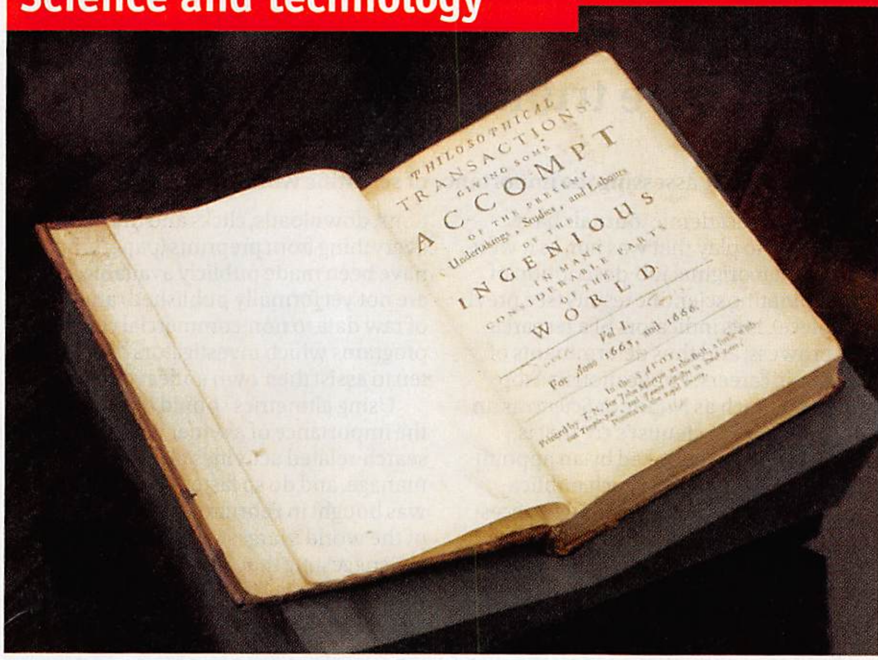


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Open science

# Time's up

**Scientific journals were once a great idea. Now, though, they are slowing progress. But that is about to change**

ON JANUARY 1st the Bill & Melinda Gates Foundation did something that may help to change the practice of science. It brought into force a policy, foreshadowed two years earlier, that research it supports (it is the world's biggest source of charitable money for scientific endeavours, to the tune of some $4bn a year) must, when published, be freely available to all. On March 23rd it followed this up by announcing that it will pay the cost of putting such research in one particular repository of freely available papers.

To a layman, this may sound neither controversial nor ground-breaking. But the crucial word is "freely". It means papers reporting Gates-sponsored research cannot be charged for. No pay walls. No journal subscriptions. That is not a new idea, but the foundation's announcement gives it teeth. It means recipients of Gates' largesse can no longer offer their wares to journals such as *Nature*, the *New England Journal of Medicine* or the *Proceedings of the National Academy of Sciences*, since reading the contents of these publications costs money.

That will hurt. Publication in such Premier-league journals is the stuff careers are built on. But it will also hurt the journals themselves. Their prestige is based on their ability to pick and publish only the best. If some work is out of bounds to them, no matter how good it is, that will diminish their quality. And if other patrons of science follow suit, those journals' businesses could begin to crumble. Moreover, by actively directing the beneficiaries of its patronage towards the repository in question, set up last year by the Wellcome Trust (after Gates, the world's second-largest medical-research charity), the foundation is pointing to a specific type of alternative—and to a future for scientific publication that, if not completely journal-free, is likely to be at least, "journal-lite".

## Wellcome to the 21st century

Periodical journals have been the principle means of disseminating science since the 17th century. The oldest still around, the *Philosophical Transactions of the Royal Society* (pictured above), appeared first in 1665. Over the intervening three and a half centuries journals have established conventions for publication—such as insisting on independent (and usually anonymous) peer review of submissions—that are intended to preserve the integrity of the scientific process. They have, though, come under increasing attack in recent years.

One criticism, in a world where most non-commercial scientific research is sponsored by governments, is that there should be no further charge for reading the results of taxpayer-funded work. Journals, in other words, should have no cover or subscription price. A second is that the process of getting a paper published takes too long. Months—sometimes years—can pass while a hopeful researcher first finds a journal willing to publish, and then waits for peer review and the negotiation of amendments. That keeps others in the field in the dark about new results for longer than is really necessary, and thus slows down the progress of science. Third, though this is less easy to prove, many researchers suspect that anonymous peer review is sometimes exploited by rivals to delay the publication of competitors' papers, or, conversely, that cabals of mates scratch each others' backs, review-wise.

