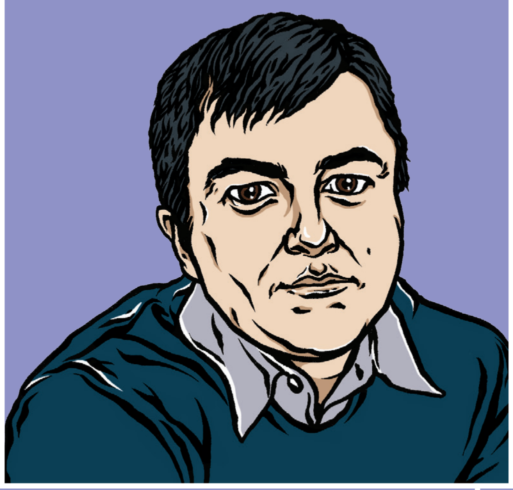
QUANTUM TALES

GRAPHENE, 2004

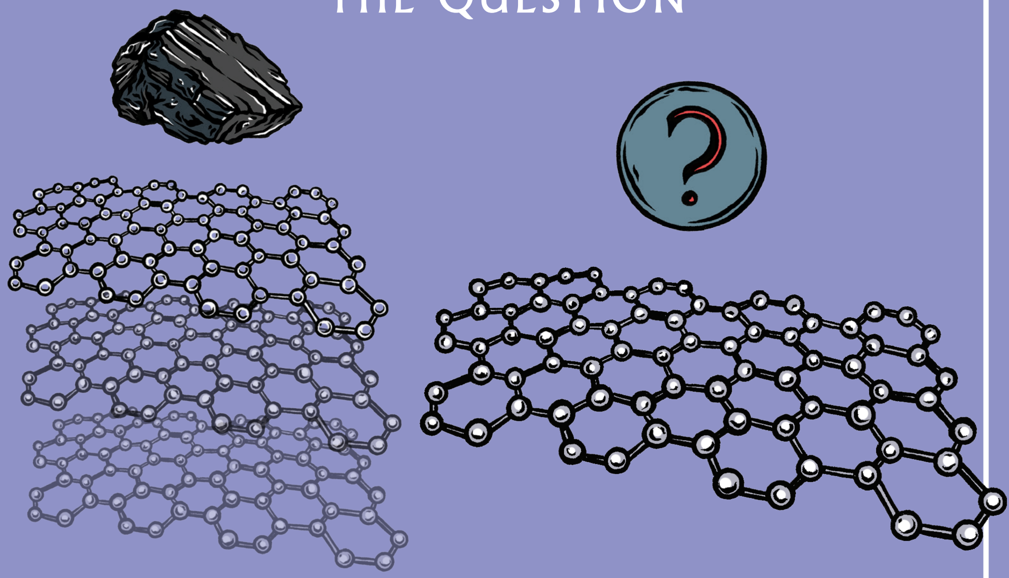
A. GEIM

K. NOVOSELOV



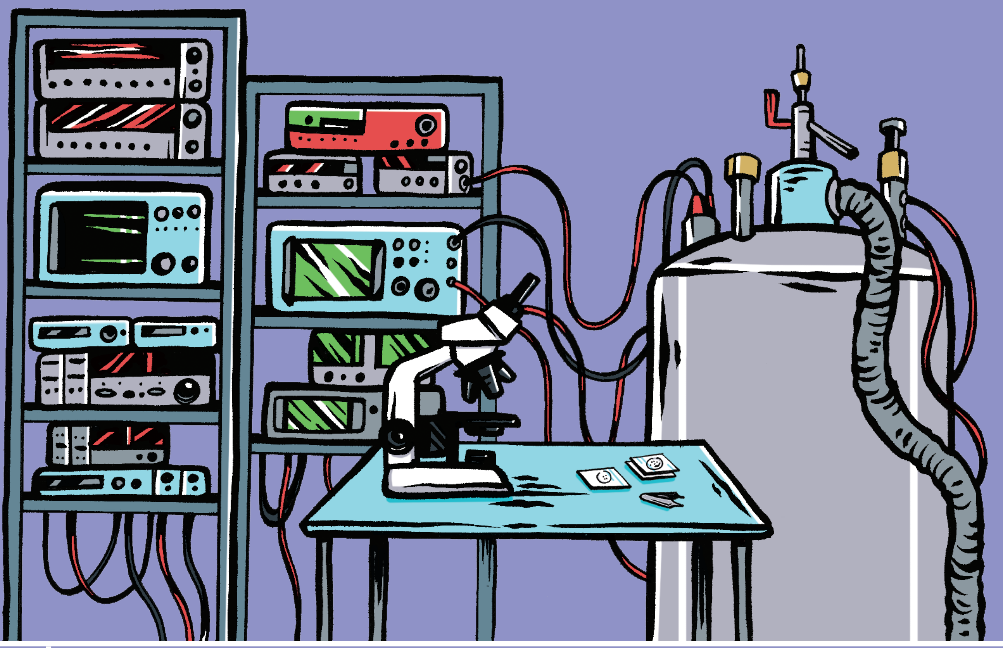
MANCHESTER UNIVERSITY, GB

THE QUESTION

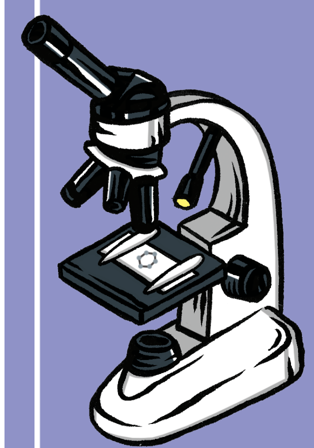


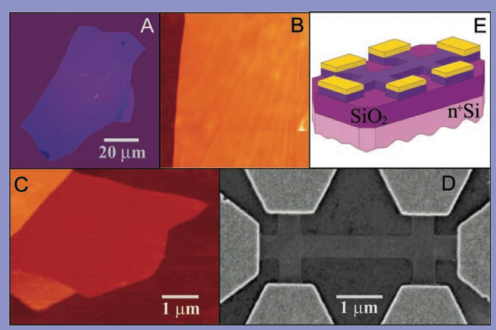
Could one create a material made of a single layer of carbon atoms from graphite? What would be its properties?

