



Robot laboratories

Gene machines

The design of synthetic lifeforms could become a new industry

IN THE basement of Imperial College sits the London DNA Foundry. The word “foundry” calls forth images of liquid metal being poured into moulds—of the early phase of the Industrial Revolution, in other words. This foundry is, however, determinedly modern. Liquid is indeed being moved around and poured. But it is in minuscule quantities, and it is not metal. Instead, it is an aqueous suspension of the genetic codes of life.

The laboratory is an example of a wider movement. Similar biofoundries are being set up around the world, from the Broad Institute in Cambridge, Massachusetts, via Silicon Valley, to the National University of Singapore. All offer ways of centralising the donkey work of genetic-engineering research. Instead of biotechnology companies buying and operating their own laboratories, foundries will do it for them.

London DNA Foundry’s operations room is filled with boxy devices, each designed to do one particular operation, such as pipetting, repeatedly and quickly. A robotic arm shuttles small plastic dishes between the machines. Each dish contains up to 1,536 minuscule wells. And in each of those wells sits several microlitres of liquid and a few strands of DNA. Using this arrangement, the foundry can mix, in the precise concentrations required, 150,000 samples of DNA in a morning.

The starting-point for the process is a library of what David McClymont, the

foundry’s head of automation, calls “parts”. These are snippets of genetic code from which different genetic “circuits” can be assembled. A circuit, in biotech speak, is a collection of genes that work together towards a common goal—for example, generating a series of enzymes that convert one type of chemical into another. The genes comprising a potential circuit are then assembled into circular DNA molecules called plasmids.

To obtain appropriate plasmids the foundry’s customers may simply order parts from the library. They may also provide their own proprietary snippets. All the required parts are then transferred to bar-coded wells in the dishes and their contents mixed automatically. The whole process is controlled by a piece of computer code, provided by the customer, that describes the experiment.

Once the mixture is correct, the test plates are whisked into a machine which multiplies the number of plasmids in each well using a process called a polymerase chain reaction (PCR). And then, when the PCR has done its work, the plasmids are introduced into living cells—either bacterial or yeast. After that, the cells are incubated, and the result is tested to see which, if any, of the circuits performs as expected.

Such is the London DNA Foundry’s scale that it can build and test about 15,000 different genetic designs in a day. True to its name, the foundry is set up to build and

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test DNA plasmids only. Some other biofoundries, however, offer a wider range of services. For example Transcriptic, a firm in Silicon Valley, will also allow customers to store entire cell lines that may be tested later, or to grow tissues from them for testing.

One of Transcriptic’s particular specialities is preclinical drug screening. This involves testing vast numbers of compounds that might possibly end up as drugs. A drug might, for example, be intended to alter the operation of a particular protein that shuttles, say, calcium in and out of a cell. In that case, potential drugs might be screened against both the protein in free suspension, and intact cells that have such channels in their membranes.

Little and large

Many of Transcriptic’s customers are small, newly founded firms that cannot afford their own test facilities. One such, Pliant Therapeutics, also in Silicon Valley, is using Transcriptic to test treatments for fibrotic disease—the formation of scar tissue in places like the lungs and the heart. Large, established firms use its facilities, too, though. It is often cheaper for them to do so than to carry out tests in house.

At the moment, each foundry is going its own way, as the industry finds its feet. But Paul Freemont, a director of the London DNA Foundry, hopes that once it is clear what processes are of most interest to customers, the sorts of industrial standards which are commonplace in other industries will start to emerge among biofoundries. That will make it easier for the process of designing new synthetic lifeforms to be scaled up from the bespoke boutique business it is now to something more like a global industry. That day is not yet here. But if there is demand, then biofoundries will surely play their part in the next phase of the Industrial Revolution. ■

Agricultural chemicals

For better or worse

Spraying herbicides changes the flavour and nutritional value of crops

GARDENERS know only too well how hard it is to keep on top of weeds, because hoeing and pulling them out is back-breaking work. With big fields to look after, most farmers turn to herbicides. Over the years these chemicals have become better at knocking out weeds but leaving commercial crops alone. Organic farmers do not use artificial herbicides, and can suffer lower yields as a result. Which system produces the “better” crop is open to debate, although it is known that crops sprayed with herbicides are biochemically transformed in subtle ways. New work shows those changes in treated crops are substantial enough to change both their nutritional value and flavour.

The investigation was led by Matthew Cutulle, a horticulturalist at Clemson University in South Carolina, in collaboration with Greg Armel at the University of Tennessee, Knoxville, and their colleagues. They ran an extensive series of trials on large fields growing sweetcorn, a widely eaten vegetable.