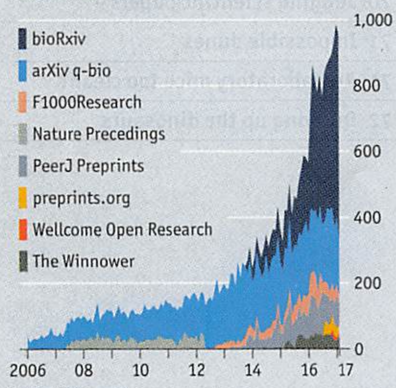
To these criticisms, another may be added, which is not the fault of journals, but still needs addressing. This is the unwillingness of many researchers to publish the data on which their conclusions are based. Some journals do insist on full disclosure of data, but not all are so particular. And, even then, the data in question will not see the light until publication day.

Partial solutions to some of these problems have been tried. The Gates foundation is experimenting with carrots, as well as sticks. It has offered the publishers of one top-flight journal, *Science*, $100,000 to make papers published this year about Gates-sponsored research free to read from the beginning. If this goes well, the experiment may be extended to other publications. Similarly, there is a movement among some publishers to make papers free to the reader by charging the authors (and therefore, ultimately, their patrons) for the costs of publication—usually in the range of $2,000-$3,000 per paper. But many now think these are half-measures, and that a real revolution in the idea of scientific publishing is needed.

Part of science has already undergone such a revolution. Since 1991 physicists have been able to deposit early versions of ▸▸

**Print first, ask questions later**

Biomedical preprint submissions, by month, to




Source: Omnes Res

their papers, known as preprints, in an online repository called *arXiv* (the "*X*" represents a Greek "chi" rather than a Latin "ex"). *ArXiv* is paid for by Cornell University Library, the Simons Foundation, a charity, and through fees from around 200 members (mostly universities). Over the years the number using it has increased, to the point where around 300 preprints are deposited every day.

This sort of "pre-publication" is rapidly becoming physics's method of choice. Depositing a paper in *arXiv* both establishes that a researcher has been the first to arrive at a discovery and makes that discovery available immediately to others. It does not provide formal peer review, but physicists are not shy of criticising the work of others, so a lot of informal (and un-anonymous) feedback can accumulate rapidly. This potential flak is a deterrent to publishing half-baked work. Nor does appearing in *arXiv* preclude later publication in a journal. The editors of periodicals were once sniffy about accepting material previously available elsewhere. In physics, they can no longer afford this luxury.

The Gates foundation's announcement is part of an attempt to extend this idea to the rest of science, particularly biomedical research. Biomedical equivalents of *arXiv* exist, but they are not much used. One of the largest, *bioRxiv*, received around 600 submissions in February. That is but a fifteenth as many as *arXiv*, even though many more biomedical papers are published per year than physics papers.

Why biologists have failed to follow physicists' lead is unclear. It may simply be a historical accident. *ArXiv* was started before most journals went online, so was initially more distinct from such journals than online databases are now. By the time biologists, less computer-literate as a clan than physicists, caught up with the idea, the online-offline distinction had blurred, and the journals saw online repositories as rivals. But whatever the cause, the result was clear: an unwillingness by non-physicists to embrace preprints.

The time, however, seems ripe to change that. Though its absolute numbers are still low, the use of *bioRxiv* is growing fast (see chart). And it is not just outside nudges that are bringing this sort of thing about. In February, for example, ASAPbio, a group of biologists who are trying to promote the use of preprints, began looking for bidders to create a website which will index all life-science preprints published in public repositories.

Outside nudges do help, though. It will not harm ASAPbio's chances of success that its plan has the backing of America's National Institutes of Health, the country's main source of taxpayer finance for medical research. And other philanthropic organisations besides the Gates foundation are also pushing in the same direction. The Wellcome Trust's creation of the repository Gates has just joined is one example. Another is the Chan Zuckerberg Biohub in San Francisco, brainchild of Mark Zuckerberg, a founder of Facebook, and his wife, Priscilla Chan. In February the Biohub announced it would disburse $50m to 47 local scientists on condition they made their work available as preprints.

There is even room for commerce in this brave, new world. The Wellcome-Gates repository is actually run by a firm called F1000, that also has its own preprint repository, F1000Research. This operates in a slightly different way from *arXiv* and its imitators in that its does include a formal process of peer review. F1000's review process involves named rather than anonymous reviewers, which many regard as a strength. But who those reviewers should be is suggested by a submitted paper's authors, which carries obvious risks of partiality. Revenue comes from a fee of up to $1,000 that authors pay on submission.