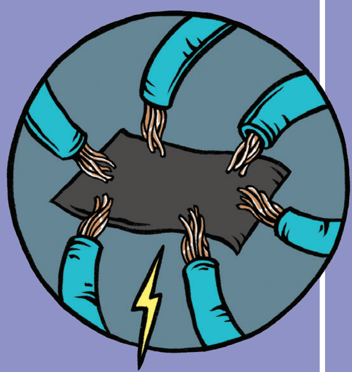
THE LAB



THE RESULT







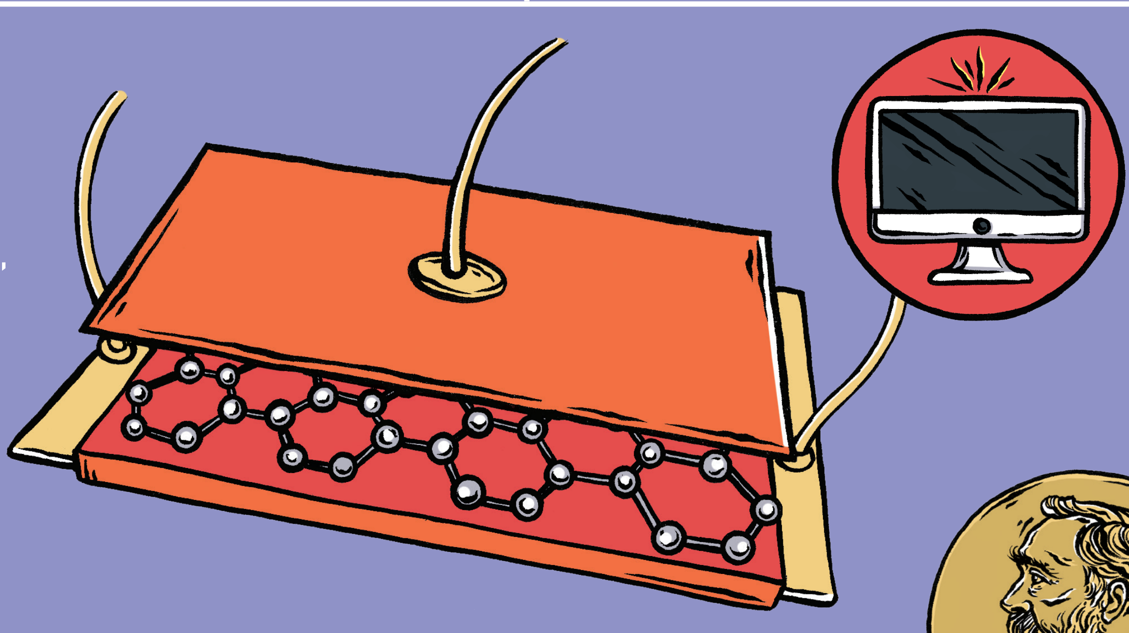
It is possible to create graphene, a 2 dimensional material of a single atom thick. Its mechanical properties are remarkable, and its electrical properties are surprising: neither an insulator nor a metal.

THE ARTICLE

Electric Field Effect in Atomically Thin Carbon Films, K.S. Novoselov, et al., Science **306**, 666 (2004)

NOWADAYS

Graphene could have many applications, especially in nanophysics. Perhaps it will play a major role in electronics in the future.



A. GEIM, K. NOVOSELOV, NOBEL PRIZE, 2010

For groundbreaking experiments regarding the two-dimensional material graphene.

Illustration & layout: Marine Joumard, in collaboration with J. Bobroff and F. Bouquet "Physics Reimagined", CNRS Univ. Paris-Sud. Discover all the quantum tales here : www.PhysicsReimagined.com

