

Books & arts

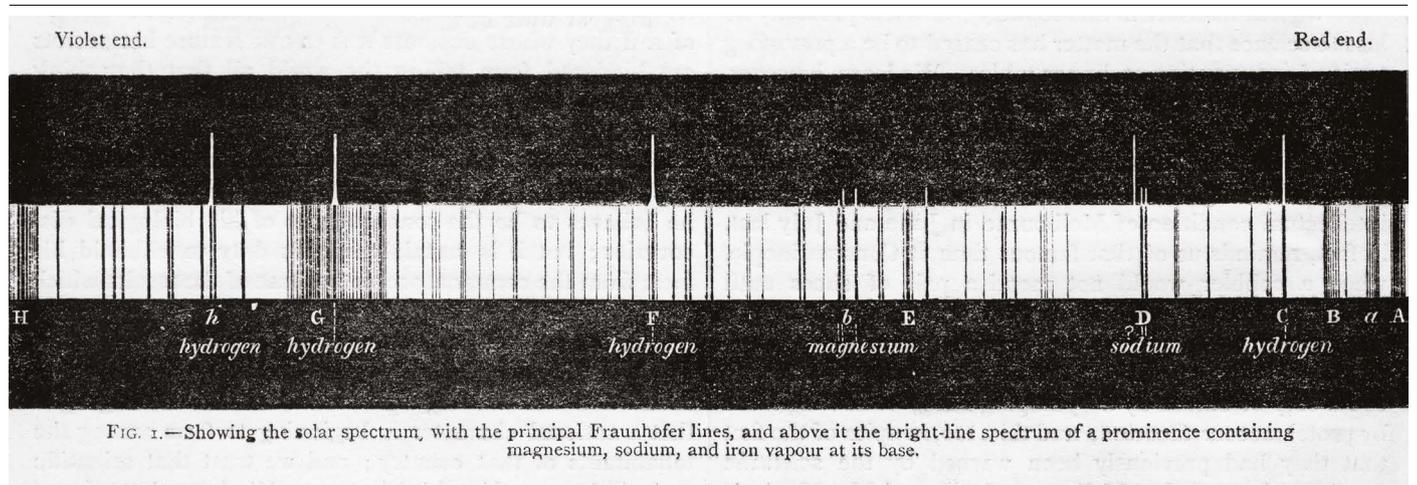


FIG. 1.—Showing the solar spectrum, with the principal Fraunhofer lines, and above it the bright-line spectrum of a prominence containing magnesium, sodium, and iron vapour at its base.

Norman Lockyer's figure of a solar spectrum, published in the first issue of *Nature*.

The evolution of scientific illustration

The interplay of image-making, research and visual technologies over the past 150 years. By Geoffrey Belknap

Science is a fundamentally visual endeavour. It pivots on the material – whether that is an atom, a gene, a crystal, a whale or a distant galaxy. Its aim is elucidation. Thus, communicating research has always been predicated on combining image and text to share discoveries, ideas and observations.

When it came on the market in November 1869, *Nature* stated its commitment to the visual with a beautifully drawn masthead showing Earth emerging from clouds. (The artist might have been engraver James Davis Cooper, who illustrated Charles Darwin's 1872 book *Expression of Emotions in Man and Animals*.) Under the masthead were the words 'A Weekly Illustrated Journal of Science'. The banner, if not the subtitle, remained on *Nature*'s front page until just after the Second World War.

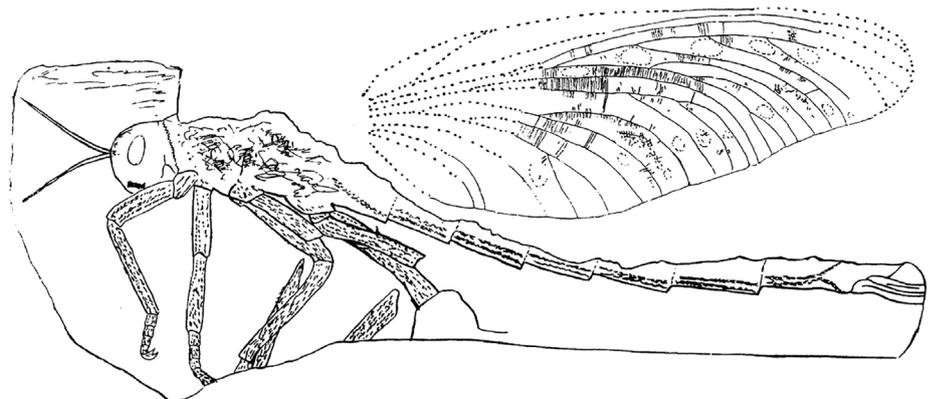
Over the years, *Nature* adapted through its succession of editors, with, in recent decades, 'sister' journals carving out their own space in increasingly specialized scientific disciplines. Images remained central throughout. For instance, in 1896, *Nature* published physicist Wilhelm Röntgen's first X-ray plates¹; in the 1920s, maps to debate Alfred Wegener's theory of continental drift²; and in 1968, the graphs that described astrophysicist Jocelyn

Bell Burnell's discovery of pulsars³.