The team worked with the four commonly used herbicides: mesotrione, topramezone, nicosulfuron and atrazine. These are often used in combination with safeners, which are chemicals that selectively help protect crops from herbicide damage. Hence a safener called isoxadifen-ethyl was also included in the experiment,

sometimes pairing it with the herbicides and sometimes allowing the herbicides to work on their own.

The researchers planted sweetcorn in several plots split between two different locations. When the plants were between five and ten centimetres in height, they exposed each plot to one of seven different herbicide/safener combinations. As a control, one field was treated with atrazine before the corn was planted (a full control using no herbicides at all would have been destroyed by weeds without an overwhelming amount of hand weeding). After 45 days the sweetcorn was gathered. The mature kernels were analysed for levels of antioxidants, sugars, amino acids, proteins, fatty acids, minerals and fibre.

Sugary outcome

The results, just published in the *Journal of Agricultural and Food Chemistry*, revealed that applying herbicides increased the amount of protein that the plants stored in their kernels by as little as 4% and as much as 12% when nicosulfuron was combined with the safener. The amounts of mineral taken up by the plants increased as well, with levels of phosphorous, magnesium and manganese going up by between 14% and 51% and iron content rising by 67% in plants exposed to the nicosulfuron/safener combination. The balance of sugars found in the tissues of the sweetcorn changed as well. Fructose concentrations shot up by 48% upon exposure to nicosulfuron; 63% to topramezone and 68% to the nicosulfuron/safener combination. Glucose concentrations increased by 19% with mesotrione, 40% with topramezone and 43% with the nicosulfuron/safener combination. In contrast, sucrose levels in the corn dropped.

It remains unclear precisely how these changes affect the flavour of sweetcorn, although Dr Cutulle thinks they are probably big enough to be noticeable. He suggests that further studies are carried out to look into the matter using panels of people carrying out tastings. Perhaps more importantly, the findings show that pesticides are capable of transforming crops in ways that shape their nutritional value. Some of these, like the iron-enhancing property of nicosulfuron combined with the safener, could help with iron deficiency in diets, which is responsible for a number of severe health conditions, such as anaemia.

Other factors, however, might not be so welcome. The fructose-enriching aspects of herbicides may make sweetcorn even sweeter, but that could be detrimental to health because fructose is increasingly being implicated in a number of illnesses, such as fatty-liver disease and diabetes. Working out how to grow the best crops has become a lot more complicated. ■

The limits of biology

Waiting for rain

Life clings on even in the driest corners of Earth

IT DOES NOT rain much in the Atacama desert. A 1,000km strip of land running along the Chilean coast, it is Earth's driest desert outside its poles. Average annual rainfall in certain parts can be as low as a millimetre or two a year, and some Atacama weather stations have never seen a drop of water.

Yet it does rain occasionally. And as Dirk Schulze-Makuch, an astrobiologist at the Technical University of Berlin, and his colleagues report in *Proceedings of the National Academy of Sciences*, a desert downpour in 2015 offered the perfect natural experiment for probing the limits of what sorts of conditions life can tolerate.

The Atacama is not quite lifeless. A few specialised animals and plants scrape a living in the less arid parts. And scientists have found evidence of microbial life even in the very driest areas. What is less clear, though, is whether those microbes are natives able to endure such extreme aridity, perhaps by becoming dormant, or whether they are merely the dead remains of interlopers, blown in on the wind but unable to survive in their harsh new environment.

The rains offered a chance to check. If the microbes were alive, or dormant, then the rain should have ushered in a brief golden age of growth, as the scarcest resource in the ecosystem—water—became briefly abundant. If the desert was merely ▶▶



Your sweetness is my weakness



Down desolation road

► strewn with corpses, though, then it would have made no difference.

Shortly after the rains in 2015, therefore, Dr Schulze-Makuch and his colleagues dug trenches in the desert and took samples from the soils at various depths. They returned in 2016 and 2017 to get more samples. The ones from 2015 showed evidence of microbial metabolism, including molecules like adenosine triphosphate, or ATP, which is used by all cells to store energy, as well as enzymes, fatty acids and the by-products of biochemical processes. Crucially, when they turned to the later samples, all those chemicals had become dramatically scarcer. Levels of ATP in 2017 were around a thousandth of their value in 2015. There were similar falls for other biological molecules, too. Those results were bolstered by others showing that different kinds of bacteria and fungi were present in different layers of desert soil. That suggests organised ecosystems rather than mere bacterial boneyards.