QUANTUM TALES

TOPOLOGY, 1972 – 1985

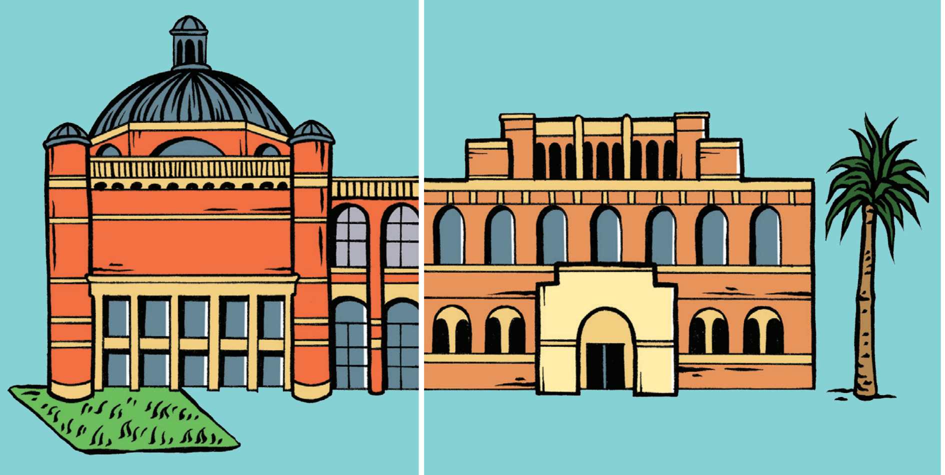
D. THOULESS

M. KOSTERLITZ

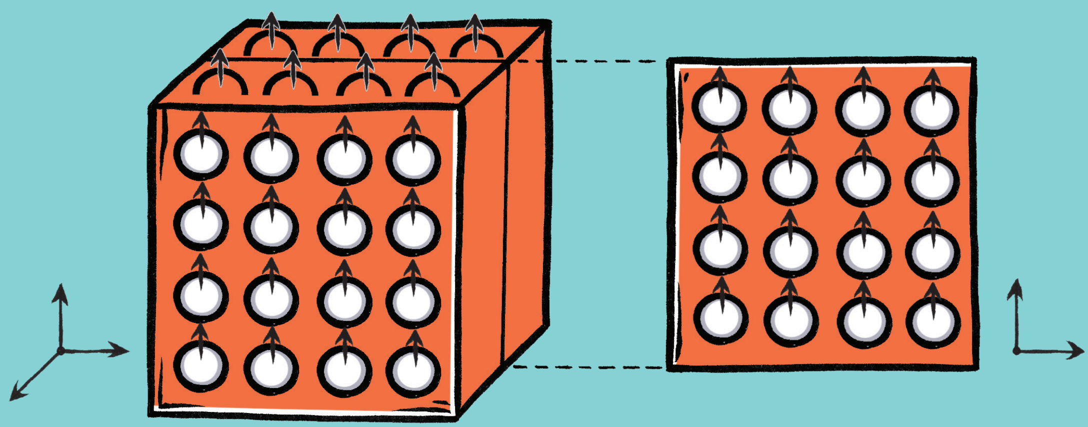
D. HALDANE

BIRMINGHAM UNIVERSITY, GREAT BRITAIN

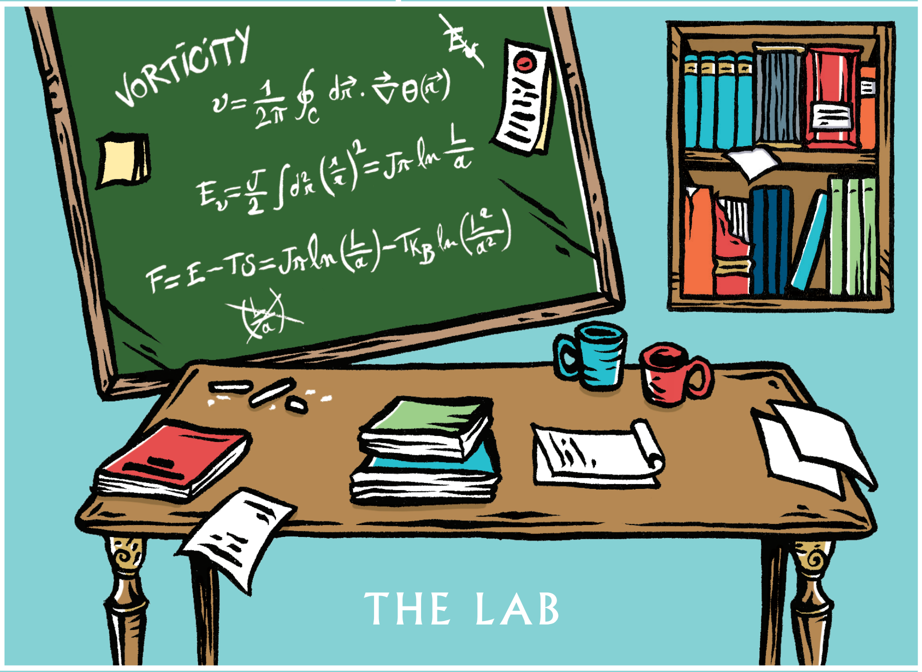
UNIVERSITY OF SOUTHERN CALIFORNIA, USA



THE QUESTION



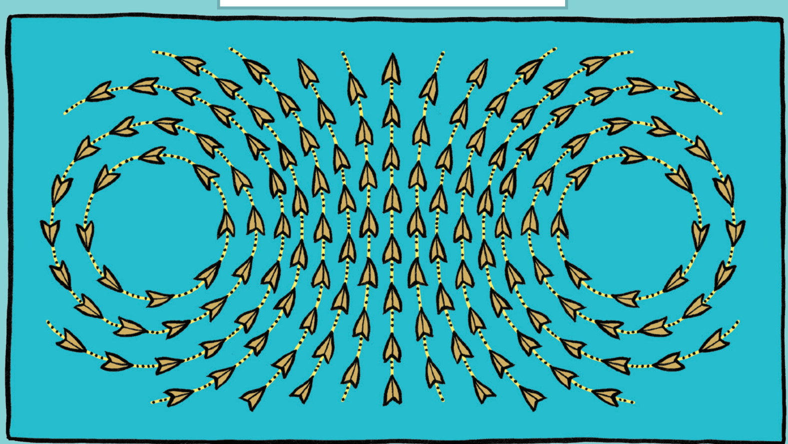
Can a superconductor or a magnet exist in two dimensions?



THE LAB

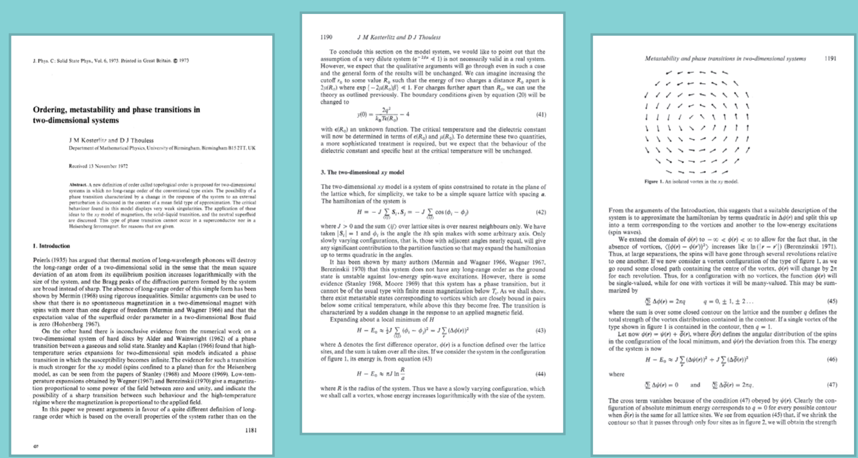
THE RESULT

$$\frac{\pi J}{k_B T_c} - 1 \approx \pi\, \tilde{y}_c(0) \exp\left(\frac{-\pi^2 J}{k_B T_c}\right) \approx 0{\cdot}12 .$$



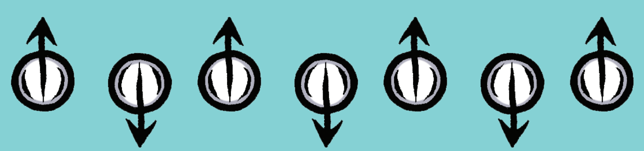
New states can appear in solids for topological reasons.
For example in magnets or 2D superfluids, vortices and anti-vortices appear which allow the order to survive.

THE ARTICLE

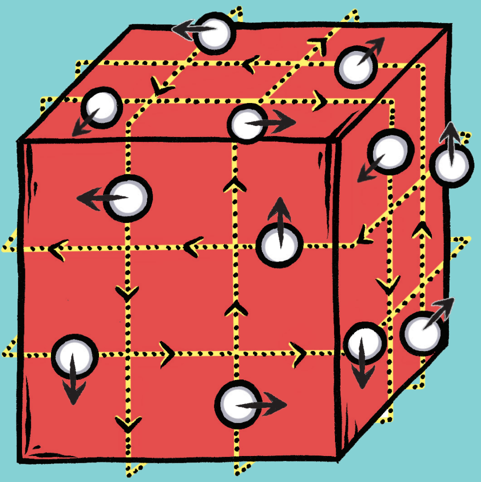


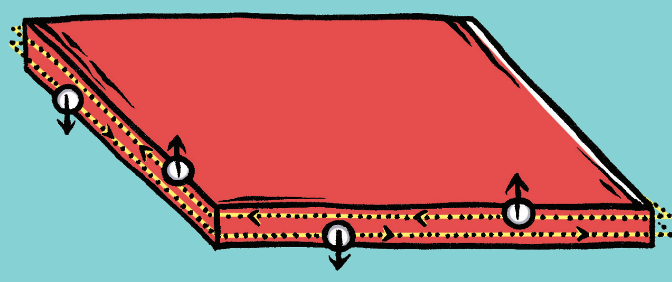
Ordering, metastability and phase transitions in two-dimensional systems
J.M. Kosterlitz, D.J. Thouless,
Journal of Physics C: Solid State Physics, **6**, 1181 (1973).

NOWADAYS



This work opened the route to the discovery of many new topological states in matter at one, two or three dimensions in magnets, metals or insulators.





D. THOULESS, M. KOSTERLITZ, D. HALDANE, NOBEL PRIZE, 2016

For theoretical discoveries of topological phase transitions and topological phases of matter.

