50 & 100 YEARS AGO

NATURE

50 YEARS AGO

What Man May Be: The Human Side of Science by George Russell Harrison — It has been estimated that each year sees the discovery of at least one million new scientific facts. Very few of us who are scientists have the capacity to digest more than a minute fraction of this feast, and to see the pattern to which it contributes. Yet we are vastly better off than the non-scientists, whose main contact with science is "through its slums, the half-world of such things as flying saucers and water dowsing"… This is an excellent book to give to almost anyone who wants to understand that science has changed both the things we do, and the way we think. There is not a dull moment in it, and probably most of those who do read it will catch something of the infectious optimism that underlies each page. Onward and upward in the best of all possible worlds.

From *Nature* 4 January 1958.

100 YEARS AGO

"The inheritance of 'acquired' characters" (*Sur la Transmissibilité de Charactères acquis*) by Eugene Rignano — A man of science to command general attention and interest must do two things; first, he must make interesting discoveries or profound generalisations; and secondly, he must do things at the right time. Darwin made his name because he fulfilled both conditions. Mendel died an unknown man because he did not fulfil the second. He was forty years too soon … If it is possibly fatal to make discoveries too soon, it is certainly fatal to make them too late. It is therefore with a certain sense of weariness, mingled with surprise, that we note the appearance of a work on the transmission of acquired characters … The author of the book before us, who is an engineer interested in sociology, believes in the transmission of acquirements, and has invented a theory of centro-epigenesis to account for the phenomenon.

From *Nature* 2 January 1908.

within organs — for efficient tumour growth[6,7]. It seems, therefore, that Ets2 has context-dependent functions: in the Apc^{Min} mice with intestinal cancer it is a tumour repressor and in the PyMT mice with breast cancer it functions as a tumour promoter within the non-cancerous stromal cells. Such a non-cell-autonomous function of Ets2 as a tumour promoter is consistent with observations[8] that Ets2 regulates the expression of genes within stromal cells to produce the extracellular matrix that is known to be essential for tumour growth and metastasis.

Taken together, the tumour-promoting and tumour-repressive activities of Ets2 may provide an intriguing explanation for the inverse correlation between *Ets2* copy number and intestinal tumour number in Apc^{Min} mice (Fig. 1). Previous studies have suggested that, in Apc^{Min} mice, early tumour cells have an inductive activity on nearby cells, which leads to polyclonality — tumours originating from more than one cell population[9]. The activity of Ets2, which can regulate stromal function as well as tumour growth, may contribute to this polyclonality and subsequent tumour survival. Although speculative, this hypothesis can be tested with animal models such as those used by Sussan and colleagues[2].

These authors' results undoubtedly provide insight into the contextual function of *Ets2*, but also reveal a paradox that will require further study. The contradictory activities of Ets2 predict a crucial point — individuals with Down's syndrome are at a lower risk of developing solid tumours, probably owing to the high Ets2 levels in their epithelial cells, but they might be at a greater risk of cancer metastasis. So therapeutic use of potential drugs with Ets2-like activity to reduce tumour incidence may have limited value, because a side effect of such drugs could be increased efficiency of metastasis[10]. Nonetheless, the findings of Sussan *et al.*[2] strongly warrant further investigation into whether natural variation in *Ets2* expression levels is associated with differential susceptibility to solid tumours. ■

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MAGNETISM

Freedom for the poles

Oleg Tchernyshyov

Magnetic poles always come in twos, a north and a south. That received wisdom has not stopped physicists from searching for 'monopoles' in accelerators and cosmic rays. Theory now indicates a better place to look.

Despite some tantalizing clues for their existence from the realms of quantum physics, magnetic monopoles — single magnetic poles without a partner — remain elusive after decades of searching. Do they exist at all in the real world? On page 42 of this issue[1], Castelnovo, Moessner and Sondhi argue yes: monopoles are alive and well in an exotic class of magnetic material known as spin ice[2].

An iron magnet has two poles, north and south: Earth's iron core makes it an extremely large example of the genre. These poles are positive and negative magnetic charges, acting as sources and sinks of the magnetic field. In general, magnetic interactions are very similar to electrical interactions: like poles repel and unlike attract, with a force inversely proportional to the square of their separation. But whereas positive and negative electric charges can exist independently, magnetic poles always seem to occur in pairs. Rather as the sorcerer's apprentice hacks his enchanted broom into pieces only for each to spring to life as a new whole broom, breaking a bar magnet in two yields smaller magnets, each with a north and a south pole, and an overall magnetic charge of zero.

This asymmetry extends to the subatomic level. Elementary particles can carry a positive or negative electric charge, but the magnetic charge is zero without exception. Yet theory offers some hints that single magnetic poles might exist in nature. In the 1930s, Paul Dirac showed that magnetic monopoles could explain the observed quantization of electric charge. Extensions of the standard model of particle physics include particles with magnetic charge.

