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Visual computing

The facial-industrial complex

BEIJING AND SAN FRANCISCO

Ever better and cheaper, face-recognition technology is spreading

TOURING the headquarters of Megvii in Beijing is like visiting Big Brother's engine room. A video camera in the firm's lobby recognises visitors in the blink of an eye. Other such devices are deployed around the office. Some of the images they capture are shown on a wall of video called "Skynet", after the artificial-intelligence (AI) system in the "Terminator" films. One feed shows a group of employees waiting in front of an elevator with a white frame around every face and the name of each person next to it. Quizzed on the Orwellian overtones of the set-up, Yin Qi, the startup's chief executive, simply remarks that "this helps catch bad guys."

Even if Mr Yin wanted to ponder the implications of the technology, he would not have the time. Megvii is busy building what he describes as a "brain" for visual computing. The firm has come a long way since its founding in 2011 (its name stands for "mega vision"). More than 300,000 companies and individuals around the world use its face-recognition technology, which is called Face++, making it one of the biggest such services. In December Megvii raised $100m, giving it a valuation of nearly $2bn and turning it into the world's first billion-dollar startup from might be called the "facial-industrial complex".

Providers in this field sell hardware and software tools to recognise faces and then connect those faces to other useful data. Although the market is fairly small—the most optimistic estimates put it at a few billion dollars—the technology has started to permeate the wider business landscape. The main reason is that the accuracy of facial recognition is rapidly improving, putting it on the same trajectory as speech recognition, which really took off when accuracy improved by a final few percentage points, to almost 100%. "Most people underestimate the difference between 95% and 99% accuracy—99% is a game-changer," Andrew Ng, a noted AI researcher, has said about speech recognition.

What's more, the smartphone will do for face recognition what smart speakers, such as the Amazon Echo, have done for speech recognition: make it acceptable to consumers. Millions of Chinese already "swipe" their faces on smartphones to authorise payments. On September 12th Apple is expected to unveil a new version of its iPhone, with technology that can reliably identify the owner's face and then unlock the device, even in the dark. That will come only a few weeks after Samsung presented a new Galaxy Note with a similar but less sophisticated feature.

It makes sense to separate facial-recognition technology into two categories: the underlying capability and the applications that make use of it. Megvii's Face++ belongs in the first category, as do similar offerings from SenseTime, another Chinese startup, NTechLab, a Russian firm, as well as Amazon, IBM and Microsoft. All provide face recognition as a cloud-computing service. Megvii's customers can upload a batch of photos and names, and use them to train algorithms, which then can recognise those particular people. Firms can also integrate the recognition service into their own offerings, for instance to control access to online accounts.

Megvii's and SenseTime's services are largely founded on good data. They have access to the Chinese government's image database of 700m citizens, who are each given a photo ID by the age of 16. Chinese government agencies are also valuable customers—more and more of the country's hundreds of millions of surveillance cameras will soon recognise faces. In Shenzhen facial recognition is used to identify jaywalkers; names and pictures go up on a screen. In Beijing the municipality has started using the technology to catch thieves of toilet paper in public restrooms (its system also prevents people from taking more than 60 centimetres of paper within a nine-minute period).

Commercial applications, often powered by one of the cloud-computing services, are spreading even faster. On Sep- ▸▸

Halt, who goes there?

Facial biometrics global revenue by region, $m

Source: Tractica
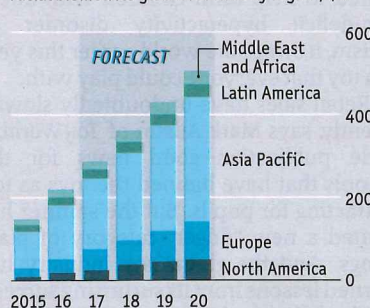
tember 1st Ant Financial, a subsidiary of Alibaba, deployed its "Smile to Pay" system for the first time in a physical store: customers at a healthier version of a KFC restaurant, called KPRO, in Hangzhou, can settle their bill by looking at a screen (see picture on previous page). Xiaomai, a chain of convenience stores, has said it will use facial scans when people enter its stores in order to study their behaviour. Several Chinese banks now let users identify themselves at ATMs with their faces.