QUANTUM TALES

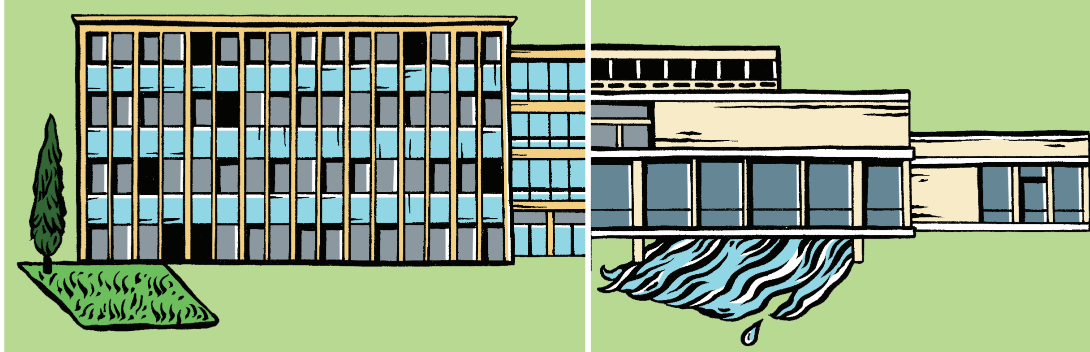
GIANT MAGNETORESISTANCE, 1988

A. FERT

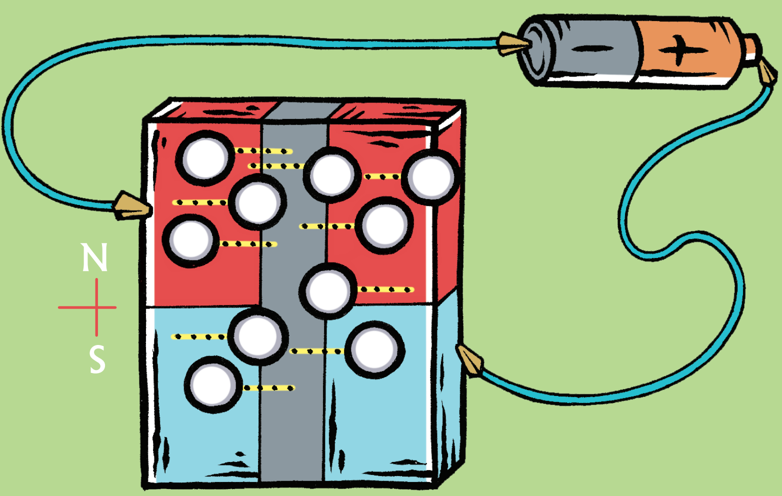
P. GRÜNBERG

LABORATOIRE DE PHYSIQUE DES SOLIDES, ORSAY, FRANCE

JÜLICH INSTITUTE, GERMANY

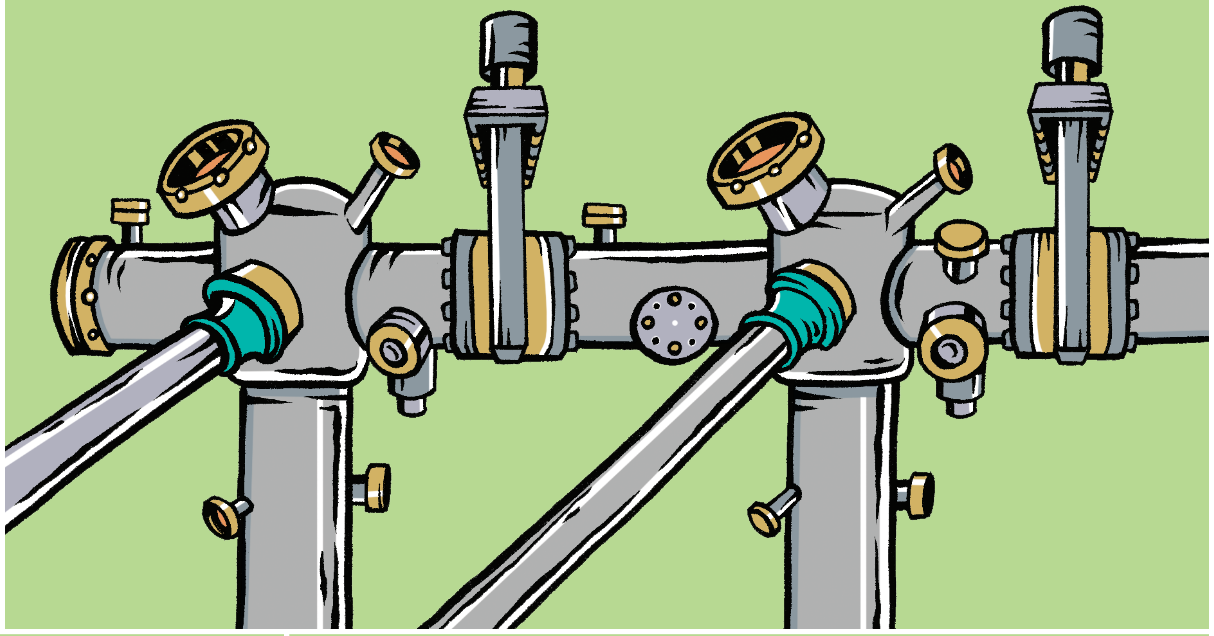


THE QUESTION

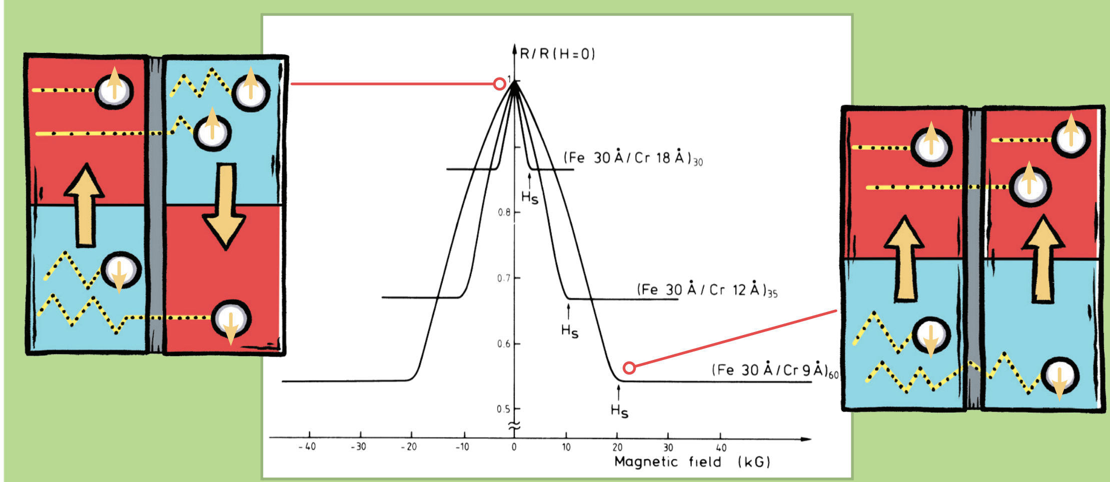


Is electrical current affected by the pole directions in thin magnetic layers?

THE LAB

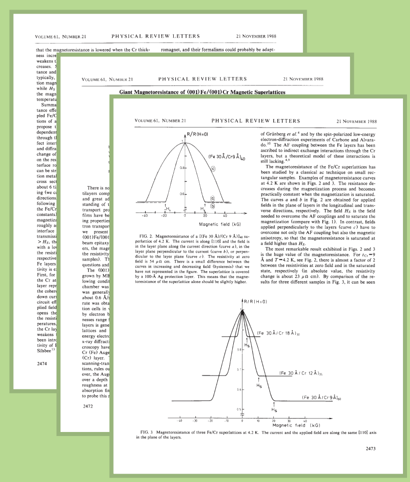


THE RESULT

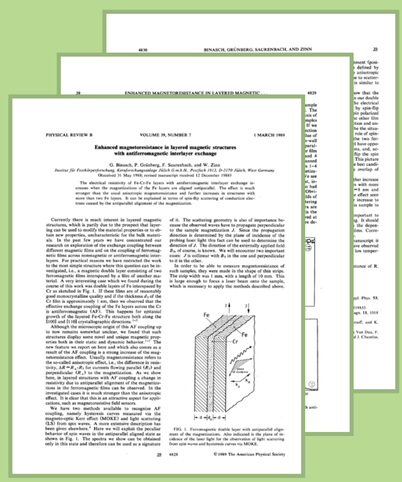


If one builds a magnetic "sandwich" and changes its poles, the electrical resistance changes a lot. In fact, the electrons carry a small magnet, the spin, which interacts with the magnetic sandwich.