The wider use of preprints might also help reduce the problem of pre-publication data-hoarding. Once a preprint is published, its authors need not fear that others ▸▸

Judging science

## Alternative truths

**Various ways of assessing the importance of scientific work**

ONE role academic journals have come to play that was not, as it were, part of their original job-description of disseminating scientific results (see previous piece), is as indicators of a researcher's prowess, and thus determinants of academic careers. Publication in a top-notch title such as *Nature* or *Science* is an adornment to a scientist's CV that is unlikely to be overlooked by an appointment committee. Using such publications as endorsements is, though, necessarily a rule of thumb. A paper's true quality is better revealed by the number of times it is cited elsewhere (ideally, in papers other than those written by the original's authors). But citations take time to accumulate. Other, faster means of assessment would be welcome.

That has led to the development of alternative metrics, or "altmetrics". These extend the concept of citation beyond references in other scientific papers—by recording, for example, how often a paper is downloaded, or when the outcome of a clinical trial is used to develop guidelines for doctors, or if a piece of work is included in a course curriculum.

Altmetric.com, based in London, was one of the first companies to work in this area. It has, since 2011, tracked mentions of published papers in sources ranging from social media and Wikipedia to policy documents published by government departments. A rival firm, Plum Analytics, in Philadelphia, tracks mentions, downloads, clicks and the like of everything from preprints (papers that have been made publicly available, but are not yet formally published) and sets of raw data to non-commercial computer programs which investigators have written to assist their own endeavours.

Using altmetrics should thus indicate the importance of a wider range of research-related activities than citations manage, and do so faster. Plum Analytics was bought in February by Elsevier, one of the world's largest scientific publishers, suggesting that altmetrics may be profitable as well as useful.

Meta, based in Toronto, takes another tack. It hopes, by bending artificial intelligence to the task, to identify important papers from the 2m or so produced every year. The firm's computers have attempted to recognise features of widely cited papers that contributed to their success. Sam Molyneux, Meta's boss, claims that as a result the firm's software can now predict the impact of newly published work.

Meta, too, was bought earlier this year—in its case by the Chan Zuckerberg Initiative, a company started by Mark Zuckerberg, a founder of Facebook, and his wife Priscilla Chan, that is being run as a philanthropic operation. Mr Molyneux says he hopes, within the next two months, to make Meta's tools available without charge to any scientist who wishes to use them.

will take credit for their work. And it is becoming easier to make data available in a way that lets the originator retain control and garner credit. Sites such as Figshare let researchers assign a unique alphanumeric code (called a Digital Object Identifier) to data sets, figures, video and so on, meaning their origins are clear.

None of this necessarily means that non-physicists will eschew journals and rush to publish their work in open repositories. Over time, though, more may come to see the advantages of doing so. As more researchers submit preprints and make their data available to others, they may find the comments they receive regarding their work helpful. Even the kudos of publication in the premier journals may slowly fade in the face of data about a piece of work's actual, rather than potential, impact (see box on previous page). Having survived three and a half centuries, scientific journals will no doubt be around for a long time yet. With luck, though, they will return to being science's servants, rather than its ringmasters. ■

Geology

# The devils and the details

### Powerful whirlwinds explain a strange feature of the Atacama desert

THE Salar de Gorbea, at the southern end of the Atacama desert, in Chile, is one of the most hostile places on Earth. It receives virtually no rainfall and the little water it does host is contained in ponds both acidic and salty. It therefore has no vegetation. It is, though, the site of some of the most extraordinary dunes on Earth.

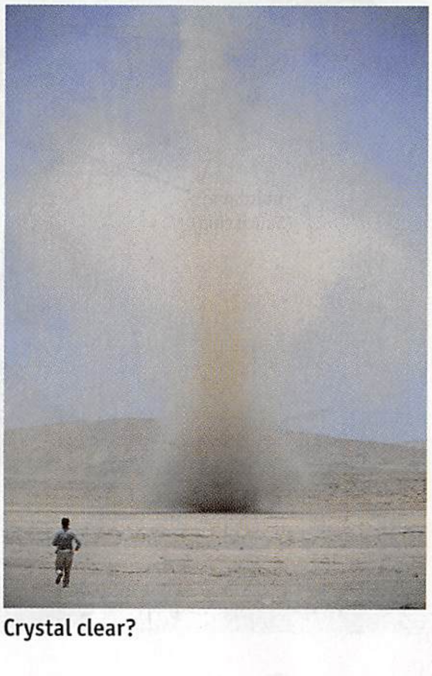
Most dunes are made of sand: grains of silica that are 2mm across, or less. There are exceptions. The White Sands National Monument in New Mexico, for example, is so called because the ingredients of its dunes are sand-grain-sized crystals of gypsum. But this exception proves the rule, because the point about a dune is that it is created by the wind, and when it comes to minerals, the wind can generally pick up and move around only sand-sized objects. The dunes of Salar de Gorbea, however, are an exception that proves no rule at all. They, too, are white, because they are also made of gypsum. But the gypsum in question includes crystals more than 20cm long. How such dunes could form by wind action has long been a mystery. Kathleen Benison, of West Virginia University, thinks, however, that she has solved it.