The West is further behind. Some industries have long used a basic kind of face recognition, including casinos wishing to turn away notorious gamblers. But it is mainly big online companies that make (cautious) use of the technology. Facebook has gone furthest by having its members tag friends on photos so the firm's algorithms can recognise them on other pictures. Google employs the technology in order to group pictures that users have uploaded to its photo service. Amazon's new home speaker, Echo Look, also has a camera, which could presumably be made to recognise faces.

Other firms are testing the waters. JetBlue and other American airlines have taken initial steps to match passengers' faces to passport photos, aiming to eliminate boarding passes. Lloyds Bank is not the only Western bank planning to copy Chinese ones and allow customers to use their faces to log into accounts. Uber, a ride-hailing firm, has a system requiring drivers in India to take a selfie before starting a shift. This should cut down on unregistered drivers impersonating registered ones. Nvidia, a chipmaker, has plans for facial recognition in its new Californian headquarters.

There is potential for products that lift sales, too. Video cameras could, for instance, recognise loyal customers and VIPs who deserve special treatment. They could detect dissatisfaction on shoppers' faces and dispatch staff to intervene. Walmart, the world's largest retailer, is said to be working on a facial-recognition system to improve customer service.

Unsurprisingly, perhaps, the spread of these services has already prompted efforts to thwart them. An Israeli startup, D-ID, which stands for "de-identification", has developed software that slightly alters photos so that algorithms cannot recognise them. This allows people to share pictures of their faces without having to worry that they will be used to identify them. Others have suggest low-tech defences against sophisticated surveillance systems, such as glasses with hallucinogenic patterns on the frame of the specs, or simply wearing masks or make-up.

Yet it is unlikely that such "adversarial attacks", in the lingo, will keep face recognition from being widely used. Mr Yin of Megvii expects the technology to become a commodity. This is why he has already

set his sights higher. He is directing the firm's computer-vision brain towards even more complex tasks, such as interpreting human behaviour and recognising objects.

In the long run Mr Yin wants his firm to develop into an "algorithm factory" that offers all sorts of building blocks for computer-vision services, which other firms will be able to combine and recombine in order to come up with ever more sophisticated offerings. Whether Megvii lives up to this ambition or not, the technologies it peddles will only spread. ∎

Toys

Fidget revolution

Sales might have peaked, but fidget spinners have changed the toy market

YOU can spin them on your nose, chin, finger or tongue. Some include LED lights; others resemble a ship's wheel, or even a skull and crossbones. The fidget spinner has three paddle-shaped blades attached to a central, weighted disc containing ball bearings. Flick a blade and it spins—for as long as 12 minutes, if it's an advanced model from Japan. Originally designed to help calm children with attention-deficit hyperactivity disorder or autism, it swept the world earlier this year as a toy that everyone could play with.

Retail sales have undoubtedly slowed recently, says Mark Austin of ToyWorld, a trade publication—good news for the schools that have banned the toys as too distracting for pupils. But the spinner has created a new "fidget" category of playthings. And the global toy industry has learned lessons from its surprising success.

The fad started in America in February. By May, all 20 of the top-selling toys on

Amazon, an online retailer, were either fidget spinners or fidget cubes, a close relation. There have been many such crazes—who can forget the great loom-band mania of 2014?—but none that spread as fast. Frédérique Tutt, an analyst of the global toy market for NPD, a data company, says the spinner took just three weeks to cross the Atlantic and go global. No one knows exactly how many have been sold but NPD estimates that at least 19m were sold in the 12 rich-world countries that it tracks (including America and the biggest European markets) during the first six months of this year. Others put the figure at over 50m.

Big toy retailers, the usual arbiters of what sells, were initially caught flat-footed. Fidget spinners were a plaything that children themselves discovered and shared on social media, particularly on YouTube and Instagram. No person or firm had a patent on spinners, so with no licensing fees to pay, anyone could make them. They are produced in huge quantities in China, often by firms that previously manufactured smartphone accessories. Others were made using 3D printing. That has been a boon for small shops, which have been able to stock these unbranded goods from wherever they can find them.

Andrew Moulsher, managing director of Peterkin, a firm that imports toys into Britain, calls it a "watershed moment" for the business. Big retailers usually plan their inventory as much as 18 months ahead of peak seasons such as summer or Christmas; schedules are often tied to toy-filled films such as the "Star Wars" and "Cars" franchises. This is where most of their attention, as well as their marketing and advertising budgets, goes. So it was easy for big retailers to miss the eruption of fidget spinners online. (Subsequently they reacted as well as they could, says Mr Austin, ordering spinners in by air freight.)

