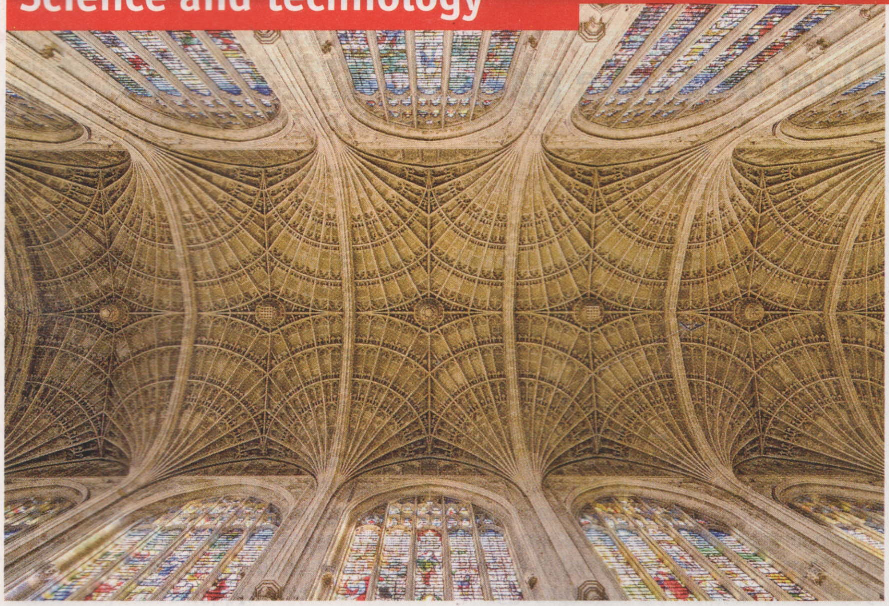

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High-tech construction

Back to the future

DONCASTER AND ZURICH

Clever computers and 3D printing allow builders to design lavish, complicated and highly efficient structures

SET in the heart of Cambridge, the chapel at King's College is rightly famous. Built in the Gothic style, and finished in 1515, its ceiling is particularly remarkable. From below it looks like a living web of stone (see picture). Few know that the delicate masonry is strong enough that it is possible to walk on top of the ceiling's shallow vault, in the gap beneath the timber roof.

These days such structures have fallen out of fashion. They are too complicated for the methods employed by most modern builders, and the skilled labour required to produce them is scarce and pricey. Now, though, new technologies are beginning to bring this kind of construction back within reach. Powerful computers allow designers to envisage structures that squeeze more out of the compromise between utility, aesthetics and cost. And 3D printing can help turn those complicated, intricate designs into reality.

In a factory that makes precast concrete, 16km south of Doncaster, in northern England, a robotic arm hangs over a wide platform, a dribble of hard pink wax dangling from a nozzle at its tip. The arm is mounted on a steel gantry which lets it move about in three dimensions, covering a volume 30 metres long, 3.5 metres wide and 1.5 metres deep. Called FreeFAB, the system uses specialised wax to print ultra-precise moulds that, in turn, are used to cast concrete panels. Hundreds of these panels are being installed in passenger tunnels as part of Crossrail, Europe's biggest construction project, which is digging a new east-west railway line across London.

Run by Laing O'Rourke, a construction firm, FreeFAB is the first 3D-printing technology used in a big commercial building project. Show offices and show homes have been printed in places such as Dubai and China, but are, for now, just concepts. The problem, says Bill Baker, an engineer who worked on the Burj Khalifa in Dubai, the world's tallest building, is that printed concrete is currently produced in layers, which are fused together to make a thicker panel. But the boundaries between the layers introduce weaknesses that make the panels unsuitable for real buildings. "These things can peel apart," he says.

