Akasaki, Amano and Nakamura persisted with gallium nitride long after their competitors had moved on to other materials, says Wolfgang Schnick, a materials chemist at the Ludwig Maximilian University of Munich in Germany.

Their success in overcoming those hurdles has opened the door to white LEDs, which can have efficiencies nearly 20 times those of conventional bulbs.

Almost all white LED-based lights consist of a blue LED chip combined with one or more luminescent materials, which convert part of the blue light to longer wavelengths. "This has led to a revolution in the lighting industry, and will have more and more impact on the way people are lighting their homes," says Dirk Poelman, a materials scientist at Ghent University in Belgium.

Schnick says that the development "cannot be estimated too highly". "This will help to save up to 20% of the global electricity consumption," he says.

Schnick added that in future, blue LEDs are likely to find uses in portable devices that can disinfect or sterilize water, and perhaps in computer memories that use light instead of electricity to store data. Blue lasers — also invented by Akasaki and Amano, and separately by Nakamura — are already used in Blu-ray Disc technology.

The story is not without twists. Nakamura, who left Japan in 2000 to join the University of California, Santa Barbara, sued Nichia in 2001 over the scant compensation he received for inventing the blue LED technology while he worked there. The case was settled in January 2005, when Nakamura accepted ¥840 million (US$8.1 million at the time). "Nakamura was quite determined to show that gallium nitride could be an effective LED technology. He pushed it very hard — it was something they were not initially concentrating on," says Martin Dawson, a photonics researcher at the University of Strathclyde in Glasgow, UK.

Speaking on a crackling telephone line to journalists in Sweden on 7 October, Nakamura said that the feeling of winning the prize was "unbelievable". Staffan Normark, permanent secretary of the Royal Swedish Academy of Sciences, told journalists that the trio had not been expecting the prize. "They had not been waiting all day and all night for this call," he said.

Announcing the prize, Per Delsing, chairman of the academy's Nobel Committee for Physics, said that the award cherished the tradition of its founder, the engineer and inventor Alfred Nobel. "I really think that Alfred Nobel would have been happy about this prize," he said. ■

Additional reporting by **Richard Van Noorden**.

NOBEL PRIZES

Prize for place cells

Discoverers of brain's navigation system get physiology Nobel.

BY ALISON ABBOTT & EWEN CALLAWAY

Brain cells that make up the biological equivalent of a satellite-navigation system have garnered three scientists the 2014 Nobel Prize in Physiology or Medicine. The discovery of the cells sheds light on one of neuroscience's great mysteries — how we know where we are in space.

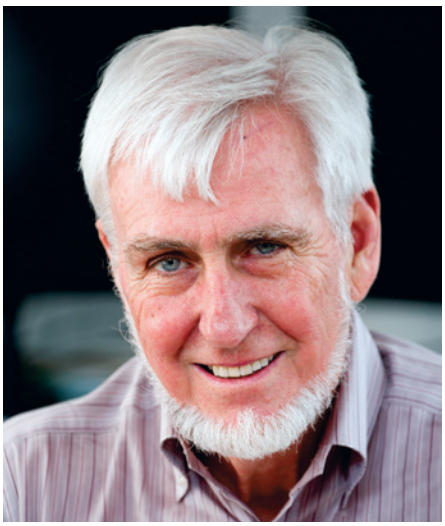
John O'Keefe of University College London won half of the prize for his discovery in 1971 of 'place' cells in the hippocampus, a part of the brain associated with memory. Edvard and May-Britt Moser, who are married and jointly run a lab at the Kavli Institute for Systems Neuroscience in Trondheim, Norway, share the other half for their 2005 discovery of 'grid' cells in an adjacent brain structure, the entorhinal cortex. Along with other navigation cells, grid and place cells allow animals to keep track of their position. Both cell types were discovered in rats, but have since been found in humans.

"Understanding where we are in space is one of the most fundamental issues for survival," says Tobias Bonhoeffer, director of the Max Planck Institute of Neurobiology in Martinsried, Germany.

The discoveries will also be key to answering the broader question of how the brain makes sense of the world, says neuroscientist Botond Roska of the Friedrich Miescher Institute for Biomedical Research in Basel, Switzerland. "These are three deep-thinking people who have changed the way we think about the brain," he says.

Most neuroscientists once doubted that brain activity could be linked with behaviour, but in the late 1960s, O'Keefe began to record signals from individual neurons in the brains of rats moving freely in a box. He put electrodes in the hippocampus and was surprised to find that individual cells fired when the rats moved to particular spots. He concluded that the memory of an environment may be stored as a specific combination of place-cell activities in the hippocampus (J. O'Keefe and J. Dostrovsky *Brain Res.* **34,** 171–175; 1971). "I realized that if you put them all together, you could have something like a map," says O'Keefe.

Fast-forward to the 1990s, and his work attracted the attention of the Mosers, then PhD students at the University of Oslo. They joined him in London as postdocs, but within months they had moved to the Norwegian University of Science and Technology in Trondheim to set up their own lab. There they discovered that some cells in the entorhinal cortex fire when rats pass the points of a hexagonal grid. They found out that the brain uses this pattern as a coordinate system for spatial navigation (T. Hafting *et al. Nature* **436,** 801–806; 2005).



DAVID BISHOP/UCL

John O'Keefe, co-winner of a 2014 Nobel prize.

The pattern constitutes what is known as a neural code. It is the only one known to be generated entirely in the brain, marking a milestone for computational neuroscience (see page 154).

Both place and grid cells have practical relevance. The early stages of Alzheimer's disease affect the entorhinal cortex, and one of the first symptoms is losing one's way. The disease goes on to devastate the hippocampus, stripping sufferers of their memories. "It is a good example of how very basic research can help us gain the deeper understanding we need in such devastating diseases to move towards therapies," says Richard Morris, a memory researcher at the University of Edinburgh, UK.

May-Britt was presiding over a lab meeting when the call came from the Nobel committee in Stockholm. "I hesitated to answer it," she told *Nature*, laughing. "But I did — and I couldn't believe it; I even cried." Edvard's excitement was delayed: he was on a aeroplane to Munich, Germany, when his wife got the call. O'Keefe heard the news while working on a grant revision at home. "I'm totally delighted and thrilled," he said in front of a phalanx of television cameras at a London press conference.

The Mosers once described their time in O'Keefe's lab as "probably the most intense learning experience in our lives". O'Keefe has similar memories. "It was intense — because they're intense. They're absolutely superb scientists." ■