Developing and manufacturing a toy can take even longer than inventory planning—up to three years. But now there is pressure to spot new fads and bring products to market far more quickly. After the fidget spinner, both manufacturers and retailers know they must respond faster to signals from social media. A Californian company, MGA, which was founded in 1979, spotted that children were watching YouTube videos of other youngsters opening presents; to take advantage of this "unboxing" trend, it managed to produce the L.O.L. Surprise! doll, which contains several layers of gifts, in just nine months. It has become another best-seller.

The spinner's successor may be the roller, an oblong object weighted at either end. Mr Moulsher started importing Japanese Mokuru rollers into Britain in July and has sold about 40,000. Learning from the fidget fad, he hopes the new school term and a smart social-media strategy will see sales rocket. Teachers, be warned. ∎
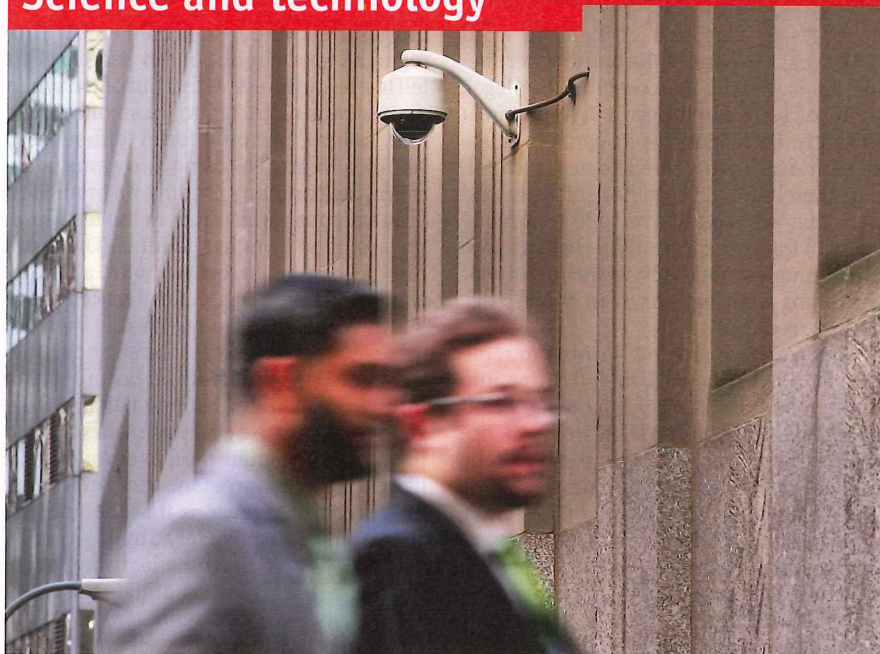
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Facial technology (1)

Keeping a straight face

In the first of two stories about faces and technology, artificial intelligence is used to spot signs of sexuality

MODERN artificial intelligence is much feted. But its talents boil down to a superhuman ability to spot patterns in large volumes of data. Facebook has used this ability to produce maps of poor regions in unprecedented detail, with an AI system that has learned what human settlements look like from satellite pictures. Medical researchers have trained AI in smartphones to detect cancerous lesions; a Google system can make precise guesses about the year a photograph was taken, simply because it has seen more photos than a human could ever inspect, and has spotted patterns that no human could.

AI's power to pick out patterns is now turning to more intimate matters. Research at Stanford University by Michal Kosinski and Yilun Wang has shown that machine vision can infer sexual orientation by analysing people's faces. The researchers suggest the software does this by picking up on subtle differences in facial structure. With the right data sets, Dr Kosinski says, similar AI systems might be trained to spot other intimate traits, such as IQ or political views. Just because humans are unable to see the signs in faces does not mean that machines cannot do so.

The researchers' program, details of which are soon to be published in the *Journal of Personality and Social Psychology*, relied on 130,741 images of 36,630 men and 170,360 images of 38,593 women downloaded from a popular American dating website, which makes its profiles public. Basic facial-detection technology was used to select all images which showed a single face of sufficient size and clarity to subject to analysis. This left 35,326 pictures of 14,776 people, with gay and straight, male and female, all represented evenly.

Out of the numbers

The images were then fed into a different piece of software called VGG-Face, which spits out a long string of numbers to represent each person; their "faceprint". The next step was to use a simple predictive model, known as logistic regression, to find correlations between the features of those faceprints and their owners' sexuality (as declared on the dating website). When the resulting model was run on data which it had not seen before, it far outperformed humans at distinguishing between gay and straight faces.