One environment in which monopoles might pop up is crystalline solids. In a crystal at a low temperature, excitations above the ground state often behave like elementary particles: they

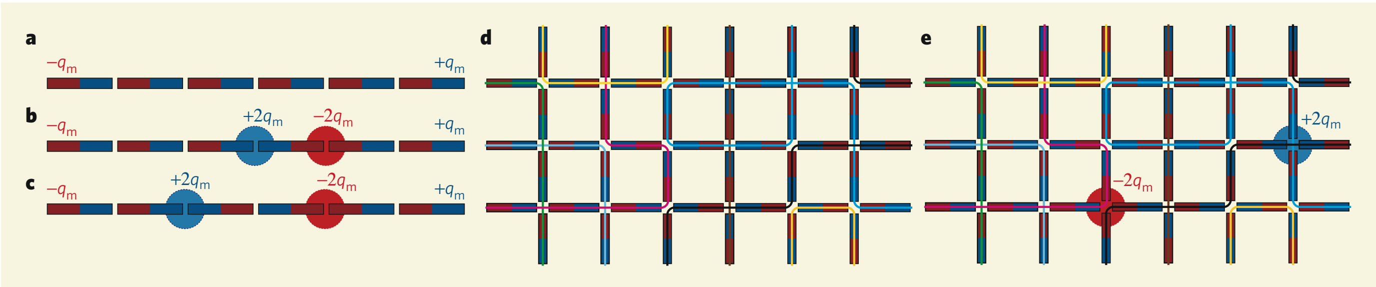

Figure 1 | Making monopoles. a, In the lowest-energy state, all the elements in a chain of magnetic dipoles point in the same direction: the north pole (magnetic charge $+q_m$) of one magnet touches the south pole (magnetic charge $-q_m$) of the next. The charges cancel out all the way along the string, except at the ends. **b**, Flipping one of the dipoles in the middle excites the chain out of its ground state, creating two magnetic charges $+2q_m$ and $-2q_m$. **c**, Each of these charges can be moved independently of the other by flipping a dipole next to it — they are free monopoles. **d**, Castelnovo *et al.*[1] study spin orientations in spin ice. Shown here is square spin ice, a two-dimensional variant that has been produced in an artificial form, as an array of nanoscale magnets[10]. Four magnetic poles meet at each point on the square lattice, and the energy is lowest when two are north poles and two are south poles. Spin ice in the ground state can be construed as a series of strings of magnetic dipoles embedded in a higher-dimensional lattice. **e**, Flipping dipoles on a single string (the black one) creates a pair of well-separated magnetic poles just as in one dimension.

carry a quantized amount of energy, momentum, electric charge and spin. In their theoretical study, Castelnovo *et al.* find the first instance of such an excitation with a non-zero magnetic charge. Under certain conditions, these magnets behave as a gas of independent magnetic poles. There is even a phase transition at which a thin vapour of these monopoles condenses into a dense liquid.

How a monopole can be created in a world of magnetic dipoles can be understood by considering a one-dimensional string made by laying tiny dipoles end to end. In this case, a single misaligned dipole gives rise to two independent magnetic charges that can be moved far apart, for the price of putting some energy into the system (Fig. 1a–c). The monopoles that arise are boundaries separating regions with perfectly aligned dipoles. These topological defects, known as domain walls, or 'kinks', have recently been studied in magnetic nanowires[3].

The emergence of free magnetic monopoles is an example of the phenomenon known as 'fractionalization': that the collective behaviour of many particles in a condensed-matter system is most effectively described in terms of fractions of the original particles. Fractionalization is often tied to topological defects[4] and is common in one-dimensional systems, such as the string already mentioned. The only confirmed case in two dimensions is the fractional quantum Hall effect, which occurs in a cold gas of electrons placed in a strong magnetic field[5]. Measurements of conductance[6] and electrical noise[7] in this system indicate the involvement of 'quasiparticles' with one-third of an electron's charge.

Castelnovo and colleagues provide the first example of fractionalization in a three-dimensional system. But how does the physics of free monopoles on a string survive in a higher-dimensional setting? The answer lies in the special nature of the ground states of the authors' chosen system, spin ice, which allows one-dimensional ideas to be transferred to two and three dimensions (Fig. 1d,e).

The monopoles in spin ice are magnetic analogues of electrically charged defects H_3O^+ and OH^- in water ice. The movement of these defects through water ice causes it to conduct electricity when an electric field (potential difference) is applied across it. Might it be possible to create a steady magnetic current in spin ice by placing it in a magnetic field? Unfortunately not. The motion of a kink alters the state of a string, making it impassable to the next magnetic charge. In water ice, a kink of a different flavour, known as a Bjerrum defect[8], repairs the damage done by the original defect. Because there is no analogue of Bjerrum defects in spin ice, magnetic monopoles are somewhat limited in their motion, and cannot sustain a direct magnetic current.

That still leaves the possibility of generating an alternating magnetic current, which would be interesting in its own right. In any case, learning how to move magnetic monopoles around would be a step towards technologies such as magnetic analogues of electric circuits and magnetic memories[9] operating on the atomic scale. ■

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AQUACULTURE

The price of lice

Andrew A. Rosenberg

Wild salmon stocks in Canadian coastal waters are being severely affected by parasites from fish farms. So intense are these infestations that some populations of salmon are at risk of extinction.

The global demand for fish is on the rise, and farmed sources are taking much of the strain — the catch of wild fish has levelled off, and may well be declining[1], but aquaculture production is expanding rapidly[2]. The ecological costs of that expansion can be heavy, however, as Krkošek *et al.* show in *Science*[3]. The message of their paper is that there are some serious issues that cannot be ignored if the expansion of aquaculture is to be productive rather than destructive.

Consumers can readily see the shift towards aquaculture, particularly for products such as farmed salmon, which has become a staple of supermarkets and restaurants in Europe and North America. Those buying fish will be aware of press reports of overfishing and resource depletion. Some may even look for eco-labels or carry a little card to guide them towards the purchase of sustainable products. As my colleague Carl Safina has said, "Give a man a fish and you have fed him for a day. Give a man a seafood choice card and you have made him impossible to dine with."

But aquaculture products tend to be subject to less public attention, even as issues