THE ARTICLES



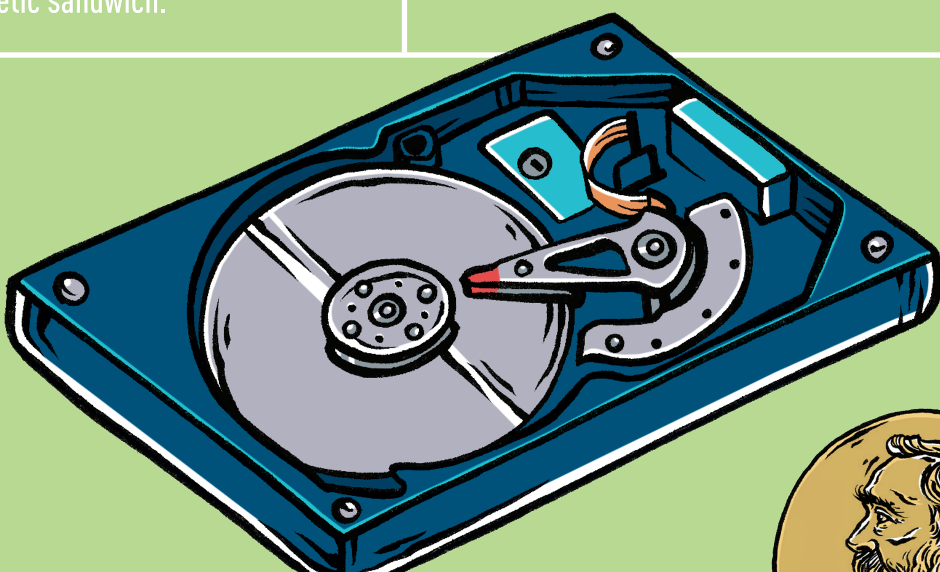
Giant magnetoresistance of Cr magnetic superlattices,
M. N. Baibich et al., PRL **61**, 2472 (1988)



Enhanced magnetoresistance in layered magnetic structures,
G. Binasch et al., PRB **39**, 4828 (1989)

NOWADAYS

This discovery allowed the development of read-write head for hard disks.
It has also opened a new field of research called spintronics.



A. FERT, P. GRÜNBERG, NOBEL PRIZE, 2007

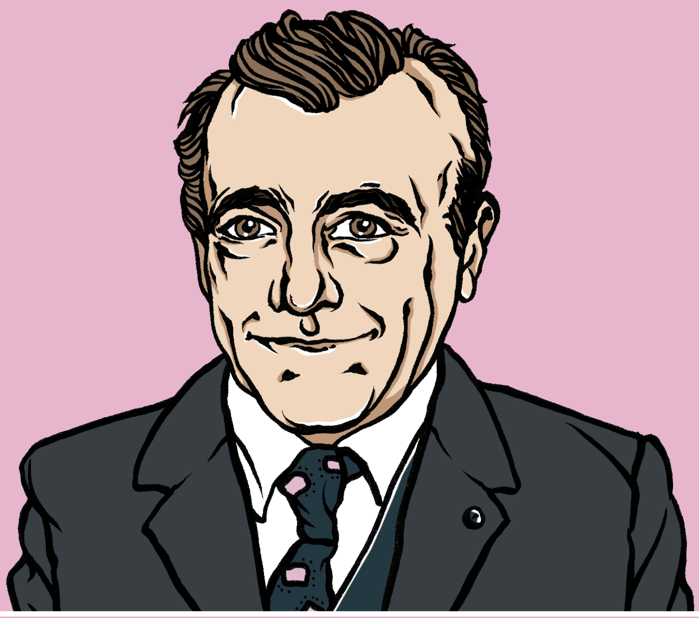
For the discovery of giant magnetoresistance.

Illustration & layout: Marine Joumard, in collaboration with J. Bobroff and F. Bouquet "Physics Reimagined", CNRS Univ. Paris-Sud. Discover all the quantum tales here : www.PhysicsReimagined.com

QUANTUM TALES

ANTIFERROMAGNETISM, 1936

L. NÉEL

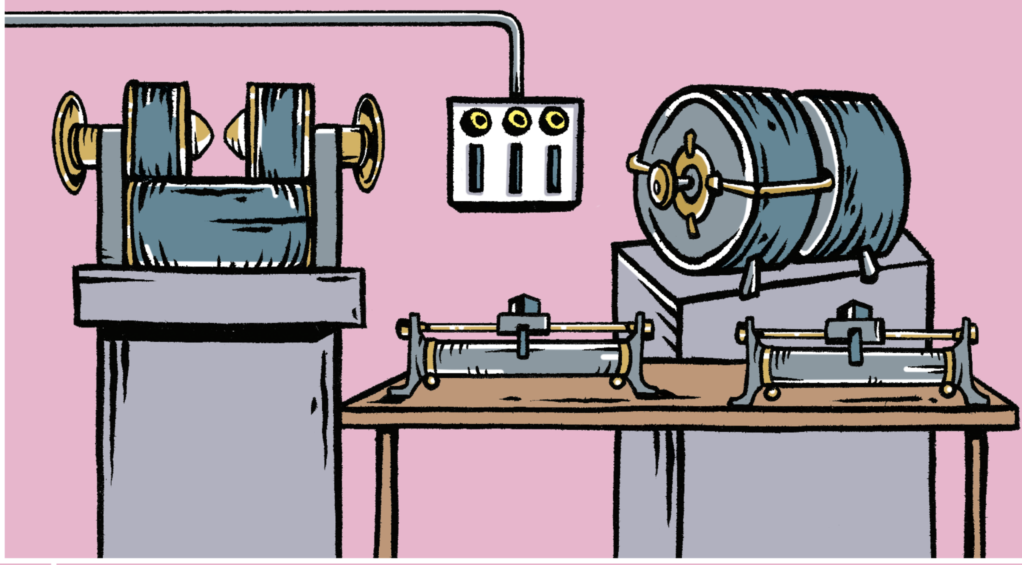


INSTITUT DE PHYSIQUE DE STRASBOURG, FRANCE

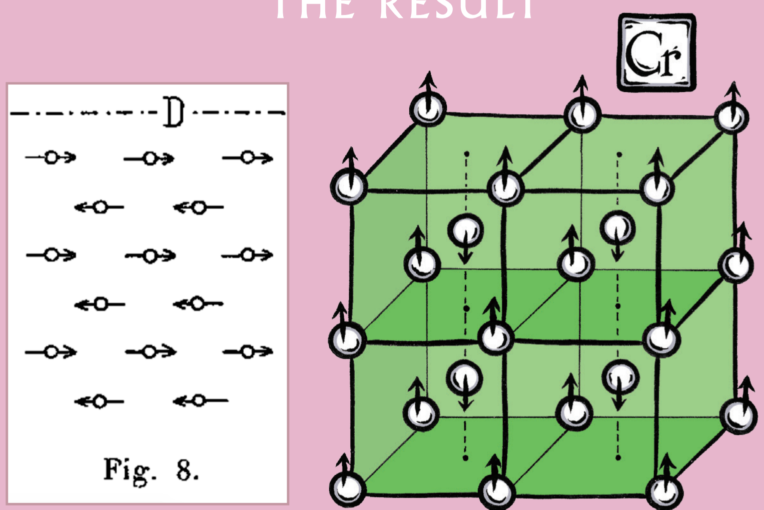
THE QUESTION

Why some metals or oxides such as chromium do not seem to display any magnetism?

