PHYSICS

Nobel for 2D exotic matter

Physics award goes to theorists who used topology to explain strange phenomena.

BY ELIZABETH GIBNEY AND DAVIDE CASTELVECCHI

Physics prizewinners Michael Kosterlitz (left), David Thouless (centre) and Duncan Haldane (right).

LEHTIKUVA/RONI REKOMAA/REUTERS; TRINITY HALL, UNIV. CAMBRIDGE; DOMINIC REUTER/REUTERS

David Thouless, Duncan Haldane and Michael Kosterlitz have won the 2016 Nobel Prize in Physics for their theoretical explanations of strange states of matter in 2D materials, known as topological phases.

The British-born trio's work in the 1970s and 1980s laid the foundations for predicting and explaining bizarre behaviours that experimentalists discovered at the surfaces of materials, and inside extremely thin layers. These include superconductivity — the ability to conduct without resistance — and magnetism in very thin materials. At the time, these mathematical theories were quite abstract, said Haldane in an interview with the Nobel Committee just after winning the prize. He said that he was "very surprised and very gratified" to receive the award. But physicists are now exploring similar states of matter for potential use in a new generation of electronics, and in quantum computers.

Thouless and Kosterlitz's breakthroughs began while at the University of Birmingham, UK. The pair demonstrated that, in theory, superconductivity could occur at low temperatures in thin layers of materials, but would disappear at higher temperatures. They also explained the mechanism that would make the effect vanish. Their theory, the Kosterlitz–Thouless (KT) transition, turned out to apply to many different kinds of 2D material.

In 1982, Thouless also explained a phenomenon known as the quantum Hall effect. In this odd effect, when electrons are confined to thin films, chilled to near absolute zero and subjected to a strong magnetic field, they flow in an orderly way with conductivity that increases in steps with an increasing magnetic field. Thouless viewed the problem through the concept of topology, which describes properties that remain unchanged if an object is deformed but not torn. Just as a knot tied in an unbroken circle of string cannot be removed without cutting the string, topological properties tend to be robust. Changes happen only in sudden steps rather than smoothly, and Thouless showed that the quantum Hall effect was just such a topological phenomenon.

Haldane applied the concept of topology to chains of magnetic atoms. These atoms have a quantum property known as spin, and in 1982, he predicted that certain chains of the atoms could show topological properties that result in half spins at either end. Because this quantum property depends on the collective action of the whole chain, rather than on any individual particle, similar phenomena are now being explored as robust ways to encode information in a quantum computer.

"In different ways, they showed how the concept of topology could give rise to new forms of matter that hadn't previously been understood," says Nigel Cooper, a theoretical physicist at the University of Cambridge, UK.

The theorists now all work in the United States: Thouless at the University of Washington, Seattle; Kosterlitz at Brown University in Providence, Rhode Island; and Haldane at Princeton University in New Jersey. Thouless takes half the prize; the other half is split between Kosterlitz and Haldane. ■

NOBEL PRIZES

Medical award for cell recycling

Japanese biologist Yoshinori Ohsumi recognized for work on crucial biological process.

BY RICHARD VAN NOORDEN AND HEIDI LEDFORD

Molecular biologist Yoshinori Ohsumi has won the 2016 Nobel Prize in Physiology or Medicine for his work on autophagy: the processes by which the cell digests and recycles its own components.

The 71-year-old Ohsumi, a professor at the Tokyo Institute of Technology in Yokohama, was recognized for experiments in the 1990s that used baker's yeast (*Saccharomyces cerevisiae*) to identify genes that control how cells destroy their own contents. Similar mechanisms operate in human cells and are sometimes involved in genetic disease.

"He's a very humble yeast geneticist who basically transformed the field," says Sharon Tooze, a cell biologist at the Francis Crick Institute in London.

