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THE ROYAL SWEDISH ACADEMY OF SCIENCES

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2016 to **David J. Thouless, F. Duncan M. Haldane** and **J. Michael Kosterlitz** "for theoretical discoveries of topological phase transitions and topological phases of matter".

The Nobel Prize 2016 **in Physics**

The mysterious landscape of topological matter

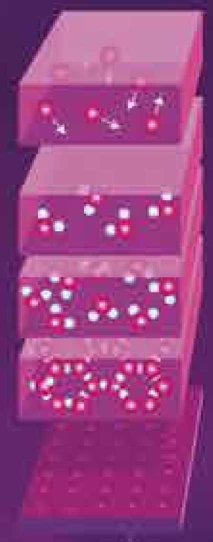
This year's Laureates opened the door to an unknown world with strange states of matter. Their pioneering work led to the present-day search for new and exotic materials. Many physicists hope for applications in materials science and electronics.

David Thouless, Duncan Haldane and Michael Kosterlitz have used advanced mathematical methods to explain strange phenomena in unusual states (or phases) of matter, such as superconductors, superfluids or thin magnetic films. Kosterlitz and Thouless have studied phenomena that arise in a flat world – on surfaces or inside extremely thin layers that can be considered two-dimensional, compared to the three dimensions (length, width and height) that usually describe our physical world. Haldane has also studied matter that forms threads so thin they can be considered one-dimensional.

The physics that takes place in these low dimensional materials is very different from the familiar world around us. Thin matter consists of billions of atoms and even if each individual atom's behaviour is known in the tiniest detail, entirely unexpected collective phenomena may occur when the atoms interact with each other.

The key insight of the three Laureates' discoveries was that topological concepts are necessary for describing the new collective behaviour of the materials – new topological phases of matter and topological phase transitions between them. Topology is the branch of mathematics which only change step-wise in a phase transition. Using modern topology as a tool, the Laureates were able to present surprising results.

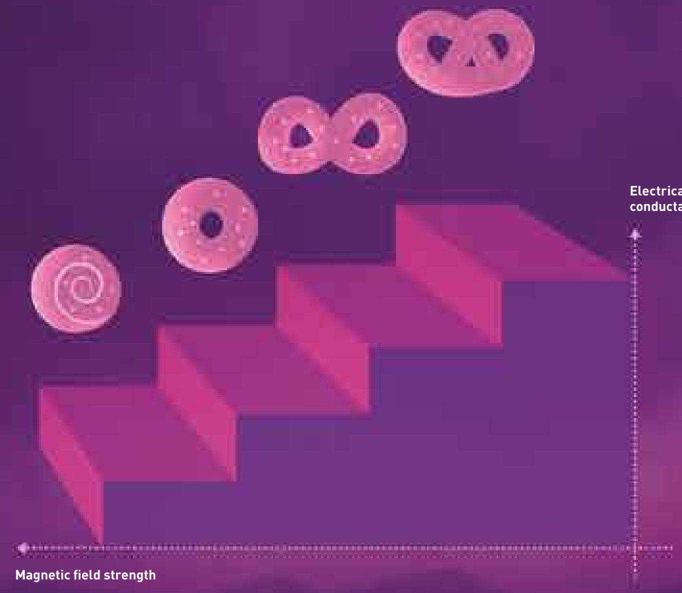
Topological insulators, topological superconductors and topological half-metals are now being widely investigated. In the last decade, this field has defined frontline research, driven by the hope that topological materials will be useful for future generations of electronics or realising the dream of quantum computers.



Phases of matter and phase transitions

The most common phases of matter around us are solid, liquid and gas. When the temperature changes there may be a transition from one phase to another. A phase transition occurs when ice, which consists of well-ordered solid crystals, is heated and melts into water, a more chaotic liquid phase of matter.

