THIS WEEK

EDITORIALS

Prior art

The earliest known drawing — crayon on a rock shard — suggests early humans engaged in abstract art.

If a picture tells a thousand words, a cross-hatched design drawn on a fragment of rock some 73,000 years ago could speak volumes. The problem will be understanding what it tells us. The design, reported in *Nature* this week (C. S. Henshilwood *et al. Nature* https://doi.org/10.1038/s41586-018-0514-3; 2018), occurs on a lentil-shaped rock flake, and was found in Blombos Cave, on the southern shore of South Africa, by archaeologist Christopher Henshilwood and his colleagues. The flake bears an abstract design drawn, the authors say, using a crayon made of red ochre.

It is hard to claim that the design is beautiful, dazzling or engrossing. But the artwork is destined to be priceless and famous, because it seems to be the earliest evidence for a drawing in the archaeological record, by some margin. Apart from some cave paintings from Spain dated to around 64,000 years ago — presumably the work of Neanderthals (D. L. Hoffmann *et al. Science* **359**, 912–915; 2018) — the next instance of drawing came around 40,000 years ago with cave paintings found at opposite ends of Eurasia: in the spectacular art decorating the walls of caves in Spain and France, and the more recently discovered cave art in Sulawesi in Indonesia (M. Aubert *et al. Nature* **514**, 223–227; 2014). Despite being located 12,000 kilometres apart, cave paintings such as these contain images that we instantly recognize as figurative art, including a range of animals, and stencils of hands that speak to us, millennia later, as signs of human self-awareness.

A key distinction of this latest piece is that it is a drawing — a design made by applying pigment — rather than an engraving, made by scratching or cutting a design into a surface. Engraving has a longer prehistory than art. The earliest engravings known are on pieces of shell from Trinil, Java, dated to around 540,000 years ago, well before modern humans evolved, and presumably made by *Homo erectus*. Other ancient engravings have been found around the world; all are extremely simple: just lines, sometimes cross-hatched. There is nothing remotely similar to what we would recognize as imagery, and there is insufficient evidence to say whether they might represent something utilitarian, such as tally sticks or calendars. So, were these Palaeolithic hashtags actually designs intended to convey meaning, or mindless graffiti? Some might have been the unintentional result of another action, such as cutting food items, just like the scratches left on a chopping board after slicing a loaf.

A drawing, by contrast, is much harder to dismiss. To be sure, the one from Blombos is as cross-hatched as the engravings, but it could not have been created as the accidental by-product of another process. Although proving intentionality is extremely hard, the authors examine the evidence they have — including detailed study of the ochre residues — with forensic thoroughness. It seems clear that the drawing was a fragment of something bigger, because some of the lines look as if they continued on to pieces now long gone. In addition, the authors attempted to restage history, using pieces of ochre themselves to show that such drawings can be made using crayons carved out of ochre (rather than, say, by brushwork), and that creating the design on such a rock fragment is possible only by deliberate rotation of the design through an angle, much as later artists might rotate their canvas.

That the ancient artist chose to sketch with red ochre is less of a surprise. The mineral, largely consisting of iron oxide, has been used as a pigment since time immemorial. Its earthy red hues clearly meant a lot to the early modern human inhabitants of Blombos Cave and other nearby sites. They used it as an ingredient in paint, and perhaps even as a sunscreen. Between around 100,000 and 73,000 years ago, the people of the region produced artefacts tens of thousands of years in advance of humans anywhere else in the world, including finely worked stone and bone tools and engraved ochre pieces.

> ***"It seems clear that the drawing was a fragment of something bigger."***

That the early *Homo sapiens* living there were able to produce such designs suggests they possessed relatively 'modern' cognition and behaviour. What we cannot know is why they made the marks, or what they represent; unlike images of animals or hands, the drawing's abstract nature offers no clues. And that raises a fascinating question about the history of art. Whereas the humans living in South Africa 100,000 years ago were using technology as yet undreamed of elsewhere, they had yet to invent figurative art. So, are the cave paintings of Lascaux and Sulawesi unconnected, independent inventions, or did modern humans create cave art somewhere else along the way, and then take it with them as they moved through the world? What is clear is that they started a trend, one that eventually led to Piet Mondrian, Jackson Pollock, Bridget Riley and the many great artists of today. ■

Noether's legacy

It's time to acknowledge the lasting impact of a brilliant mathematician.

Emmy Noether was a force in mathematics — and knew it. She was fully confident in her capabilities and ideas. Yet a century on, those ideas, and their contribution to science, often go unnoticed. Most physicists are aware of her fundamental theorem, which puts symmetry at the heart of physical law. But how many know anything of her and her life?

A conference in London this week, the Noether Celebration, hopes to change that. It's a welcome move. In a world where young scientists look for inspirational female role models, it is hard to think of a more deserving candidate.

Noether was born in 1882 in Erlangen, Germany. Her parents wanted all their children to get doctorates, so although many universities at the time did not formally accept women, she went. After graduation, sexist regulations prevented Noether from getting jobs in academia. Undaunted, for many years she lectured in Erlangen and, from 1915, at the University of Göttingen — often for free.

At the time, that city was the centre of the mathematical world, largely due to the presence of two of its titans — Felix Klein and David Hilbert. But even when Noether was being paid to teach at Göttingen and making her most important contributions, fate and further discrimination intervened: Hitler took power in 1933 and she was fired for being Jewish. She escaped to the United States and taught at Bryn Mawr College in Pennsylvania, until she died in 1935, at the age of just 53.