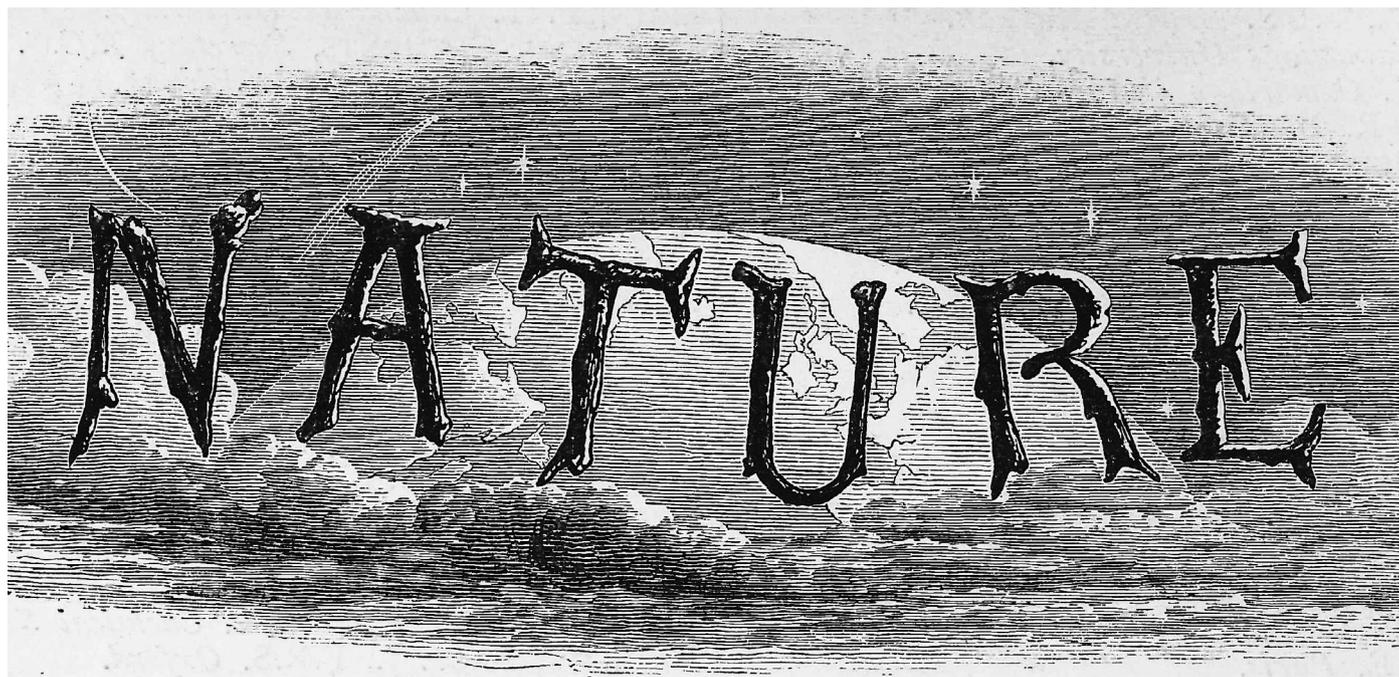
In some ways, the role of images in science publishing hasn't changed much over the past 150 years. Much scientific evidence takes the form of visualizations: illustrations, graphics and latterly photographs. What has shifted, inevitably, are the tools. Initially, *Nature* and other science journals featured monotone printed engravings. Now, its visual landscape is digitized, often mobile, presented in vivid colour and vastly expanded to reflect changes in technological capacity and science itself,

as the cover of this anniversary issue attests.

The late nineteenth century saw intense flux in scientific disciplines; boundaries between them were more porous. Images of discoveries sat cheek by jowl on journal pages with diatoms and archaeological artefacts (such as 800–450 BC stone tools found in Scotland by archaeologist Robert Munro⁴). Whereas many images are now used to interpret or visualize data, these early examples were mainly representations of scientific data – a photograph of an eclipse, say, or a drawing



A drawing of 'Titanophasma Fayoli Brongniart', published in *Science* in 1883.



The illustration on *Nature's* inaugural cover, in 1869.

of a geological formation.