When shown one photo each of a gay and straight man, both chosen at random, the model distinguished between them correctly 81% of the time. When shown five photos of each man, it attributed sexuality correctly 91% of the time. The model performed worse with women, telling gay and straight apart with 71% accuracy after looking at one photo, and 83% accuracy after five. In both cases the level of performance far outstrips human ability to make

this distinction. Using the same images, people could tell gay from straight 61% of the time for men, and 54% of the time for women. This aligns with research which suggests humans can determine sexuality from faces at only just better than chance.

Dr Kosinski and Mr Wang offer a possible explanation for their model's performance. As fetuses develop in the womb, they are exposed to various levels of hormones, in particular testosterone. These are known to play a role in developing facial structures, and may similarly be involved in determining sexuality. The researchers suggest their system can pick up subtle signals of the latter from the former. Using other techniques, the program was found to pay most attention to the nose, eyes, eyebrows, cheeks, hairline and chin for determining male sexuality; the nose, mouth corners, hair and neckline were more important for women.

The study has limitations. Firstly, images from a dating site are likely to be particularly revealing of sexual orientation. The 91% accuracy rate only applies when one of the two men whose images are shown is known to be gay. Outside the lab the accuracy rate would be much lower. To demonstrate this weakness, the researchers selected 1,000 men at random with at least five photographs, but in a ratio of gay to straight that more accurately reflects the real world; approximately seven in every 100. When asked to select the 100 males most likely to be gay, only 47 of those chosen by the system actually were, meaning that the system ranked some straight men as more likely to be gay than men who actually are.

However, when asked to pick out the ten faces it was most confident about, nine of the chosen were in fact gay. If the goal is to pick a small number of people who are ▶▶

very likely to be gay out of a large group, the system appears able to do so. The point is not that Dr Kosinski and Mr Wang have created software which can reliably determine gay from straight. That was not their goal. Rather, they have demonstrated that such software is possible.

To calculate the selves of others

Dr Kosinski is no stranger to controversial research. He invented psychometric profiling using Facebook data, which relies upon information in a person's profile to model their personality. The Trump campaign used similar models during last year's presidential campaign to target voters, an approach which has generated criticism.

Dr Kosinski says he conducted the research as a demonstration, and to warn policymakers of the power of machine vision. It makes further erosion of privacy "inevitable"; the dangers must be understood, he adds. Spouses might seek to know what sexuality-inferring software says about their partner (the word "gay" is 10% more likely to complete searches that begin "Is my husband…" than the word "cheating"). In parts of the world where being gay is socially unacceptable, or illegal, such software could pose a serious threat to safety. Dr Kosinski is at pains to make clear that he has invented no new technology, merely bolted together software and data that are readily available to anyone with an internet connection. He has asked *The Economist* not to reveal the identity of the dating website he used, in order to discourage copycats.

It is true that anyone wishing to replicate Dr Kosinski's work to determine intimate traits from faces will face significant challenges in applying laboratory science to the outside world. But they will be helped by ever-growing volumes of data and improving algorithms. "The latter, over time, inevitably win," says Alessandro Acquisti of Carnegie Mellon University, who has shown that an individual's social security number can be discovered using face recognition and online information. For those with secrets to keep, all this is bad news. ∎

images that could be matched to real photographs for eight out of ten people. (This fell to a less impressive five out of ten when the test was restricted to those of a single race, which narrows facial differences.) About a year ago, using the same algorithm, the company produced a prediction of what your correspondent looked like at the age of 20 from her genome. The result can be compared below with a photograph of her at that age. Readers can judge for themselves if it is a reasonable likeness.

Critics immediately took to social media to dispute the findings. Jason Piper, a former employee of Human Longevity, argued that "because everyone looks close to the average of their race, everyone looks like their prediction". One thing in Dr Venter's favour, however, is that the findings are based on a relatively small group of people. With machine-learning techniques, the larger the set of data the better the results; working with tens of thousands of genomes could well improve the prediction rate.

Creating pictures of people's faces from their genomes has a number of potential uses, especially in forensic science. It might be possible to reconstruct the face of a perpetrator from any genetic material they have left behind, such as blood or body fluids. That would allow police to "see" the face of suspects in cases of murder, assault and rape. It could also help with identifying unrecognisable victims who have been burned or maimed. Unsolved cases might be reopened if suitable samples were still available.