Noether devoted her career to algebra and came to see it in a striking new light. "All of us like to rely on figures and formulas," wrote Bartel van der Waerden, her former student, in his obituary of Noether. "She was concerned with concepts only, not with visualization or calculation."

Noether saw maths as what are now called structures. To her, the characteristics of a structure's components — be they numbers, polynomials or something else — mattered less than the networks of relations among an entire set of objects. This enabled her to give proofs that applied to more general structures than the original ones, and which revealed unseen connections.

It was a new and elegant approach that changed the face of algebra. And Noether realized that it could influence other parts of maths. One was topology, a field in which "she published half a sentence and has an everlasting effect", one mathematician wrote. Before Noether, topologists had been counting holes in doughnuts; she brought to bear the full power of her structures to create something called algebraic topology.

The results that Noether published 100 years ago were, for her, a rare foray into physics, in which she was not particularly interested. Albert Einstein had just developed his general theory of relativity, and was struggling to understand how energy fitted into his equations. Hilbert and Klein were working on it, too, and asked Noether for help.

That she did help is an understatement. Noether's expertise in symmetry led her to discover that the symmetries of a physical system are inextricably linked to physical quantities that are conserved, such as energy. These ideas became known as Noether's theorem (E. Noether *Nachr. d. Ges. d. Wiss. zu Göttingen, Math.-phys. Kl.* **1918**, 235–257; 1918).

As well as answering a conundrum in general relativity, this theorem became a guiding principle for the discovery of new physical laws. For example, researchers soon realized that the conservation of net electric charge — which can neither be created nor destroyed — is intimately related to the rotational symmetry of a plane around a point. The impact was profound: those who created the standard model of particle physics, and the researchers who attempt to extend it, think in terms of Noether's symmetries.

"Before Noether, topologists had been counting holes in doughnuts."

Some biographies inaccurately portray Noether as a somewhat helpless genius at the mercy of men's charitable actions. In reality, she was an assertive personality, recognized leader and the first female plenary speaker at the renowned International Congress of Mathematicians.

The status of women in mathematics and science has improved since Noether's time, but bias and discrimination remain. Too few leading female mathematicians receive the recognition they deserve. (Only one woman, Maryam Mirzakhani, has received the Fields Medal, and none has won the Abel Prize — the field's top awards.) Noether is an inspiration: including to UK mathematician Elizabeth Mansfield, who co-organized the London meeting and works on modern extensions of Noether's work.

We don't know how many potential Emmy Noethers have been unfairly denied the chance to show their talents. More people should know — and should celebrate — one who changed the scientific world against the odds. ■

Experts needed

Pakistan needs the courage to listen to independent expertise, including on science.

It took US President Donald Trump 18 months to announce a science adviser. By contrast, Pakistan's new prime minister, Imran Khan, is widely expected to appoint a science minister in the early stages of his administration. It will be a welcome move: scientific expertise will be essential in shaping the country's future. But whoever it is will have a fight on their hands to ensure that inclusive and evidence-based advice prevails.

Khan has come into office promising anything but business as usual. In an echo of America's New Deal and the first post-Second World War European governments, he has pledged a welfare state, affordable health care, school reform, improvements to agriculture (the backbone of the economy), and an axe to public-sector corruption.

To do all this, his government will need medical researchers and health-care specialists to advise on plans for a national health service; primary- and secondary-school educationalists to work out how best to get every child into a good school; and science and innovation policy experts to guide academic researchers on the path to quality improvements and better community engagement.

Khan has repeatedly said that he will appoint the best people to top jobs. On that score, however, his ministerial team of mostly political appointees has had mixed reviews. What the new ministers lack in particular is a wide-ranging and credible network of experts to call on. There is a shortage of people — and especially women — from high-level academic and other professional backgrounds plugged into policymaking. Khan knows this and has appealed for help. So far, the calls have been heeded by economists in particular, as evidenced by the prime minister's 18-member Economic Advisory Council — albeit an all-male one.

But one obstacle to gathering expertise is the state's persistent failure to confront rising intolerance, particularly against minorities. In a backwards move, Khan last week bent to the will of the TLP, a far-right political party that attracted more than 2 million votes in July's elections, and he removed Princeton University economist Atif Mian from the Economic Advisory Council. Mian's nomination was challenged by the TLP solely because he belongs to the Ahmadiyya, a much-persecuted minority Muslim community. Mian is highly regarded and his dismissal has been roundly condemned; the other two international members of the council resigned in protest.

The move signals an unwillingness by Khan to appoint advisers who can speak truth to power — and that could have a wider, chilling effect. It will make other independent experts think twice about joining Khan's cause or advocating vital but unpopular reforms.

The new government has ratcheted up expectations with a list of tasks on which lives depend. One of Pakistan's most urgent challenges, for example, is to improve the availability and quality of water. Agriculture uses 90% of supplies, but a population of 200 million — and rising — means that the country is officially classified as 'water-scarce'. Climate change is projected to reduce water availability further, and poor water quality is a major source of disease. In response, the government wants to build more dams, but the expert consensus is that the cost of dams outweighs the benefits, and so other solutions must be sought.

Will that type of expertise be listened to, and will Pakistan forge the right path? Right now, citizens at home — and many in the international community — are willing Imran Khan's nation-building project to succeed. As a star cricketer, Khan once described his style of play as that of a cornered tiger. He needs to muster this legendary courage and call out bigotry; otherwise, whatever goodwill exists towards his government will evaporate very fast indeed. ■