Gypsum is a form of calcium sulphate created by the evaporation of water laden with that substance. Dr Benison knew that gypsum crystals of the size found in Salar de Gorbea's dunes form in ponds 5km from those dunes. She thus suspected that these ponds are the source of the dunes' crystals. This suspicion was reinforced, she explains in a paper just published in *Geology*, when she compared the internal bands marking stages of the growth of crystals from the dunes with those of crystals from the ponds. They appeared identical. That suggested crystals are somehow being transported from the ponds to the dunes.

She was able to rule out one mechanism for such transport—that the crystals had been moved by long-vanished streams or rivers—for several reasons. First, the Atacama is believed to have been too dry for streams to form for millions of years. Second, gypsum dissolves in water (this is, indeed, the reason dunes made of it are rare, for most deserts have at least some rainfall). And third, the faces of crystals from the dunes were scored in ways which indicated that they had been bashed around by strong winds.

The only inland winds obviously powerful enough to have done this are in the funnels of tornadoes. The Atacama desert does not, though, experience such storms. It does experience lesser whirlwinds, called dust devils. But the textbooks say that dust devils are not powerful enough to lift and carry objects the size of the crystals found in the dunes.

Textbooks, however, are not always correct, so Dr Benison decided to check for herself. She went to Salar de Gorbea and monitored the dust devils there. She found that devils do regularly form in valleys along the edge of the region. Some then pass over the ponds where the gypsum crystals are growing, pluck crystals out of those ponds, carry them the 5km to the dunes, and then dissipate, dropping their loads on the accumulating heaps.


Crystal clear?

What she does not yet know is how they do it, for the textbooks are, in one sense, correct. The most powerful recorded dust devils have wind speeds of 70kph. This is indeed insufficient to carry mineral particles bigger than 2mm across. For the devils of Salar de Gorbea to be transporting large gypsum crystals they must be far more powerful than that. Dr Benison seems therefore to have substituted one mystery for another. The devils clearly are responsible for Salar de Gorbea's dunes. What is responsible for these devils' great powers remains to be found out. ■

Animal experiments

# Dirty secrets

### Are laboratory mice being kept in conditions that are too clean?

THE hygiene hypothesis posits that certain diseases—notably asthma, eczema and type-1 diabetes—which are becoming more common than they once were, are caused in part by modern environments being too clean. The diseases in question result from misfunctions of the immune system. The hygiene hypothesis suggests such misfunctions are the result of children's immune systems being unable to learn, by appropriate exposure to viruses, bacteria, fungi and parasitic worms, how to respond properly.

If modern human homes are unnaturally clean, though, they are as nothing compared with the facilities in which experimental mice are housed. Those are practically sterile. That led Lili Tao and Tiffany Reese, two researchers at the University of Texas Southwestern Medical Centre, in Dallas, to wonder if such mice would display extreme versions of the predictions of the hygiene hypothesis.

This would matter, because mice are often used in medical experiments on the assumption that their reactions are similar enough to those of human beings for them to act as stand-ins. Conversely, laboratories' spotlessness might also mean mice are sometimes too healthy to act as useful models for disease. As they explain in *Trends in Immunology*, Dr Tao and Dr Reese therefore combed the scientific literature to look for both phenomena.

A nice example which the two researchers found of the hygiene hypothesis at work is that stopping laboratory mice being infected with murine cytomegalovirus, which is common in their wild kin, damages their immune response to a host of other pathogens, bacterial as well as viral. Mice so infected will survive subse- ▸▸

quent exposure to otherwise-lethal doses of *Listeria monocytogenes* (a soil- and food-borne bacterium) and *Yersinia pestis* (the bacterium that causes plague). These mice are also better able than others to handle retrovirus infections. And the effects on them of multiple sclerosis—an illness the underlying cause of which is suspected to be an inappropriate immune response—are reduced.