As Dr Venter is quick to point out, this technology has other implications, among them for privacy. He considers that genomic information must now be treated as personal information, even if it is presented as an anonymised sequence of letters—as is currently the case in some countries. It will, he warns, be possible to ▸

Facial technology (2)

Making faces

Researchers produce images of people's faces from their genomes

CRAIG VENTER, a biologist and boss of Human Longevity, a San Diego-based company that is building the world's largest genomic database, is something of a rebel. In the late 1990s he declared that the international, publicly funded project to sequence the human genome was going about it the wrong way, and he developed a cheaper and quicker method of his own. His latest ruffling of feathers comes from work that predicts what a person will look like from their genetic data.

Human Longevity has assembled 45,000 genomes, mostly from patients who have been in clinical trials, and data on their associated physical attributes. The company uses machine-learning tools to analyse these data and then make predictions about how genetic sequences are tied to physical features. These efforts have improved to the point where the company is able to generate photo-like pictures of people without ever clapping eyes on them.

In a paper this week in *Proceedings of the National Academy of Sciences*, Dr Venter and his colleagues describe the process, which they call "phenotype-based genomic identification". The group took an ethnically diverse group of 1,061 people of different ages and sequenced their genomes. They also took high-resolution, three-di-

mensional images of their faces, and measured their eye and skin colour, age, height and weight. This information was used as a "training set" to develop an algorithm capable of working out what people would look like on the basis of their genes.

Applying this algorithm to unknown genomes, the team was able to generate
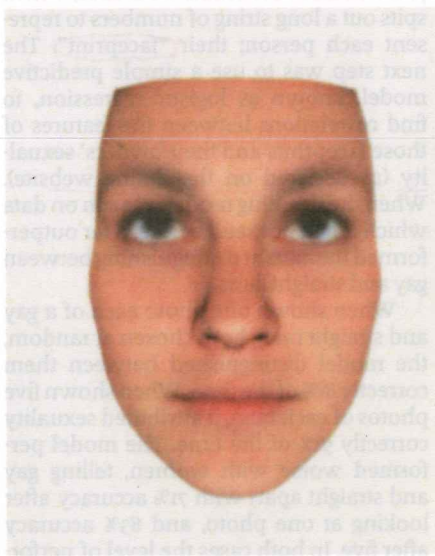
What the genes predicted, and what we got

construct a face from the limited genetic data that people currently post online, for example, from DNA-testing services such as 23andMe.

This in turn raises the possibility that people may no longer be willing to have their genetic information included in public sequencing efforts, even though such work can help combat diseases. If facial projections can be made from genomes, then someone's appearance could subsequently be matched to real online photographs. This might mean that people's genetic sequences, and all their flaws, could be connected to their identity in public.

The connection between genes and faces can work both ways. Just as genomes can be used to build up a picture of faces, so facial features are able to reveal genetic diseases. It is reckoned that 30-40% of genetic diseases cause changes to the shape of the face or skull, allowing, in some cases, experienced doctors to diagnose a condition simply by looking at a patient's face. So why not train an app to do that?

Face healer

Companies already are. Face2Gene is a smartphone app developed by FDNA, a startup based in Boston co-founded by Moti Shniberg and Lior Wolf. Mr Shniberg's previous venture was bought by Facebook to develop the photo-tagging feature that identifies people in pictures uploaded to the social-media site. The FDNA app allows a doctor to snap a picture of a patient, upload it to the internet (along with the patient's height, weight and clinical data) and let the firm's algorithm produce a list of possible diseases from its online database. The app can access information on 10,000 diseases; facial recognition works for 2,500 of them, so far.

Each diagnosis comes with a probability score that reflects the chances of the app being correct. It also lists any genetic mutations known to cause the disease, which can help with an analysis of a patient's condition. Dekel Gelbman, FDNA's chief executive, estimates that the app is being used by doctors and researchers in 130 countries. The patients' data are stored securely, anonymised and encrypted.

As with Dr Venter's work, the deeper the pool of data available to facial researchers, the more valuable it becomes. Christoffer Nellaker of the University of Oxford has set up a website called "Minerva & Me", where both the healthy and those with diseases can upload pictures of themselves and provide consent for their images to be used for studies. He is also setting up a network, the Minerva Consortium, to encourage artificial-intelligence researchers to share their data.

