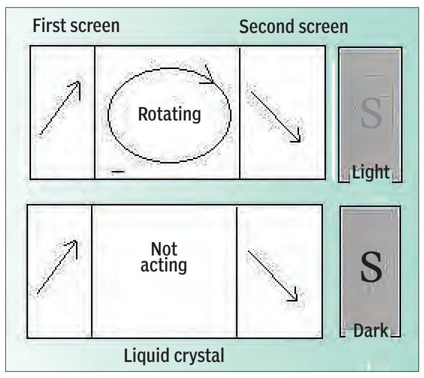
Nobels ring in Year of Light

THE AWARD OF THE 2014 NOBEL PRIZES FOR PHYSICS AND CHEMISTRY TO WORK IN THE FIELD OF PHOTONICS SEEMS TO BE WELL TIMED, SAYS **S ANANTHANARAYANAN**

The United Nations has proclaimed 2015 as the *International Year of Light*, the objective being to raise awareness of the achievements of light science and its applications — and its importance to humankind. Different stakeholders, including Unesco, scientific societies and unions, educational and research institutions, technology platforms, non-profit organisations and private sector partners are coming together to promote and celebrate the significance of light and its applications during 2015.

Hiroshi Amano, Isamu Akasaki and Shuji Nakamura

Almost to bring in the year, the Royal Swedish Academy of Sciences, in October 2014, selected two groups of inventors who made a breakthrough in "efficient light emitting diodes" and "super resolved fluorescence microscopy", both areas in the field of light technologies, for the Nobel Prize in Physics and Chemistry, respectively.



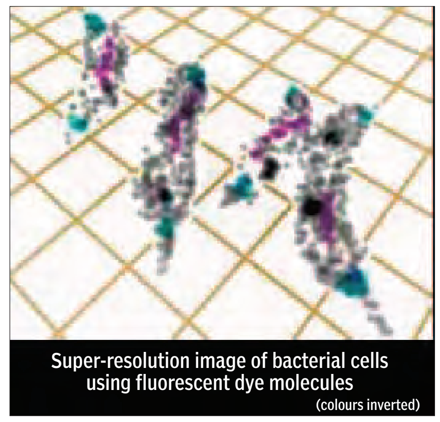
The physics prize went to Japanese scientists Isamu Akasaki, Hiroshi Amano and Shuji Nakamura for their work in extending light-emitting devices, called diodes, to efficiently shine in the blue region of the spectrum, which enabled a group of such devices to create white light. The early *Light Emitting Diodes*, or LEDs, were a great step forward from the previous technology of *Liquid Crystal Display*, or LCD, but their use was limited because devices that gave off blue light had not been developed.

The earliest device used for display was the TV tube, also called the Cathode Ray Tube, which was an electron beam that struck a screen coated with chemicals. The electron beam was made to scan the whole screen several times a second and the strength of the beam varied as it moved to create bright or dark spots, which formed the display. The trouble was that this device needed high voltage to create the electron beam and was bulky. The coating on the screen was also poisonous and difficult to dispose of.

The LCD consisted of an array of small devices that could be light or dark, depending on voltages applied to each of them. Each LCD cell was actually a window that opened or shut, according to the voltage applied, and consisted of a pair of transparent but conducting screens with a property of allowing only light in which the vibrations were in a particular plane to pass. The screens were separated by a material, the liquid crystal, which rotated the plane of vibration of light coming through the first screen before it struck the second screen. And this second screen was oriented so that in the normal course the light passed this screen also and the cell appeared grey. But when a voltage was applied across the two screens, which were conducting, the liquid crystal stopped turning the plane of vibration of light and light did not pass through the second screen. The cell then appeared dark. The devices worked with very low currents and could be made small enough so the array could display reasonably clear images.

LCDs were succeeded by the LED, which made for a much finer grain of images and faster switching on or off, better power efficiency and longer life. The LEDs were tiny specks of crystals consisting of atoms, which had not just a few electrons to allow less current to pass, like an insulator, but were also without free electrons that allow currents readily, as in conductors. Now, this class, known as semiconductors, can be modified by adding an impurity so that they have either a few extra electrons that carry current, or a few places that lack an electron, called *holes*, which can also carry current in the opposite way. If there is a junction of these two kinds of semiconductor, the free electrons on one side drift into the other side to combine with holes, but also create a charge difference by moving about, and the movement stops. But if a voltage is applied, which keeps the current going, the instances of electrons combining with holes gives off some energy, which can be flashes of light. Such devices can then be displays or even light sources for communication, and they are a great step forward in efficiency.