In *Nature's* inaugural issue, such data-led, representational images had an important role. The journal's first editor, astronomer Norman Lockyer, had co-discovered helium in 1868 using electromagnetic solar spectroscopy. He illustrated his article 'The Recent Total Eclipse of the Sun' with two photographic images: a solar spectrum and an engraving derived from a photograph of a solar eclipse.

These are not photographs as we would understand them. Before the 1890s, most images reproduced for journals were wood engravings, which were inked and set for printing alongside the typeset. To make them, the engraver would either copy by eye or lay

a photograph directly onto the woodblock while carving.

The art of precision

Precision was centrally important. If a line on Lockyer's spectrum was in the wrong place, it might suggest that the Sun is composed of calcium rather than hydrogen. So, to ensure accuracy, skill and collaboration were necessary. The era's illustrators and engravers were often scientists themselves, or worked closely with researchers. Illustrators might even copy the image directly onto the block or plate ready for the engraver to do their work.

In their book *Objectivity* (2007), science historians Lorraine Daston and Peter Galison describe such collaborative processes of image-making as "four-eyed sight". Authors and image-makers worked together to shape and construct an observationally reliable image⁵. Similar collaborations were common throughout the century. For the first issue of his *Magazine of Natural History*, for instance, botanist John Claudius Loudon had an engraver copy the prints from John James Audubon's *Birds of America* (1827–1838). These worked as field guides for readers, even as the magazine became a forum for debating new findings with an expert community.

By the time *Nature* appeared, the model of a journal targeting a professional scientific community was emerging. Researchers might be 'amateur' naturalists who collected and described species, such as the botanist Alfred William Bennett and cryptogamist Miles Joseph Berkeley, who sent images to *Nature* depicting the cause of 'rust' on wheat and barberry plants⁶. Or they might belong to the nascent class of university-based laboratory scientists

such as physicist Peter Guthrie Tait, who sent in a sketch visualizing his apparatus for measuring the wavelength of monochromatic light⁷. Specialist journals such as the *Journal of Physiology*, launched in 1878, reflected emergent disciplines while also making space for both amateurs and professionals.

Compelling imagery was becoming a competitive factor in this burgeoning marketplace

"Compelling imagery was becoming a competitive factor in this burgeoning marketplace of ideas."

of ideas. The non-scientific *Illustrated London News*, launched in 1842, had established a precedent for capturing large readerships through abundant visuals. As I described in my book *From a Photograph* (2016), *Nature* responded to this pressure to some degree⁸. Yet as historian Melinda Baldwin points out in *Making Nature* (2015), it wasn't until 1890 that the journal first made a profit⁹. The cost of images had a big effect on the bottom line. The geologist Edward Charlesworth, who took over ownership of the *Magazine of Natural History* from Loudon, had to slim issues down to squeeze in more images on each page¹⁰.

Nature, with its all-encompassing one-word title, also catalysed direct competition, such as astronomer Richard Anthony Proctor's *Knowledge* (subtitled 'An Illustrated Magazine of Science') and the US illustrated weekly *Science*. In 1883, one of the latter's early editors, the entomologist and palaeontologist Samuel Hubbard Scudder, published a description of a giant



Drawing in the *Magazine of Natural History*.

MAGAZINE OF NATURAL HISTORY/AUDUBON'S BIRDS OF AMERICA

fossil stick insect discovered in coal deposits in France by another entomologist, Charles Brongniart. Its accompanying engraving (see page 25) effectively stitches together two pieces of observational data – the body and wings of the insect, separated in the coal bed.

Such simple line engravings had become a staple. The same year in *Nature*, Canadian botanist Grant Allen published a series depicting the shapes of leaves, arguing that their shapes reflect levels of competition with other plants for access to energy sources.

Between the 1880s and 1900, the old collaborations gave way to technological interlocutors: photographers. Science journals viewed photography as a way of seeing that enabled “mechanical objectivity”. There was greater trust in the power of ground lenses and silver halides to capture the world in a way that the eye cannot. As with all visual technologies, however, it needed selection, organization and interpretation for data to be rendered into a comprehensible image.

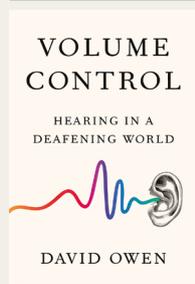
The work of French physiologist Étienne-Jules Marey is an iconic example. Following Eadweard Muybridge, who had captured animal locomotion through ‘instantaneous photography’ in the 1870s, Marey developed his own method: chronophotography. In an 1882 issue of *Nature*, he described his ‘photographic gun’, which used a rotating photographic plate to take sequential images of a flying bird¹¹, helping to pave the way to understanding powered flight. Meanwhile, the Carte du Ciel project at the Paris Observatory, which ran from 1887 to 1950, led to the creation of 22,000 glass-plate negatives of stars from more than 20 observatories¹².