THE LAB

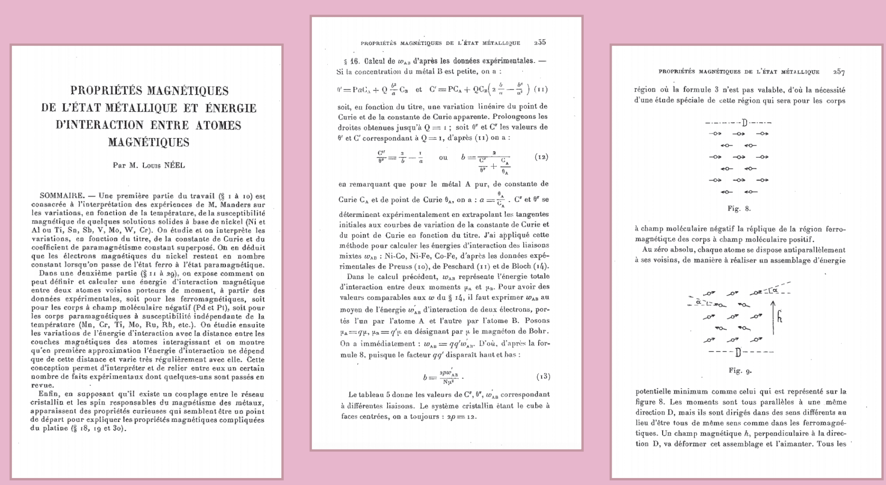


THE RESULT



In some metals and oxides, the atoms carry small magnets called spins which order antiparallel to each other. These antiferromagnets do not show poles as in real magnets even though they too display a long range order.

THE ARTICLE



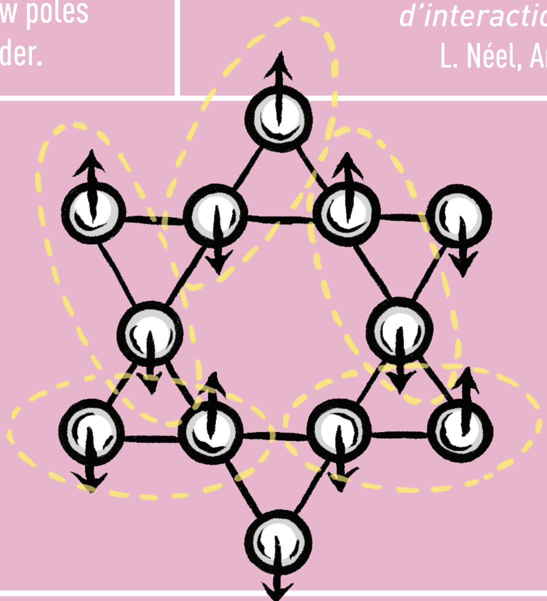
PROPRIÉTÉS MAGNÉTIQUES DE L'ÉTAT MÉTALLIQUE ET ÉNERGIE D'INTERACTION ENTRE ATOMES MAGNÉTIQUES

Par M. Louis NÉEL

Propriétés magnétiques de l'état métallique et énergie d'interaction entre atomes magnétiques,
L. Néel, Annales de Physique, 5, 232 (1936)

NOWADAYS

The study of magnetism in solids is a still a lively research field. For example, new "spin liquid" states have been recently discovered in solids which display star structures in which spins cannot order even close to absolute zero.



L. NÉEL, NOBEL PRIZE, 1970

For the discovery of giant magnetoresistance.

QUANTUM TALES
SUPERCONDUCTIVITY, 1911

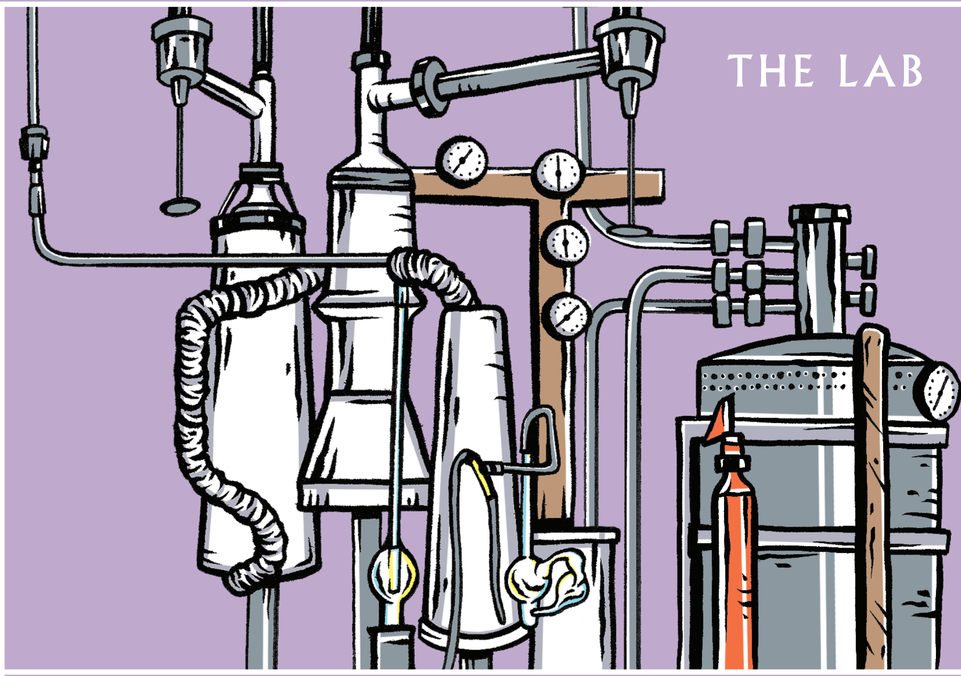
KAMERLINGH ONNES

LEYDEN UNIVERSITY, NETHERLANDS

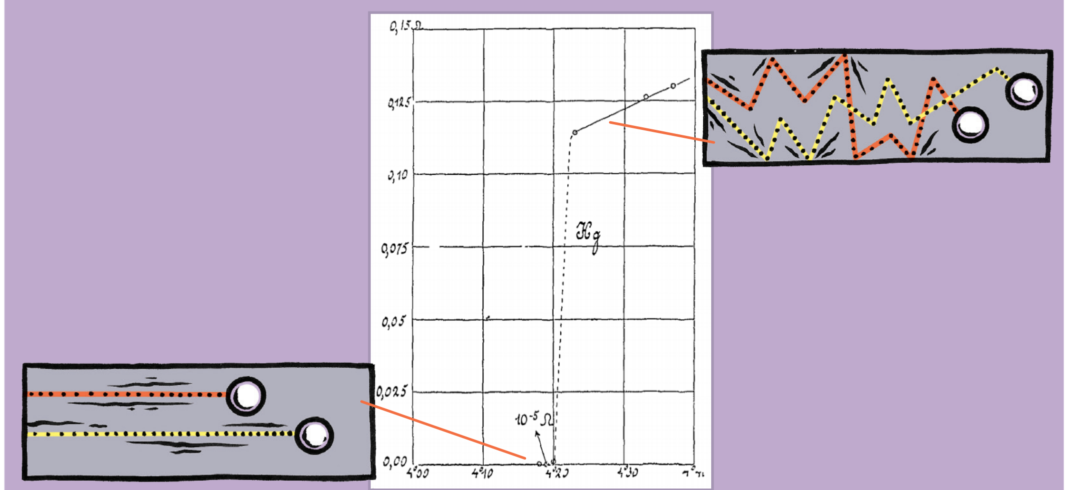
THE QUESTION

Does a metal such as mercury conduct better or worse at low temperature?