The driest soils on Earth, in other words, do indeed seem to play host to microbial ecosystems that can flourish when the rains eventually come. As a demonstration of life's resilience, that is interesting enough. But it may have broader implications. Astrobiologists such as Dr Schulze-Makuch see the Atacama as the closest Earthly analogue for the surface of Mars. There is plenty of geological evidence to suggest that the Mars of billions of years ago was much wetter than it is today. And results from orbiting probes suggest that dribbles of water occasionally appear on the modern planet's surface, possibly caused by the intermittent melting of subterranean ice. If life did arise on Mars, then it may still be clinging on, lying dormant in the regolith and waiting for the next brief pulse of meltwater.

Admittedly, Mars is even less hospitable than the Atacama. Besides the aridity,

the Martian surface is bitterly cold and blasted by solar radiation. That radiation creates powerful oxidants that would likely destroy any living cells. If anything does survive, it will be deeply buried. That is one reason why the ExoMars rover—built by Roscosmos and the European Space Agency, and due to blast off in 2020—carries a drill capable of digging almost two metres below the surface. ■

Psychology

Sniffing out authoritarianism

How your sense of smell may affect your politics

HUMANS, like other animals, have evolved to notice and avoid sources of infection, whether that be rotten food or sickly members of their own species. This “behavioural immune system” can have unexpected consequences. Studies have, for instance, shown that those whose noses are more easily offended are also more likely to shun foreigners or disapprove of homosexuals. More broadly, people who live in regions with more to fear from pathogens tend to be less promiscuous and gregarious (such risky behaviour may spread disease). These effects are, by their nature, generally small but evidence has been amassed that they do in fact exist.

This led Marco Liuzza of the Magna Graecia University of Catanzaro, in Italy, and his colleagues to wonder whether there might be a link between a person's sensitivity to malodorousness and the likelihood of them being sympathetic to right-wing authoritarian views. In work published this week in *Royal Society Open Sci-*

ence, he shows that there is.

Members of the team have developed a body-odour disgust scale (BODS). This is based on asking volunteers a series of questions about different scenarios, such as noticing that a friend's feet smell. From this it can be established how strongly, on a scale of one to five, a person reacts to bad smells. To see if this ranking reflected a person's authoritarian leanings, the team recruited 201 volunteers through Amazon Mechanical Turk, a website where people from all over the world carry out small tasks in exchange for cash.

Passing the smell test

The volunteers completed the BODS questionnaire and others that gauged the extent to which they sympathised with certain authoritarian views (“Our country needs a powerful leader, in order to destroy the radical and immoral currents prevailing in society today”, for instance) and with more socially, fiscally or morally conservative views. The researchers found that those scoring highly on the BODS scale did indeed hold more authoritarian views. They found no such correlation between the BODS score and more broadly conservative opinions.

As their work was being conducted in 2016, when Donald Trump's campaign to become president of the United States was in full swing, the researchers wondered if such a relationship would hold true for Americans. If so, would there be any hint of an increased sensitivity to bad smells among his supporters?

To test this idea, they recruited 159 more participants solely from the United States and repeated the experiment. They found a similar pattern with their American volunteers: those sensitive to bad smells tended to hold authoritarian views. The effect was small, enough to explain between 4% and 16% of the difference in viewpoints (family background, economic circumstances and other factors would presumably account for much of the rest).

Last, the team recruited more Americans to test whether the BODS score would tell them anything about voting intentions in the presidential election. Expecting an even weaker correlation this time, they used 391 participants in the hope that they would be able to discern an effect, if it were there. They did indeed find such a relationship. High BODS scores were a feature of those intending to vote for Mr Trump, but not the Democratic Party's nominee, Hillary Clinton. This time, however, the association was even weaker—enough to account for only about 1% of voting intention.

A tiny effect, but an effect nevertheless. The work of Dr Liuzza and his colleagues adds to the persistent evidence suggesting that prejudices and political views can be influenced by a person's desire to avoid disease and bad smells. ■



Hollywood after Weinstein

After the fall

The Weinstein scandal is set to change not only the personnel in Hollywood but the stories that make it to the screen

IN 2009 Nina Jacobson—formerly president of a Walt Disney studio, by then an independent film producer—was pitching a new franchise to Hollywood bigwigs. “The Hunger Games”, based on a bestselling novel, was the sort of dystopian sci-fi epic that might seem an easy sell. Yet several executives passed, partly because the heroes were teenagers—and partly because the central character was a woman. “I was taught as though it were a common-knowledge truth that girls will identify with a male protagonist, but boys will not identify with a female protagonist,” says Ms Jacobson, who eventually sold the project to Lionsgate, a minor studio. Starring Jennifer Lawrence, it became a huge hit.

Ms Jacobson describes the industry’s rules of thumb about women on screen as “bias disguised as knowledge”. The trouble was, she says, that “there weren’t enough cases to prove the theories wrong.” There may be soon.