The colour of the light emitted can also be changed by varying the materials and strong emitters in a number of colours, which could be combined, have been developed. But for creating white light, it was necessary to have a source of the blue component too, and developing a good source of this colour did not succeed for a long time.



Super-resolution image of bacterial cells using fluorescent dye molecules
(colours inverted)

The achievement of the three Japanese Nobel laureates was to work on the energy difference when electrons fell into holes in different materials and then to overcome the problems in creating defect-free crystals of the best material — finally to arrive at Gallium Nitride, and a method to grow the crystals and then to dope them with the right impurities.

Development of an efficient LED source of blue light has enabled a new generation of image displays and also highly energy efficient white light sources for daily lighting.

The prize for chemistry went to Eric Betzig of Virginia, USA; Stefan Hell of Gottingen, Germany; and E Moerner, Stanford University, for their independent work in developing very high resolution microscopy that uses a molecular property called fluorescence.

Normal microscopy has a natural limit to how good it can get, and this limit is imposed by the frequency of the light used, the medium through which the light passes and the diameter of the microscope lens. Using high frequency light for high resolution would destroy the samples and there are physical limits to the size of lenses. But in fluorescence, the emission of light is by single molecules within the sample being studied, and each molecule is a point source. When observing a point source, the limitations of frequency of light and the size of the lens can be compensated by observing a greater number of photons, which can be done in fluorescence by making a large number of observations, or by recording the fluorescence for a long time.

The first successful sensing of single molecules using light was reported by WE Moerner, along with a colleague, in 1989. Soon after, in 1992, Eric Betzig discovered a method of positioning a sub-wavelength size hole in a metal screen at the tip of an optical fibre and exciting single molecule fluorescence.

Stefan Hell worked on another way to increase resolution, which takes off from observing fluorescence where the emission is not of one photon at a time but of two or more. This method increases resolution by a factor that depends on the number of photons, but its implementation is nearly impossible. Hell used a device of suppressing fluorescence in a doughnut-shaped area and shrinking the hole of the doughnut, a method that mimics high intensity emission and, hence, high resolution.

The use of this method, with intense emitters of fluorescence, has been able to reach resolution as low as 10 nanometres.

With a further refinement of using statistical methods to resolve single molecule events from among others, the recent progress in this field of optical nanoscopy has been breathtaking. Not only has imaging below the limit set by the wavelength of light become possible, a variety of applications has helped push back the frontier of our understanding of matter at the very small scale.

Erik Betzig, Stefan Hell and WE Moerner

THE WRITER CAN BE CONTACTED AT
simplescience@gmail.com

MEMBRANE POTENTIAL

TAPAN KUMAR MAITRA EXPLAINS THE IMPORTANCE OF NEURONS IN TRANSMITTING SIGNALS FROM ONE PART OF AN ORGANISM TO ANOTHER

All cells maintain an electrical potential across their membranes but neurons are specialised to use membrane potentials as a means of transmitting signals from one part of an organism to another. For this function, they possess slender processes (dendrites and axons) that either receive transmitted impulses or conduct them to the next cell. The membrane of an axon may or may not be encased in a myelin sheath.

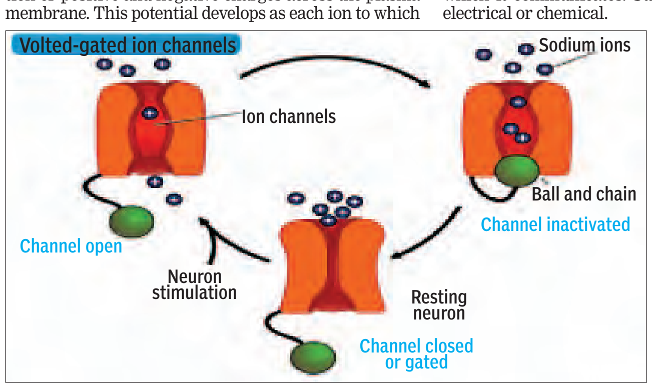
Cells develop a membrane potential due to the separation of positive and negative charges across the plasma membrane. This potential develops as each ion to which the membrane is permeable moves down its electrochemical gradient. The maximum membrane potential that an ion gradient can produce is the equilibrium potential for that ion — a theoretical condition that is not achieved in cells because it requires that the membrane be permeable only to that ion.

To calculate the resting membrane potential of a cell, the Goldman equation is used. The resting potential for the plasma membrane of most animal cells is usually in the range -60 to -75 mV. These values are quite near the equilibrium potential for potassium ion, but very far from that for sodium ion (about +55 mV), reflecting the greater permeability of the resting membrane for potassium.