THE LAB

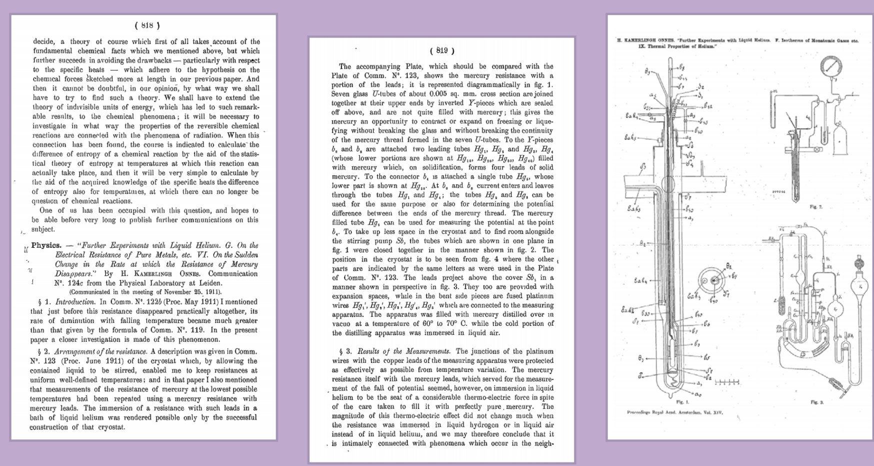


THE RESULT



The electrical resistance of mercury suddenly drops down to zero at low temperatures. The metal conducts perfectly: this is superconductivity.

THE ARTICLE



Further experiments with Liquid Helium
Com. N°124c from the Phys. Lab. at Leyden,1911

NOWADAYS

levitating train: the fastest in the world;
magnetic resonance imaging (MRI);
electrical cables: for better electrical conduction

K. ONNES, NOBEL PRIZE, 1913

For his investigations on the properties of matter at low temperatures which led, inter alia, to the production of liquid helium.

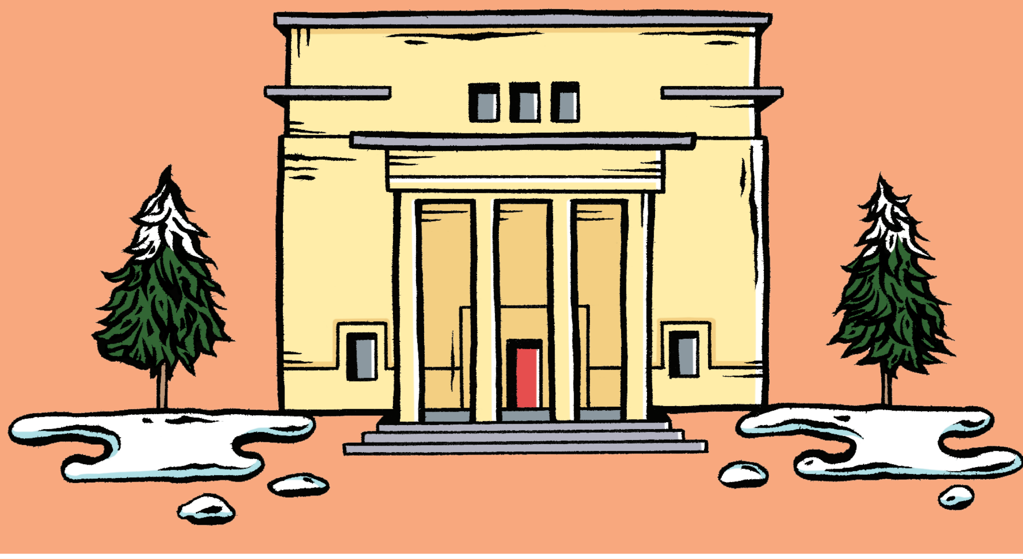
Illustration & layout: Marine Joumard, in collaboration with J. Bobroff and F. Bouquet "Physics Reimagined", CNRS Univ. Paris-Sud. Discover all the quantum tales here : www.PhysicsReimagined.com

QUANTUM TALES

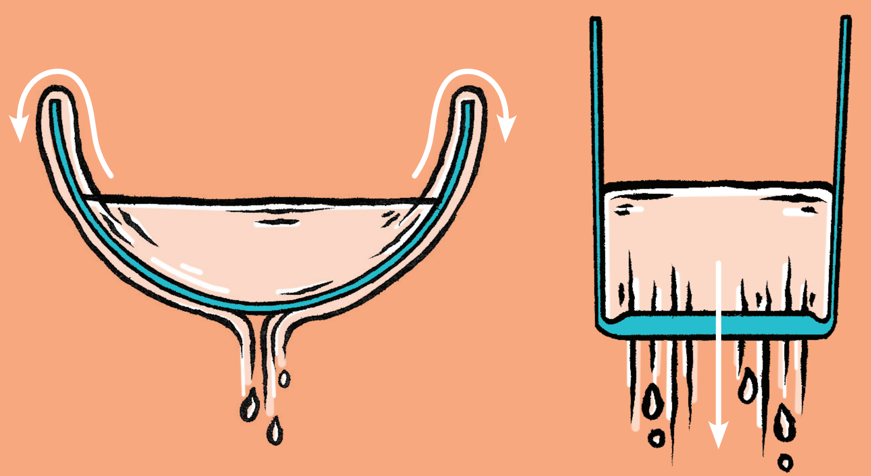
SUPERFLUIDITY, 1937

P. KAPITSA

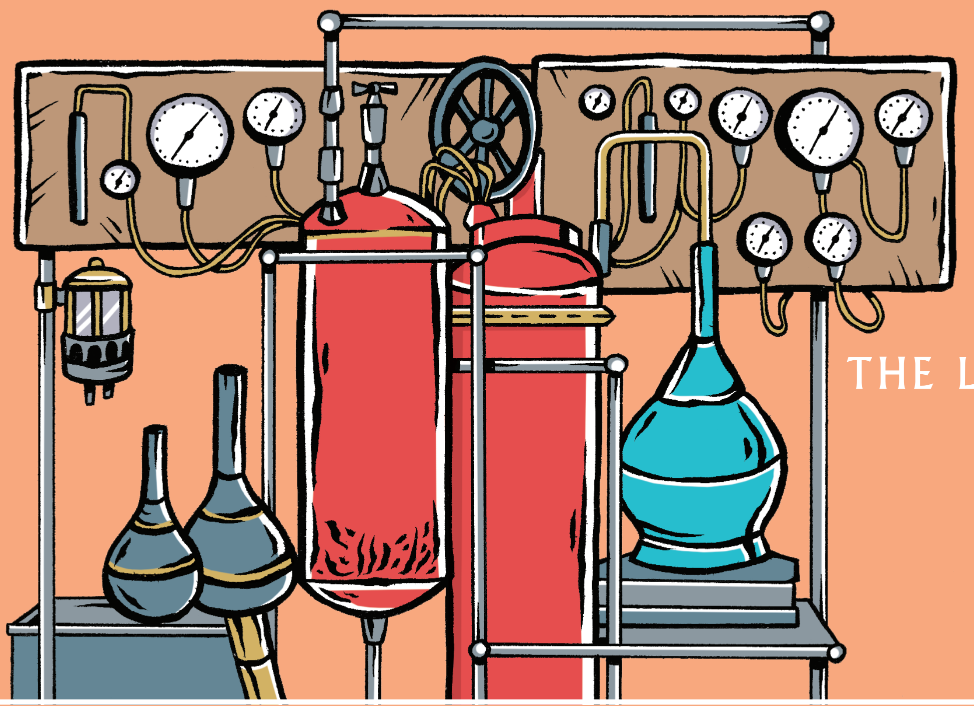
INSTITUTE FOR PHYSICAL PROBLEMS, MOSCOW, RUSSIA