Maximilian Muenke of the National Human Genome Research Institute in Bethesda, Maryland and Marius Linguraru of the Children's National Health System in Washington, DC, and their colleagues are trying to broaden things out, too. They have published a series of studies using facial-recognition algorithms that were trained with photos of African, Asian and Latin American patients to identify different genetic diseases with accuracies of more than 90%. In many poor countries, expensive antenatal tests to identify genetic diseases are not available. A baby with Down's syndrome, for example, is usually identified before birth in Europe and America, but in poor countries many are not diagnosed before they are a year old. The researchers intend to produce an app that will help doctors to identify dozens of the most common syndromes using a smartphone. ■
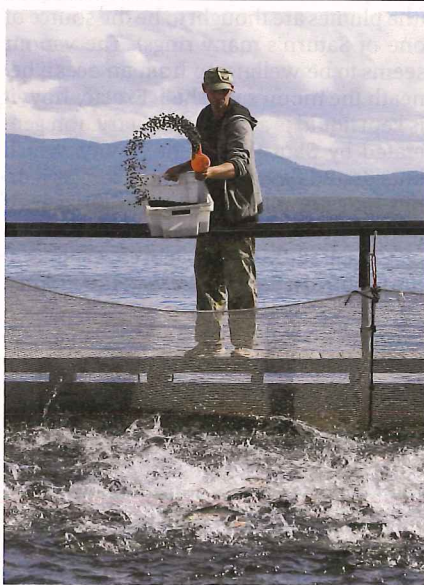
Fish farming

Feeding-time worries

Antibiotic resistance in fish farms is passed on from fish food

THE mucky sediment below fish farms usually teems with antibiotic-resistant bacteria. The presence of such bacteria is a cause of increasing concern because resistance can limit the ability to fight diseases, but it is also not that surprising: pisciculturalists have a long history of dosing fish they are breeding and rearing with antibiotics. But some scientists suspect there is more to it than that. One group, led by Jing Wang of Dalian University of Technology in China, has found that the problem is also linked to what the fish are being fed.

Dr Wang knew from previous reports that fish farmers who had not used antibiotics for years, or had never used them at all, still had sediment in their marine farms carrying bacteria with many of the genes associated with drug resistance. The genes had to be getting into the bacteria somehow; one possible pathway was through antibiotic-resistance genes in fish food mingling in various ways with bacteria in the sediment.

Working with a team of colleagues, Dr Wang set up an experiment to find out if that was the case. As they report in *Environmental Science and Technology*, the researchers obtained five commonly used fishmeal products and subjected each one to a detailed genetic analysis. This revealed the presence of 132 drug-resistance genes, suggesting that heavy antibiotic use on the fish products which are themselves ground up into fishmeal formulations, was behind the transfer of genes.

But that, too, was not as straightforward as it seemed. Further analysis revealed that of the five products, the one with the highest concentration of residual antibiotics was a fishmeal from Russia. It contained 54 nanograms of antibiotics per gram of food, although it had only eight resistance genes present. In contrast, a fishmeal from Peru had just 16 nanograms of antibiotics per gram of food, but carried a disturbing 41 resistance genes.

The next step was to discover whether mixing resistance genes from fish food into bacteria-rich sediments would allow the resistance traits to transfer over. To test this out, the team set up microcosms of fish farms in flasks containing 300 millilitres of seawater and 200 grams of sediment. The microcosms were incubated and gently shaken periodically for 50 days and then had a small amount of the Peruvian fishmeal added to them, or were left untouched to function as controls. The researchers regularly collected bacterial samples from the sediments for a further 50 days and analysed them.

The results were clear. Although the control microcosms started with some resistance genes present (as there is bound to be in nature) the number did not increase. In contrast, the number of resistance genes present in the microcosms exposed to the Peruvian fishmeal increased tenfold.

The discovery of fish food as a source of resistance genes migrating into oceanic bacteria is worrying, and the researchers say more work is needed to determine if these resistance traits can find their way into the human food chain. But, says Dr Wang, the Russian fishmeal, which clearly came from fish that had been given a lot of antibiotics before being ground up yet did not contain much resistant genetic material, points to a solution. This is to concentrate on processing methods that destroy the DNA in fishmeal with heat and chemicals. That should rid fish feed of much of its cargo of resistance genes before the food is packed and shipped. ■