another tissue-regenerating species, the African Spiny mouse, which can completely repair holes of up to four millimetres in its ears with new skin. In the process, they also furthered the scientific understanding of the biological factors that lie behind this unusual trait.

A long-standing question in biology is why humans have such poor regenerative abilities compared to other animals. Injuries can cause us to develop scar tissue, but why can't we grow an entirely new piece of skin, or a new digit or limb? Previous theories have tended to assume there is a "magic bullet" for regeneration but an analysis of the Spiny mouse's genes has shown the trait is actually much more complex and involves the interplay of a number of different genetic factors.

The Spiny mouse can completely regenerate tissue to close four-millimetre holes in its ears.

The team also found that the regeneration begins when the mouse forms a blastema, or a mass of cells that eventually grow into organs or body parts. Thomas Gawriluk, co-author of the study, believes developing a deep understanding of the process is a vital step in using it to help humans. By figuring out the miniscule molecular and cellular processes that occur during regeneration, we would have a good foundation on which to develop new regenerative medicines. "First we need to understand how mammalian regeneration works in a natural setting, then comes the potential to create therapeutic treatments for humans," he said.

DOUG BOLTON/THE INDEPENDENT

Brain keeps watch

When it comes to bedding down in an unfamiliar place, the old adage about sleeping with one eye open may not be that far from the truth. New research helps explain this "first-night effect", finding that one brain hemisphere remains more active than the other, researchers at Brown University and their colleagues reported on 21 April in *Current Biology*.

"Researchers noticed the first-night effect for a long time, but we didn't know what was going on in the brain," study co-author Masako Tamaki said. To find out, he and his colleagues monitored the brain activity and sleep quality of 35 volunteers who spent two nights sleeping in their lab. They used a novel brain imaging technique that combines magnetoencephalography (MEG), structural MRI, and polysomnography — including electroencephalogram (EEG) signals, eye and muscle movements, and heart rate. They focused on a type of sleep called slow-wave activity, which measures the depth of sleep, as opposed to Rapid Eye Movement sleep.

What they found was that the left hemispheres of the volunteers' brains lit up more compared with the right one during their first night sleeping in the lab, but not on the second. The increased activity was located in a brain circuit called the default mode network, which is most active when a person is awake and resting.

THE SCIENTIST

Life from water

The beginnings of life on earth may previously have been explained in terms of a dramatic crash of lightning or a collision with a comet, but a new study proposes another origin altogether — the humble puddle.

Scientists from the NSF/Nasa Center for Chemical Evolution showed in a simple laboratory reaction that they could produce missing links towards RNA — one of the "building blocks of life" — using water. Whether or not they find that the ingredients for life would have been more easily brought about than expected, they will have an impact for our understanding of how probable it is that life could have formed and exists elsewhere in the universe.

To conduct the research, the scientists looked at a pair of chemical ancestors of the compounds that go together to make RNA, a close relative of DNA. RNA is very similar to DNA and scientists think that DNA-based life would have been preceded by life forms that made heavy use of RNA, which itself may have been preceded by another proto-RNA. Using these two chemicals, they were able to form what appeared to be the building blocks of life – "proto-nucleotides" that look a lot like those found in RNA, and so are likely to be their ancestors. The two ingredients used would have been abundant on the early earth and would have been "well suited for primitive information coding", according to Nicholas Hud, who led the research project. But he and his team want to be sure about how those parts may have come together before claiming for sure that they have discovered the truth about the ancestors of the all-important RNA and DNA.