THE QUESTION

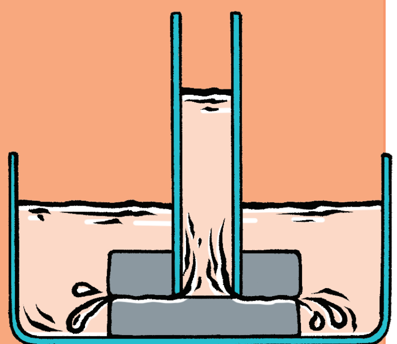


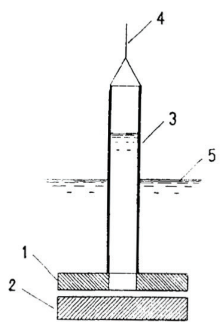
What does a liquid become at close to absolute zero if it doesn't freeze?



THE LAB

THE RESULT

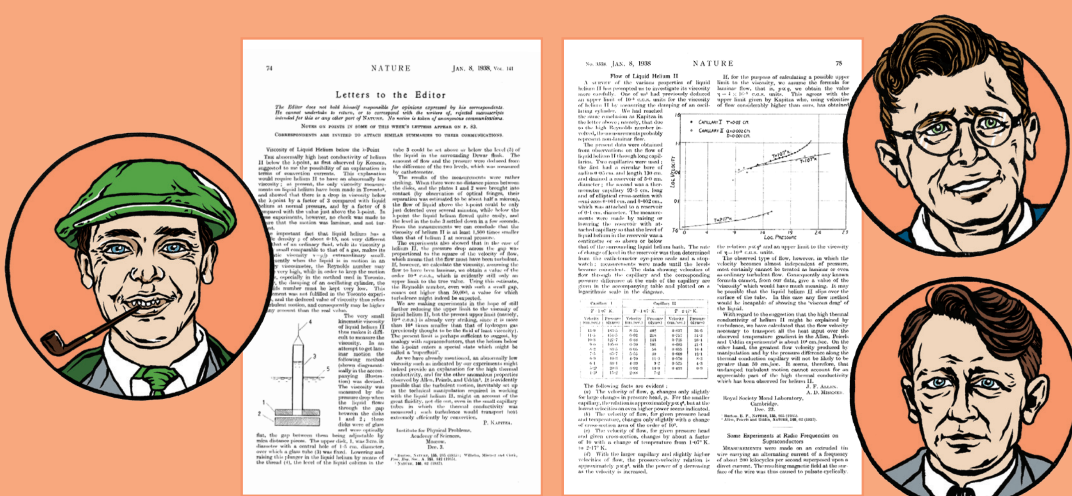




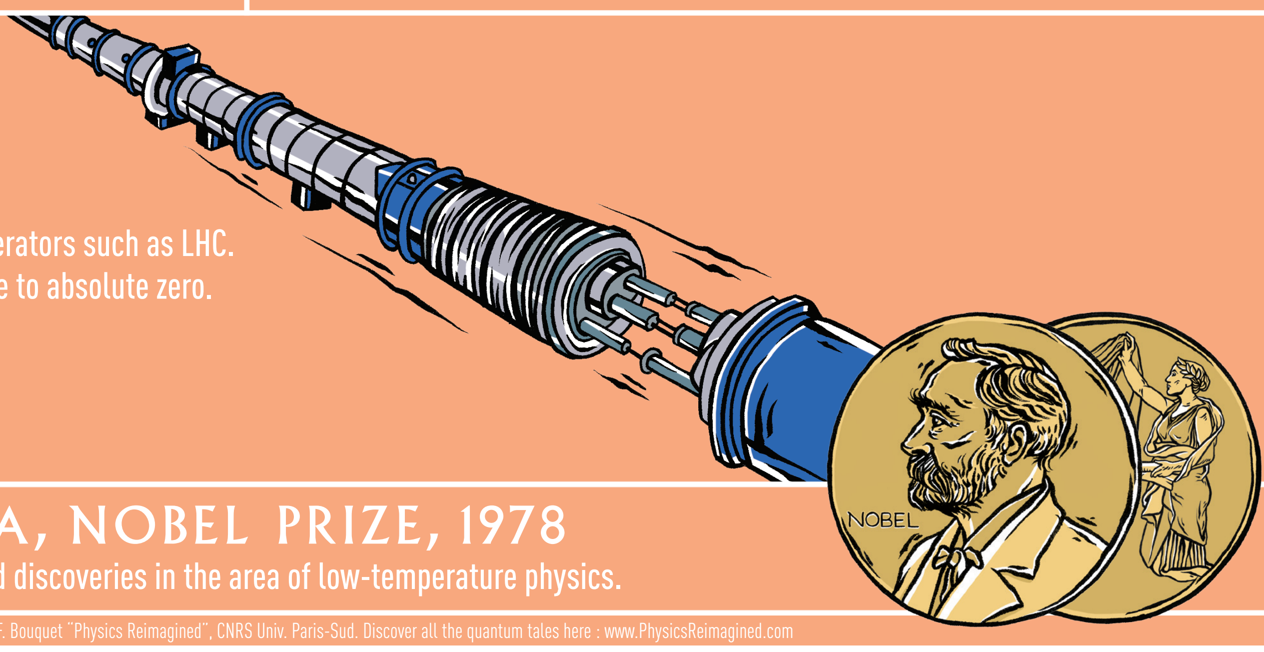
The very small kinematic viscosity of liquid helium II thus makes it difficult to measure the viscosity. In an attempt to get laminar motion the following method (shown diagrammatically in the accompanying illustration) was devised. The viscosity was measured by the pressure drop when the liquid flows through the gap between the disks 1 and 2; these disks were of glass and were optically flat, the gap between them being adjustable by mica distance pieces. The upper disk, 1, was 3 cm. in diameter with a central hole of 1·5 cm. diameter, over which a glass tube (3) was fixed. Lowering and raising this plunger in the liquid helium by means of the thread (4), the level of the liquid column in the

Liquid helium close to absolute zero is placed in a column above two disks. The helium then flows out between the disks even when the disks touch each other. Kapitsa calls it superfluidity.

THE ARTICLES



Viscosity of Liquid Helium below the λ-Point, P. Kapitsa, Nature 74, 141 (1938)
Flow of liquid helium II, J.F. Allen, A.D. Misener, Nature 75, 141 (1938)



NOWADAYS

Superfluid helium allows cooling down particle accelerators such as LHC.
It is also an essential tool for physics research close to absolute zero.

P. KAPITSA, NOBEL PRIZE, 1978

For his basic inventions and discoveries in the area of low-temperature physics.

Illustration & layout: Marine Joumard, in collaboration with J. Bobroff and F. Bouquet "Physics Reimagined", CNRS Univ. Paris-Sud. Discover all the quantum tales here : www.PhysicsReimagined.com