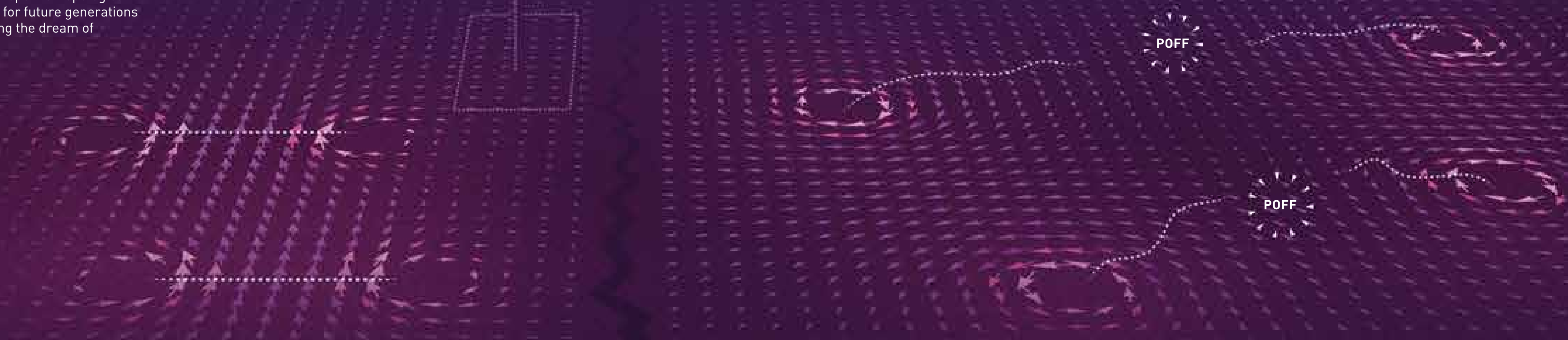
In extreme cold, close to absolute zero (–273 degrees Celsius), matter takes on mysterious quantum phases that behave in unexpected ways. If we look inside the flat world of two-dimensional quantum matter, even more exotic phases appear that are now being investigated.



Topology

This branch of mathematics studies the properties of an entire system that changes only in integer steps, such as the number of holes in baked goods, which is always an integer 1, 2, 3... There is no such thing as half a hole.

Topology was the key to the Nobel Laureates' discoveries. David Thouless used topology to explain why electrical conductance inside thin layers in strong magnetic fields increases in steps when the strength of the magnetic field decreases.



David J. Thouless
Born 1934 in Bearsden, UK. Emeritus Professor at the University of Washington, Seattle, WA, USA.

F. Duncan M. Haldane
Born 1951 in London, UK. Eugene Higgins Professor of Physics at Princeton University, NJ, USA.

J. Michael Kosterlitz
Born 1943 in Aberdeen, UK. Harrison E. Farnsworth Professor of Physics at Brown University, Providence, RI, USA.

Superconductors and superfluids

Strange things happen in the cold. For example, the resistance encountered by all moving particles can suddenly cease to exist. This is the case when electrical current flows with no resistance in a superconductor, or when a vortex in a superfluid spins forever without slowing down.

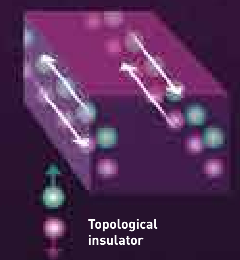
Topological phase transition

Scientists long believed that phase transitions were impossible in a flat, two-dimensional world. But in the early 1970s, David Thouless and Michael Kosterlitz challenged that idea (the former out of curiosity and the latter out of ignorance, as they themselves have claimed) by creating a model for a topological phase transition.

The leading role in a topological phase transition is played by small vortices that form tight pairs at low temperatures (left image). When the temperature rises, a phase transition takes place: the vortices suddenly separate, moving away from each other on their own (right image).

Future materials

When Duncan Haldane studied exotic phases of materials he discovered, among other things, that chains of magnetic atoms found in some materials display topological properties. Initially, no one believed Haldane's reasoning about atomic chains, but it turned out that he had discovered the first example of a new type of topological material that is now intensively studied by physicists. Important examples of such materials are topological insulators which, although they do not conduct electrical current inside the material, still conduct electricity on the surface.



FURTHER READING More information on the Nobel Prize in Physics 2016: *http://kva.se/nobelphysics2016* and *http://nobelprize.org* **E-BOOK:** ● **Jose, J. V.** (2013). *40 Years of Berezinskii–Kosterlitz–Thouless Theory* (1st ed.). *http://www.worldscientific.com/worldscibooks/10.1142/8572*

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