The action potential of a neuron represents a transient depolarisation and repolarisation of its membrane, due to the sequential opening and closing of voltage-gated sodium and potassium ion channels. These channels have been characterised structurally by molecular techniques and functionally by patch clamping. They are voltage-gated ion channels whose probability of opening, and consequently their conductance, depends on membrane potential.

An action potential is initiated when the membrane is depolarised to its threshold, a point at which the rate of sodium influx exceeds the maximum rate of potassium efflux under resting conditions. The entry of sodium ions drives the membrane potential to approximately +40 mV before voltage-gated sodium channels inactivate. Depolarisation also stimulates the opening of slower voltage-gated potassium channels, which leads to repolarisation of the membrane, including a short period of hyperpolarisation. This sequence of channel opening and closing generally takes a few milliseconds.

The depolarisation of the membrane due to an action potential spreads by passive conductance to adjacent regions of the membrane, which in turn generates a new action potential. In this way, an action potential is propagated along the membrane, eventually reaching a synapse between a nerve cell and another cell with which it communicates. Such synapses may be either electrical or chemical.



Facilitated diffusion is when transport proteins are needed to help move molecules across a membrane, those that cannot move by diffusion on their own. A channel protein allows specific molecules to simply pass through (aquaporins). Channel proteins that transport ions are called ion channels, many of which are gated, only opening or closing in response to a stimulus.

In an electrical synapse, depolarisation is transmitted from the presynaptic cell to the postsynaptic cell by a direct gap junctional connection. In a chemical synapse, the electrical impulse increases the permeability of the membrane to calcium. As calcium ions cross the presynaptic membrane, they cause synaptic vesicles to fuse with the membrane. The synaptic vesicles contain neurotransmitter molecules, which are released into the synaptic cleft by the fusion event. Neurotransmitter molecules diffuse across the cleft to the postsynaptic membrane, where they bind to specific receptors, often ligand-gated ion channels.

The best understood is the acetylcholine receptor, which is an excitatory receptor. Binding of acetylcholine stimulates this channel to open, permitting sodium to enter. The resulting sodium influx produces a local depolarisation of the postsynaptic membrane, which in turn can initiate an action potential in the postsynaptic cell. Following depolarisation, the enzyme acetylcholinesterase hydrolyses the acetylcholine, thereby returning the synapse to its resting state.

Specific neurotransmitters can produce either excitatory or inhibitory postsynaptic potentials. Therefore, transmission of an action potential from one neuron to another requires that the cell body of postsynaptic neuron integrate the excitatory and inhibitory activity of thousands of synaptic inputs. Through temporal and/or spatial summation, incoming signals can depolarise the nerve cell body sufficiently to initiate a new action potential at the axon hillock.

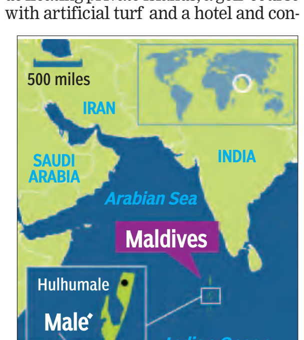
THE WRITER IS ASSOCIATE PROFESSOR, HEAD, DEPARTMENT OF BOTANY, ANANDA MOHAN COLLEGE, KOLKATA, AND ALSO FELLOW, BOTANICAL SOCIETY OF BENGAL, AND CAN BE CONTACTED AT
tapanmaitra59@yahoo.co.in

Tackling overcrowding

HOMES ON FLOATING PLATFORMS MADE LARGELY OF PLASTIC BOTTLES ARE IN THE OFFING TO EASE HOUSING PROBLEMS IN THE MALDIVES

The Maldives, one of the most densely populated nations, has embarked on a series of floating developments that could take the pressure off a severe housing shortage and counter sea-level rises owing to climate change. The firm behind the project is also proposing to build cheaper floating platforms, made largely from plastic bottles, to house schools and essential services in the aftermath of floods elsewhere in the developing world.

The first initiative, The 5 Lagoons Project, is a joint venture between the Maldivian government and a Netherlands company, Dutch Docklands. Located near the capital, Malé, it is aimed at tourists, but there are plans to develop affordable floating homes for citizens in future. Koen Olthuis, an architect who co-founded Dutch Docklands, says the first construction phase — comprising 185 luxury villas — began four months ago, with completion expected in July 2016. Later phases include floating private islands, a golf course with artificial turf and a hotel and convention centre that could attract climate-change conferences.



The structures float on concrete and styrofoam foundations, anchored to the seabed with cables or telescopic mooring piles — tube-like structures that can extend up and down with changing sea levels.