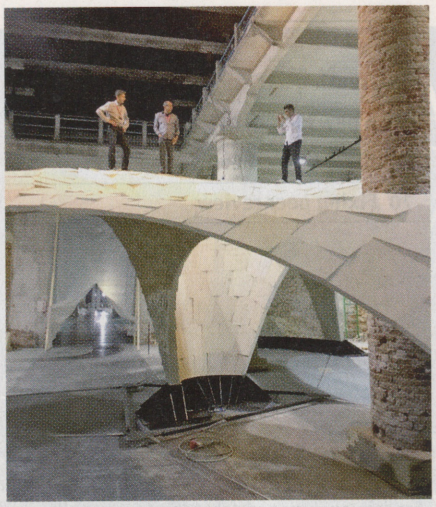
Breaking the moulds

FreeFAB gets around that problem by printing moulds rather than trying to print structural material directly. Invented by James Gardiner, an Australian architect, it has big advantages over traditional mould-making techniques. One is that it creates far less waste. Ordinary moulds are made from wood and polystyrene, and can only be used to produce a single shape. Once they are finished with, they are scrapped and sent to landfill. FreeFAB's wax can be melted down and poured back into the tank, ready to be re-extruded into a new form. It took Dr Gardiner three years to find a wax which could be printed, milled and recycled.

The system also makes it cheaper to make even complicated moulds. Production of traditional moulds is highly skilled work. Making a mould for a concrete panel that curves along two different axes, like the ones used in Crossrail, takes about eight days, says Alistair O'Reilly, general manager at GRCUK, the firm in whose factory FreeFAB is installed. FreeFAB can print one in three hours. That speed makes it possible to meet the design demands of more complicated buildings. Subtly curved panels can be used inside houses to deaden sound and keep certain rooms quiet, for instance. Doing that with traditional methods would be too expensive. FreeFAB—or something like it—could make such components much cheaper. And because the concrete itself is not being printed, the panels are just as strong as ones made in the traditional way. FreeFAB's parts do not peel, and have withstood twice the required force in bomb-proofing tests.

It is early days. The factory in Doncaster has had teething problems—it has proved tricky to print moulds without flaws big enough to be visible in panels cast from them. For now the factory supplies concrete cast from a mix of traditional moulds and 3D-printed ones. But if the technology matures enough, Laing O'Rourke plans to spin it out as a startup focused on this new way of creating buildings.

If that happens, Philippe Block, an architectural engineer at the Swiss Federal Institute of Technology, in Zurich, might be an early customer. Dr Block makes floors that have the flowing, veined look of biological membranes. Just a few centimetres thick, they are modern versions of the chapel ceiling at King's. Instead of building floors that rely on steel reinforcement to hold them up, Dr Block builds them under compression, so that each bit of the floor holds up the rest in a shallow vault. Each is bespoke, designed by a computer to effi- ▸▸



Walking on an eggshell

ciently deal with the specific loads it must bear. This allows him to build much thinner structures out of materials much weaker than reinforced concrete.

Such floors are useful as well as beautiful. In skyscrapers, for instance, the floors and the structures that support them account for a good deal of the building's mass. Dr Block calculates that his new, thinner floors would need only about a third as much material as a typical floor slab. At the same time, their thinness allows him to claw back enough vertical space to fit three floors into the space that would be taken by two floors built in the standard way.

Dr Block has already tested many versions of his ideas, most recently at the Venice Architecture Biennale in 2016. There, he and a team constructed a 15-metre vaulted "tent" out of 399 blocks of cunningly shaped limestone, each precisely milled to match the pattern of forces necessary to hold the vault up. Called the Armadillo Vault, its dome was half as thick as an eggshell would be at the equivalent size.

The next test is in a real building, specifically a demonstration house called NEST in the Zurich suburbs. Dr Block's group will make the floors for a new part of the building called HiLo. The main bottleneck in the production of Dr Block's structures is the creation of each element. It is expensive and slow to mill all the parts from blocks of stone, or to build traditional moulds for each individual component. So Drs Block and Gardiner are planning to work together on HiLo, using FreeFAB to print moulds that will produce segments of the floors. If all goes according to plan, the work should be done by 2018.

That could be just the beginning. Dr Gardiner talks of using ductal concrete, which is reinforced with steel fibres that make it lighter than concrete reinforced with steel rods but just as strong, to build thin bridges that span rivers in a single bound. For now, that is a project for the future. But all the components are in place. ■

Treating autism

Blast from the past

A sleeping-sickness drug first discovered a century ago may help with autism, too

MICE are not humans. But they are similar enough that many drugs that work in mice turn out to work in people as well. Three years ago Robert Naviaux, a researcher at the University of California, San Diego, published a paper suggesting that a drug called suramin could alleviate the symptoms of autism in mice. That was interesting, for despite all the research into autism, few effective treatments are available. Now, in a paper published in *Annals of Clinical and Translational Neurology*, Dr Naviaux reveals that the experiments have been repeated on humans, and the drug seems effective for them, too.