Throughout the first half of the twentieth century, photography became crucial to science. Kathleen Lonsdale pioneered the form of crystallography in which X-rays are directed at a sample to measure diffraction and determine its atomic and molecular structure. Lonsdale published her 1928 findings on the benzene ring in the *Proceedings of the Royal Society*¹³. Her X-ray diffraction photographs – such as the 1941 series of eight, on diamonds – regularly appeared in *Nature*'s pages¹⁴.

The technique became crucial to the explosive discovery¹⁵ of DNA's structure by molecular biologists James Watson and Francis Crick, published in *Nature* in 1953. The key piece of evidence, ‘Photograph 51’, showed the diffraction pattern of DNA and was taken, under the supervision of crystallographer Rosalind Franklin, by then-graduate student Raymond Gosling¹⁶.

Photography was also used to disprove one of the biggest twentieth-century scientific hoaxes. In 1912, amateur archaeologist Charles Dawson claimed to have discovered the missing link between humans and apes in what looked like an early human skull found in Piltdown, Sussex. In 1913, the anatomist David

Books in brief



Volume Control

David Owen Riverhead (2019)

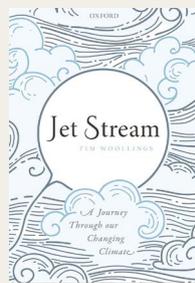
“For a deaf child, having hearing parents can be a serious handicap,” notes *New Yorker* staff writer David Owen in this sensitive study of hearing. (He is personally involved, as someone with tinnitus who saw his grandmother struggle with deafness.) Meshing the science with individual auditory experiences, Owen discusses hearing aids, cochlear implants, genetically deafened mice, sign language, Thomas Edison and noise levels in US cities and towns — all in absorbing, anecdotal detail, although regrettably with no diagrams.



Reality Ahead of Schedule

Joel Levy Smithsonian (2019)

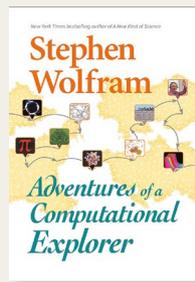
This picture-packed volume by science journalist Joel Levy tours scientific advances sparked by ideas in science fiction. The title comes from a definition of sci-fi by Syd Mead, an industrial designer behind the look of futuristic movies such as *Blade Runner* (1982). But how prescient is sci-fi? Levy shows how H. G. Wells's 1903 story ‘The Land Ironclads’ inspired Winston Churchill to promote the development of the military tank in 1915. But Wells did not envisage its key technical idea: caterpillar tracks, for added grip.



Jet Stream

Tim Woollings Oxford University Press (2019)

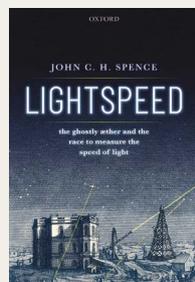
The jet stream — strong high-altitude air currents — was discovered in the 1920s. In this analysis of its complex impact on weather, physicist Tim Woollings relates how in 1944, the Japanese used the jet stream to launch trans-Pacific incendiary balloons. By strange chance, one hit the US plant that provided plutonium for the bomb that devastated Nagasaki in 1945. Today, argues Woollings, the jet stream is “very likely” to be threatened by another product of human activity: rising carbon dioxide emissions.



Adventures of a Computational Explorer

Stephen Wolfram Wolfram Media (2019)

Computer scientist and businessman Stephen Wolfram, designer of the technical-computing system Mathematica, proffers good stories in this collection of autobiographical essays. In ‘Something I learned in kindergarten’, he recalls himself as a six-year-old spotting a bite taken out of the Sun: a solar eclipse, something unknown to the other children. In ‘My life in technology’, he recalls rejecting the Latin word *mathematica*, learnt at school, as too long and ponderous. Silicon Valley luminary Steve Jobs convinced him otherwise.



Lightspeed

John C. H. Spence Oxford University Press (2019)

Starting with Albert Einstein, scientific consensus holds that the speed of light is a universal constant. So writes physicist John Spence in his history of attempts to measure the speed of light. Spence considers the implications of its constancy for modern physics and technology. For instance, the ether — a theoretical space-filling medium rejected in Einstein's relativity — is still “anything but empty”. Despite its appealing vignettes of great physicists, this is a challenging read. **Andrew Robinson**



Nature cover illustration from August 2019.