On the other hand, early infection with a different common pathogen, *Yersinia pseudotuberculosis*, affects murine immune systems in a way that leaves mice more open to subsequent attack, rather than less so—the reverse of the hygiene hypothesis. By unknown means, such infection permanently diverts immune cells called dendritic cells from their normal homes in lymph nodes and to the wall of the gut, where they cause sustained inflammation. Similarly, early exposure to certain herpes viruses, also common in the wild, can result in latent infections that cause no perceptible symptoms unless a kind of parasitic worm called a helminth also turns up. That reactivates the infection. Anyone attempting to mimic human worm infestations using mice should be aware of this.

Those studying vaccines, too, need to be aware of the confounding effects of hygiene. Laboratory-bred mice have fewer memory T-cells than those brought up in the outside world. Memory T-cells are the parts of the immune-system that remember prior infections, thus enabling a rapid response if the agent which caused that infection is encountered again. Generating such T-cell memories is a vaccine's job.

Moreover, an experiment done by Dr Reese herself showed that exposing young mice to human pathogens, such as herpes and influenza viruses, altered their subsequent responses to vaccines for other diseases. Animals so exposed produce fewer antibodies against a yellow-fever vaccine than do pathogen-free mice.

As is often the case with these sorts of preliminary literature reviews, the outcome is a grab-bag of intriguing results, rather than a coherent hypothesis or prescription for action. But the evidence Dr Tao and Dr Reese have assembled suggests there is something going on here that needs investigating. It seems to be a classic example of the law of unintended consequences. The point of raising mice hygienically is to eliminate as many uncontrolled factors from an experiment as possible. That hygiene itself might be such a factor has not, until now, crossed people's minds.

How to respond is unclear. Running trials twice, with "dirty" and "clean" mice, could be one approach. Another might be to agree on a set of bugs to which early exposure is permitted. What this work does show, though, is that in research, cleanliness is not necessarily next to godliness. ■

Palaeontology

# Old hipsters

**The way dinosaurs are classified may be about to undergo a radical rethink**

AS EVERY school-aged aficionado of dinosaurs knows, those terrible reptiles are divided into two groups: the Saurischia and the Ornithischia—or, to people for whom that is all Greek, the lizard-hipped and the bird-hipped. The names go back 130 years, to 1887, when they were invented and applied by Harry Seeley, a British palaeontologist.

Seeley determined that the arrangement of the bones in a dinosaur's pelvis—specifically, whether the pubic bone points forwards (Saurischia) or backwards (Ornithischia)—could be used to assign that species to one of these two groups. In his view, and that of subsequent palaeontologists, the evolution of other features of dinosaur skeletons supported the idea that these two hip-defined groups were what are now referred to as clades, each having a single common ancestor. Seeley thereby thought he had overthrown the dinosaurs as a true clade themselves: he believed Saurischia and Ornithischia were descended separately from a group called the thecodonts.

Subsequent analysis suggests he was wrong about that. The dinosaurs do seem to be a proper clade, with a single thecodont ancestor. But the basic division Seeley made of them, into Saurischia and the Ornithischia, has not been challenged—until now.

The challengers are Matthew Baron, of Cambridge University, and his colleagues. Writing in *Nature*, they suggest dinosaur classification needs to be shaken up. Their system still has two groups, but it looks very different from Seeley's.

Based on an analysis of 74 types of dinosaurs and close relatives of dinosaurs, which examined 457 skeletal characteristics, they propose that hip-structure is not the be-all and end-all that Seeley and his successors thought it was. Instead, they separate the two great subgroups of Saurischia, the sauropods (*Brontosaurus*, *Diplodocus*, etc) and the theropods (*Tyrannosaurus*, *Allosaurus*, etc) and reassign them. The sauropods are teamed up with a group called the Herrerasauridae, which are so primitive they are not easily fitted into the Saurischia-Ornithischia system, to form a reconstituted Saurischia. The rest of the Ornithischia and the theropods, meanwhile, are joined as a newly named group, the Ornithoscelida.

Whether Dr Baron's classification will hold up remains to be seen. Any system based on comparative anatomy rather than DNA is vulnerable to the evolution of similar features on separate occasions—giving an illusion of relatedness that is actually untrue. Indeed, the problem with relying on anatomical features, such as hip-shape, to classify animals is well illustrated by dinosaurs themselves. It was not bird-hipped Ornithischia that gave rise to birds, but lizard-hipped theropods.