Nobody is sure what causes autism. One theory points the finger at something called the "cellular danger response". This involves compounds known as purines, which command cells to halt their usual activities and brace for an imminent viral attack. That response is normal and, provided it switches off when the danger has passed, beneficial. But some researchers believe that the mechanism can end up switched on permanently. This, they think, can encourage the development of autism.

Dr Naviaux's past work with mice shows that when mothers are exposed to a virus-like stress while pregnant, the cellular danger responses of their pups can become permanently activated. And one side-effect of the response is to inhibit the growth of neural connections that is normal in young brains. The result is a set of behaviours—difficulty with social situations, and a strong preference for familiar things and for routine—that bear a strong resemblance to autism in humans.

Suramin, which was discovered in 1916 and has long been used to treat the sleeping sickness spread by tsetse flies, blocks purines from binding to neurons. Dr Naviaux reasoned this might help the neurons of young mice afflicted with autism to begin making connections again. Sure enough, as long as the mice were on the drug, they shed many of their autistic traits. The next step was to see if the same would happen with humans.

Like all early-stage clinical trials, this one was small. Dr Naviaux and his colleagues recruited 20 autistic boys between the ages of five and 14. The boys were paired by age, IQ and the severity of their autism, such that for every participant who was given suramin, a similar participant was given saline solution as a placebo. This pairing, and a decision to exclude any recruits who were found to be taking prescription drugs, left the experiment with ten participants in total.

All had suramin levels in their blood monitored for six weeks. Each was given tests designed to measure language ability, social interactions and repetitive behaviours. All the tests were run before the drug was administered and then again seven and 45 days later.

Every participant given suramin showed statistically significant improvements in their performance on the tests at seven days. Those on the placebo showed no significant improvement. At 45 days, the ▸▸

Distant cousins

boys who were given the drug were performing better on the tests than they had before the infusion, but it was clear that as suramin was leaving their system, their autistic traits were returning.

Those findings matched the experience of the children's parents. They did not know whether or not their children had been given suramin or a placebo. But those who had received the drug reported big changes in behaviour. One said that her 14-year-old boy, who had only been able to speak in single words and fragments of words before the infusion, started singing in the days afterwards. One week later, he walked up to his father in the kitchen and said "I want to eat chips." It was the first full sentence he had uttered in 12 years. Another boy of five began smiling after receiving his infusion. Soon after he began to giggle and laugh, telling his mother, "I just don't know why I'm so happy."

Such stories are informal and are therefore not listed in the paper (instead, Dr Naviaux has collected them on his website). But they add to the impression that he may be onto something. The next step is to try long-term doses of the drug to see if the benefits can be sustained. If they can, then a potential treatment for autism may have been hiding in plain sight for decades. ■

High-tech cricket

Test match

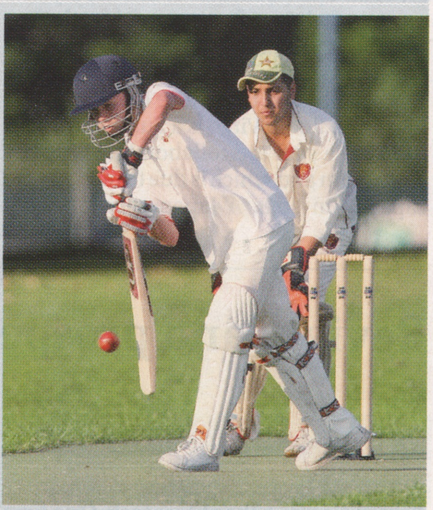
Smart bats and drones are the latest additions to the great game

THE signature sound of cricket is the thwack of a willow bat hitting a leather ball. At the ICC Champions Trophy Tournament, though, which started in England and Wales on June 1st, the bats were emitting more than those soothing reverberations. They have been fitted with sensors that enable them to fire off wireless reports that reveal how a batsman played the ball. Spectators were also treated to the slightly less pleasant whine of electric motors, as a drone armed with infra-red cameras performed reconnaissance flights over the pitch.