Waterson published a *Nature* article including three drawings taken from X-rays, revealing that the mandible of the Piltdown ‘skull’ was almost identical to a chimpanzee’s¹⁷. By the 1950s, ‘Piltdown Man’ had been debunked. *Nature* had become a site for exposing bad science through visual evidence.

By the mid-twentieth century, the long-term boom in science journals (there were already 10,000 by 1900)¹⁸ was unabated, keeping pace with the growth in academic science and the proliferation of fields. Photographic technologies remained central, but visual content was diverse and included graphs and early digital images. And starting in the 1970s, technological imaging innovations allowed science to see further and deeper. The cryo-electron microscope, first announced in *Nature*¹⁹, allowed electron microscopy to be applied to

organisms by freezing and suspending them in an aqueous solution. (In 2017, its inventors – James Dubochet, Joachim Frank and Richard Henderson – won the chemistry Nobel prize for their work on the structure of viruses.)

The invention of the charge-coupled device in 1969 meant that images could be captured on a silicon chip: photography had entered the digital realm. Digital-imaging sensors in telescopes have had a vast impact on astronomy. In 2018, Michael Koss and colleagues verified

“Macro to micro, imaging today is exquisitely precise and often beautiful.”

the theory that black holes merge through the use of visual data from the Sloan Digital Sky Survey²⁰. And in 2019, the first image of a black hole was released, created using the Event Horizon Telescope. *Nature* was key to communicating these new technologies and providing a platform for debating them.

Now, digital imaging is reaching further, with techniques such as hybrid multiplexed sculpted light microscopy under development to measure neuroactivity²¹, and NASA’s grand database of multi-wavelength images of the galaxy (see go.nature.com/2bdrua5). There are extraordinary shots of nebulae snapped by the Hubble Space Telescope, ‘extreme zoom’ images of single atoms, and the burgeoning field of data visualization – graphical representations of data.

Macro to micro, imaging today is exquisitely precise and often beautiful, able to capture worlds and structures far beyond the scope of human vision. The ‘Drawn Together’ cover image for the 8 August 2019 issue of *Nature* is a case in point. Crafted by illustrator Inna-Marie Strazhnik, it provides a visualization of work by bioengineer Tyler Ross and colleagues, who used light-activated motor proteins to move microtubules into networked structures²². Strazhnik translated the models, images and graphs in the paper into a dynamic, almost three-dimensional image.

The visual continues to work as a foundation for making sense of data. The tools, as we have seen, have radically changed. The power of images has not.

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- Röntgen, W. C. *Nature* **53**, 274–276 (1896).
- Wright, W. B. *Nature* **111**, 30–31 (1923).
- Hewish, A., Bell, S. J., Pilkington, J. D. H., Scott, P. F. & Collins, R. A. *Nature* **217**, 709–713 (1968).
- A Scottish Crannog. *Nature* **22**, 13–16 (1880).
- Daston, L. & Galison, P. *Objectivity* (Zone Books, 2007).
- Bennett, A. W. & Berkeley, M. J. *Nature* **2**, 318–319 (1870).
- Tait, P. G. *Nature* **22**, 360–361 (1880).
- Belknap, G. *From a Photograph. Authenticity, Science the Periodical Press, 1870–1890* (Bloomsbury Academic, 2016).
- Baldwin, M. *Making Nature: The History of a Scientific Journal* (Univ. of Chicago Press, 2015).
- Loudon, J. C. *Mag. Nat. Hist.* **9**, iv (1836).
- Instantaneous Photography of Birds in Flight. *Nature* **26**, 84–86 (1882).
- The Photographic Chart of the Heavens. *Nature* **38**, 38 (1888).
- Lonsdale, K., & Whiddington, R. *Proc. R. Soc. Lond. Ser. Contain. Pap. Math. Phys. Character* **123**, 494–515 (1929).
- Lonsdale, K. & Smith, H. *Nature* **148**, 112–113 (1941).
- Watson, J. D. & Crick, F. H. C. *Nature* **171**, 737–738 (1953).
- Franklin, R. E. & Gosling, R. G. *Nature* **171**, 740–741 (1953).
- Waterston, D. *Nature* **92**, 319–319 (1913).
- Shuttleworth, S. & Charnley, B. *Notes Rec. R. Soc. Lond.* **70**, 297–304 (2016).
- Dubochet, A. M., Lepault, J. & McDowell, A. W. *Nature* **308**, 32–36 (1984).
- Koss, M. J. et al. *Nature* **563**, 214–216 (2018).
- Weisenburger, S. et al. *Cell* **177**, 1050–1066 (2019).
- Ross, T. D. et al. *Nature* **572**, 224–229 (2019).