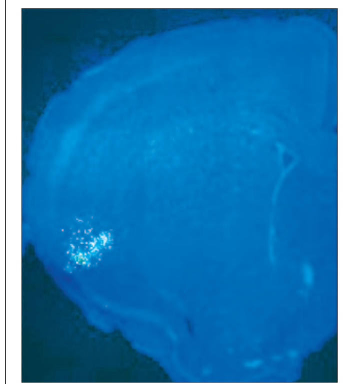
Olthuis says total investment for the project, which is backed by private investors he would not identify, could be more than $1 billion. But he expects it will be five years before construction begins of affordable floating homes for residents, for which contracts and financing are not yet arranged.

Tourism projects are needed first to generate income and demonstrate the benefits, he says.

When Dutch Docklands explained its technology to Maldivian ministries two years ago, the conclusion was that up to 20,000 houses would be needed in the next 10 to 15 years to cope with that expansion. And some of those homes could be built on floating platforms at an affordable cost of less than $40,000 each. That is not much more expensive than affordable housing of comparable size in the Maldives today, says Olthuis. Dutch Docklands is working on similar floating technology that could be used to provide safe, useable space near slums threatened by flooding in Dhaka, Jakarta and Manila. These platforms are made of thousands of plastic bottles held together with scaffolding, and could be used to provide services during floods, such as schools and power generators. One such platform is due to be sent to Jakarta from the Netherlands in mid-December, equipped with Internet facilities for education purposes.

SCIDEV.NET

PLUS POINTS



In the right hemisphere of a mouse brain stained with DAPI (blue), some neurons in the insular cortex express GFP-CREB (green).

How memory is made

When a nasty taste makes the stomach turn, neurons in the brain's insular cortex fire up to form a memory of the foul flavour. But only a subset of cells are involved in storing that memory. In mice learning to dislike saltwater, new memories favor neurons with high levels of the cyclic-AMP-response-element-binding protein (CREB), according to a study published today (November 13) in *Current Biology*.

A team of researchers at the University of California, Los Angeles, examined the development of a conditioned taste aversion response in mice that overexpressed CREB in a subset of insular cortex neurons. Precise inactivation of the CREB-expressing neurons revealed that these cells were required for the mice to remember the bad-taste experience. CREB, which activates the transcription of genes that make neurons more excitable, may play a broad role in regulating memory allocation in the mammalian brain.

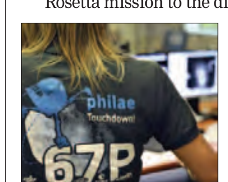
"There's a huge amount of work on molecular mechanisms of memory storage, and there's relatively little known about the processes that are important for memory allocation — which cells really code the memory," said neuroscientist Dietmat Kuhl of the University of Hamburg in Germany who was not involved in the study.

The idea that CREB determines which neurons form a memory made sense, added Mauro Costa-Mattioli of the Baylor College of Medicine. "The neurons are competing for the memory trace — not everyone can get it," he said. "Those that are more excitable have more chances."

MOLLY SHARLACH/THE SCIENTIST

Giant leap forward

On the face of it, it looks like an expensive mishap to rank alongside disappointing Mars landers and malfunctioning telescopes, but the Rosetta mission to the distant 67P comet was being celebrated recently as a giant leap forward in space exploration.



On 12 November, the washing machine-sized Philae robotic probe made a historic landing on the speeding, icy space-rock 500 million km from earth. But five days later the last of its battery power had drained, after a difficult landing left it in a dark spot. Before the batteries failed, though, it had transmitted all the data it had gathered, first to its orbiting mothership and on to mission control in Darmstadt, Germany. In doing so, it may unlock the mysteries of comets, which are made from a material older than our solar system.

It was a "rollercoaster" week for mission manager Fred Jansen, but with his team at the European Space Agency he can now start analysing a treasure trove of information. On landing last week, the probe's harpoons failed to fire and it bounced twice before coming to rest more than half a mile from its original landing site in a spot where ESA engineers feared it would not be able to recharge its solar batteries.

Despite this, it was confirmed on Monday that the lander successfully returned data from all 10 of its instruments. The machine "performed magnificently under tough conditions", said lander manager Dr Stephan Ulamec. "We can be fully proud of the incredible scientific success Philae has delivered."

What is not known is whether, having rotated its solar panels to receive maximum illumination, the lander will be able to reboot as the comet approaches the sun. Engineers had been able to push the probe up by about four centimetres, before performing a 35-degree twist.

"The official position is that we don't expect to hear from Philae again," said Christopher Carr, a principal investigator for the Rosetta orbiter. "All the science instruments have done what they needed to do; so essentially it's been a complete success. In many respects now the lander mission is done — the orbiter mission is starting."

KITTY KNOWLES/THE INDEPENDENT