Both gadgets are the brainchildren of Intel, a chipmaker commissioned by the International Cricket Council (ICC), the sport's governing body, to find new ways to keep fans entertained. Cricket is no stranger to technology. Until now, though, attention has been focused mainly on the bowler and the ball. A system called "HawkEye" tracks the ball's trajectory, helping pundits analyse bowling styles and umpires judge leg-before-wicket decisions. "HotSpot" uses infra-red cameras to determine where a ball struck the bat, or the batsman.

But the subtleties of a batsman's style have so far escaped scrutiny. Commentators must rely on little more than educated guesswork, says Anuj Dua, an Intel director. To fix that, Intel and Speculur Technology Solutions, a firm based in Bangalore, have developed BatSense, a diminutive gadget that players can attach to the top of their cricket bat.

Based on a coin-sized Intel microcomputer, BatSense incorporates accelerometers, a gyroscope and a wireless transmitter, allowing it to beam data to the commentary box on everything from bat angles to stroke speed. Besides snazzy graphics on match day, the system can also help hone a batsman's skill, says Atul Srivastava, Speculur's boss. A version aimed at amateurs that enables the device to transmit to a smartphone is



Activate the bat signal

under development.

Cricket's languid, civilised pace can pose problems for commentators, who feel the need to keep talking even when not much is happening on the field. A favourite topic is the state of the pitch, the strip in the centre of the field where most of the action happens, and the state of which can have a big impact on bowling. But as with talk of a batsman's technique, such discussions are often little more than conjecture.

Hence the drones. Before the matches, and again at lunch, a machine of the sort used to analyse farmland flies over the pitch. It maps things like topography, grass density and soil moisture, providing hard data for pundits to chew over.

Such augmentations may seem out of place in a game so wedded to tradition. The trick, says Mr Dua, is to feed fans' appetites for fresh insights without distracting them from the game itself. So drone flights will be limited. And because BatSense is so small and unobtrusive, there should be no change to that talismanic sound of leather on willow.

Astronomy

In a different light

Gravity-wave detectors are both physics experiments and telescopes

ONE of the biggest bits of science news in 2016 was the announcement, in February, that gravitational waves had been detected for the first time. A prediction of Albert Einstein's theory of general relativity, theorists had long suspected that such waves—rippling distortions in the fabric of space itself—were real. But no one had seen one. They were eventually revealed by a billion-dollar instrument called the Laser Interferometer Gravitational-Wave Observatory (LIGO), which is based at two sites in Louisiana and Washington. LIGO works by bouncing lasers down tunnels with mirrors at each end. A passing gravity wave will stretch and compress space, causing tiny changes in the time it takes a beam to traverse the tunnels.

The waves that LIGO spotted were caused by the joining, 1.3bn years ago, of a pair of black holes, 36 and 29 times as massive as the sun. Such mergers are among the most powerful events in the universe: the coalescing holes briefly pumped out 50 times more energy than all the rest of the stars in the universe combined.

They are also fairly common. LIGO's first detection took place in September 2015. Three months later, it saw another such event. And on June 1st, LIGO announced its hat-trick, reporting a third detection which had taken place on January 4th, 2017. The first detection was a spectacular piece of physics that will likely earn LIGO's masters a Nobel prize in due course. But the second and third—and others that the instrument will surely make in future—belong more to the realm of astronomy. For LIGO is both a physics experiment and a telescope that offers an entirely new way to look at the universe.

Most telescopes make use of the electromagnetic spectrum, from high-frequency gamma rays to low-frequency radio waves and every wavelength (including visible light) in between. Gravity waves are not part of the electromagnetic spectrum, and are produced by different physical forces. They can therefore be used to examine things that traditional astronomy ▸▸

cannot. LIGO's most recent detection, for instance, seems to have been caused by the merging of two black holes whose spins were not aligned. That implies that they lived separate lives before coming together as a pair. How common such encounters are is an open question in astronomy. The more such detections LIGO makes, the better the understanding astronomers will have of how black holes evolve.