The term autophagy — from the Greek for 'self-eating' — was coined in 1963 by the Belgian biochemist Christian de Duve, who saw how cells broke down their parts inside a waste-processing sac that he called a lysosome. Biologists now understand that this process is fundamentally important to living cells.

TOKYO INST. TECHNOL./REUTERS

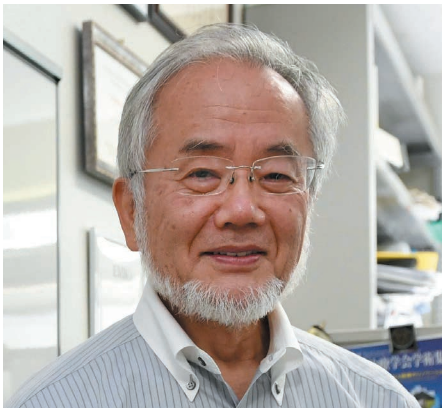
"Without autophagy, our cells won't survive," says Juleen Zierath, a physiologist at the Karolinska Institute in Stockholm who is on the selection committee for the medicine Nobel. When cells are starved, they can consume their own proteins for fuel. The same process can be used to clear out debris such as damaged proteins and organelles, or to ward off invading bacteria and viruses.

SLEEPY BACKWATER

When Ohsumi first started studying autophagy in 1988, "it was kind of a sleepy backwater of a research topic", says biochemist Michael Hall of the University of Basel in Switzerland. "It was basically considered the garbage-disposal system of the cell — just bulk, non-specific degradation of junk."

Ohsumi would go on to develop the first yeast genetics screen to identify genes involved in autophagy. "You can answer the most basic and important questions about the nature of life through yeasts," he said in an interview published on the Tokyo Institute of Technology's website in 2012. But it was a few years before biologists recognized the importance of the process in physiology and disease.

Interest in the field skyrocketed when, in 1999, Beth Levine (now at the University of Texas Southwestern Medical Center in Dallas) and her colleagues reported that a mammalian autophagy gene could suppress tumour growth. The finding launched widespread efforts to learn more about autophagy's role in cancer.



Yoshinori Ohsumi won the 2016 Nobel Prize in Physiology or Medicine.

Disruptions in autophagy have also been linked to Parkinson's disease, type 2 diabetes and other disorders — and research is ongoing to develop drugs that can affect the process.

Researchers' understanding of the complex role of autophagy in cancer has become more detailed: the process seems to inhibit tumours in the early stages of growth, but can also fuel cancer once it has spread, says Hall.

Ohsumi, who will collect 8 million Swedish kronor (US$940,000) for the Nobel prize, won the ¥50-million (US$626,000) Kyoto Prize in basic sciences in 2012 for his autophagy work.

Others have made key contributions to the field, and were considered contenders for a share of a Nobel. Biochemist Michael Thumm of the University Medical Center Göttingen in Germany also discovered autophagy genes, as did cell biologist Daniel Klionsky of the University of Michigan in Ann Arbor.

"If they're going to give it to just one, Ohsumi's the one," says Hall. "But it also would have been good to include other people."

In Japan, the prize had been widely anticipated for the past few years, with journalists showing up regularly to ask Ohsumi for interviews, says Hitoshi Nakatogawa, a biologist at the Tokyo Institute of Technology who has worked with Ohsumi for a decade. When colleagues heard of Ohsumi's win — around two hours before the official announcement — they gathered to celebrate in his lab. "We talked about how great it was that he won it alone," he says.

"Ohsumi never overlooks anything, even in the most banal kind of experiment," Nakatogawa adds. "He doesn't care about whether it will lead to something useful, whether a breakthrough can be expected, whether it will lead to more funding. He just follows his curiosity." ■

Additional reporting by **David Cyranoski**.

CORRECTION

The News story ‘Medical award for cell recycling’ (*Nature* **538,** 18–19; 2016) gave the wrong affiliation for Hitoshi Nakatogawa — he is at the Tokyo Institute of Technology.