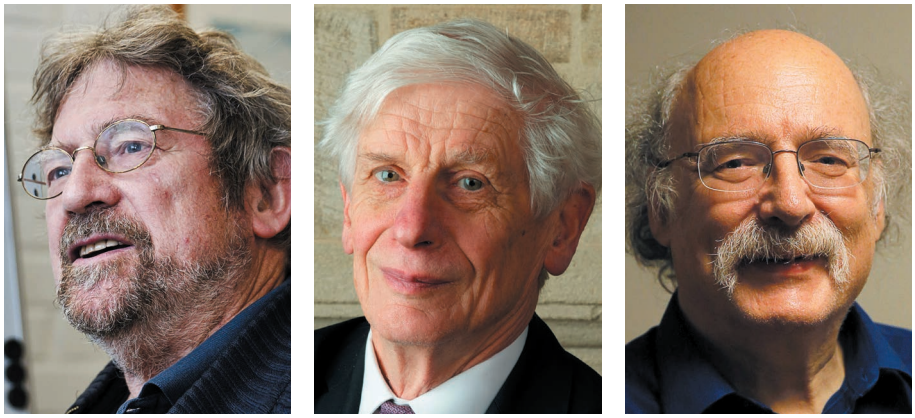
PHYSICS

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).

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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.