In the future, the trickle of data should become a flood. Virgo is a European detector whose staff are collaborating with the LIGO team and which is due to reach its full capacity in 2018. A Japanese instrument named KAGRA should begin taking data that same year. Indian researchers are keen to build a detector of their own. Things will really heat up in 2030, when the European Space Agency plans to launch LISA, a set of three satellites that together will form a space-going gravity-wave detector. The sensitivity of ground-based instruments such as LIGO is limited by the length of their tunnels. Freed from such constraints, LISA's lasers will travel between spacecraft 2.5m km apart. That will make it far more sensitive than instruments like LIGO, and help crack this new window on the universe wide open. ■

Scientific publishing

Review and prosper

Peer review is a thankless task. One firm hopes to change that

AS SCULPTURES go, it is certainly eye-catching. On May 26th a small crowd gathered outside Moscow's Higher School of Economics to watch the unveiling of a 1.5-tonne stone cube shaped like a six-sided die. Its five visible sides are carved with phrases such as "Minor Changes", "Revise and Resubmit" and "Accept". Called the "Monument to the Anonymous Peer Reviewer," it is, as far as anyone can tell, the first such tribute anywhere in the world.

Peer review underpins the entire academic enterprise. It is the main method of quality control employed by journals. By offering drafts of a paper to anonymous experts, poor arguments or dodgy science can be scrubbed up or weeded out.

That is the theory. In reality, things are murkier. Anonymity makes peer review unglamorous, thankless work. That matters, for these days scientists are under relentless pressure from universities and funding bodies to publish a steady stream of papers. Anything that distracts from that goal—including reviewing the research of others—could mean forfeiting grants or career advancement. Perhaps unsurprisingly, studies suggest many reviewers do a poor job of spotting shortcomings in the papers they are critiquing.

One solution is to make peer review more desirable and less of a duty. That is the idea behind Publons, a firm which allows scientists to track and showcase their peer-reviewing contributions. It has just been bought for a tidy sum by Clarivate Analytics, which runs Web of Science, an index that tracks how often researchers cite each others' papers. Scientists who sign up will get a verifiable, trackable measure of their contributions. Their reviews will even be given their own "DOI" numbers, unique identifiers currently used for keeping track of papers.

The hope is that once scientists can quantify their reviewing work and boast about it on their CVs, universities and funding bodies will take it into account when handing out promotions or cash. Making scientists keener to review papers could also speed up publishing, says Andrew Preston, one of the firm's founders. At the moment, much of a journal editor's time is spent tracking down potential peer reviewers, then badgering them to contribute. By making reviewing more attractive, hopes researchers might start volunteering instead. Since Publons's founding in 2012, more than 150,000 researchers have signed up, writing more than 800,000 reviews.

The firm hopes to shake up the system in other ways. Reviewers can choose how much information to reveal, and in what context. So a review of a colleague's paper might appear anonymously in the journal concerned. But reviewers' names could be reattached when it is time for performance appraisals, giving their bosses proof of the extra work. And while traditional peer review is done before publication, Publons also allows reviewers to assess a paper after it has been published.

Such "post-publication" peer review is already common on websites such as arXiv, where physicists and mathematicians post early versions of papers that will later be published in journals. The extra scrutiny may catch problems other reviewers have missed. Mr Preston points to a paper published in October in *Nature* called "Evidence for a limit to human lifespan". It passed traditional peer review. It has a very high "Altmetric" score, which measures how much attention it has gathered in the press and on social media. But Publons's reviewers do not rate it. Six post-publication reviews give the paper an average score of 4.7 out of 10, claiming concerns with the way it analysed its data.

Another goal is to fight fraud. In April Springer, a big American publishing firm, retracted 107 papers from *Tumor Biology* after discovering that the authors had tricked the journal's editors into soliciting reviews from fake e-mail addresses, which invariably offered glowing reviews. Having acquired Publons, Clarivate hopes that linking researchers' citation records with their records as reviewers will make it easier for journal editors to select reliable reviewers and harder for duplicitous authors to deceive them. (Such services are how Publons, which is free for researchers to use, hopes to make money.)

The Moscow sculpture honouring peer reviewers was paid for by an online crowdfunding campaign. On its tongue-in-cheek website, it quotes Andre Geim, a physicist who won a Nobel prize in 2010, saying that peer reviewers are "unsung heroes of science" who do their work "out of a sense of responsibility". That is admirable. But as any student of the Higher School of Economics could tell you, self-interest can be an even stronger motive. ■

Publish on a six