The scandal over Harvey Weinstein’s treatment of women, and over the other reprobates exposed in his wake, is changing Hollywood irrevocably. The #MeToo and #TimesUp movements have forced a reckoning of the industry’s monsters, of the countless careers that were destroyed by them, and of a sexist culture that let it all happen. Regal men have been dethroned. The furore will colour the Academy Awards ceremony on March 4th.

But there are signs, too, of what may prove an equally important shift, in the stories Hollywood tells. The most powerful people in the industry—who are mainly men—have justified their decisions about what to put on screen by what they say sells tickets. Ms Jacobson’s experience suggests many have been operating on flawed and myopic hunches. So does “Wonder Woman”, directed by and starring women (pictured), which last year was the third-highest-grossing film at the North American box office. Likewise “Black Panther”, with its black director and stars, is poised to become one of the most successful Marvel films ever—dispelling another assumption, that predominantly African-American films do not succeed internationally.

Back to the future

In the past such successes have typically been isolated blips. Now, as women demand more power in the production of film and television—and begin to get it—that pattern may be changing. The business of mass entertainment, and its output, are set to become more diverse, in ways subtle and profound. The trend began before the scandal but has been accelerated by it. It promises to be good for female actors and directors, for the studios, and, above all, for audiences.

In recent years women have made some headway on the small screen. In

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pay-TV and streaming television, female-dominated shows such as “Big Little Lies” and “The Handmaid’s Tale” have thrived on a business model that depends less on overall viewership than on passionate support, via subscriptions. The sprawling medium forces producers to be more original. As one executive notes, it would be difficult for another television show about a white, heterosexual, male doctor to get noticed. Some of the most influential people in TV are women, including Shonda Rhimes, a producer who signed a lucrative development deal with Netflix last year. Reese Witherspoon, producer and star of “Big Little Lies”, has acquired multiple women-centred stories to develop at her company. Women (and minorities) are increasingly being hired as directors, though they are still underrepresented: about one in six TV episodes is directed by a woman.

Mainstream Hollywood is strikingly ossified in comparison. As it happens, the first person to direct fictional films was a woman. Alice Guy was an employee of Gaumont when in 1896 she began telling short stories with film. She went on to make popular features, including action films with women in leading roles and narratives that captured an enlightened view of marriage. Eventually, though, as filmmaking became industrialised under the male-run studio system, women directors all but disappeared. Behind the camera, as in front of it, the studios’ woman problem is as deep as it is entrenched.

Male actors command about twice the screen time of female ones. Men are the heroes and villains and do most of the talking, with (at the last count) two-thirds of speaking parts in successful films, a ratio only slightly better than in the late 1940s. Women, still, are often ornaments or victims, love interests or damsels in distress: ▶▶

► useful for being disrobed, attacked or both.

So one of the simple ways that studios can be more inclusive is to put more women and minorities in central roles. The Geena Davis Institute on Gender in Media, founded by the co-star of “Thelma and Louise”, has been lobbying them for years to do this on a broad scale. Disney’s Lucasfilm, run by Kathleen Kennedy, made women the heroines of its new “Star Wars” trilogy and a spin-off, “Rogue One: A Star Wars Story”. Next year Brie Larson will star in “Captain Marvel”, the first female-led feature from Marvel Studios (now owned by Disney).

This rebalancing might seem like common sense, given that women buy half the cinema tickets. The same logic holds for minority actors, considering non-white moviegoers buy more tickets per person in North America than white ones; altogether they too account for half of total sales. Yet in the past female-led hits such as “The Hunger Games” have not been widely emulated. Perhaps “Wonder Woman”, a female superhero flick with a male star as the sidekick, will buck that trend. Flops, meanwhile, have been taken to confirm the old chauvinist biases. After “Catwoman” bombed in 2004, it took Warner Bros 13 years to release “Wonder Woman”.

Thus the number of female characters in action films has risen only slightly since 2007, from 20% to 23% in 2016, says Stacy Smith, who analyses screen portrayals of women and minorities at the University of Southern California. (Her research also found that women are much more likely to be given only one shot at directing a studio film.) Females are nudged out of the picture in varied ways. Ms Jacobson says that when she was doing research for “Antz”, an animated movie released in 1998, she learned that females had a lot of the most important jobs in ant colonies. Then an executive at DreamWorks SKG, she wanted to switch a leading role from a male ant to a female one, but was rebuffed.

Of the top 100 films at the North American box office in 2016, 34 featured women in leading or co-leading roles, compared with 20 in 2007, according to Ms Smith’s research. That looks like progress—but women are not being deployed more imaginatively. About one in four were shown nude or partially nude in that sample, almost treble the rate for men. That includes 35% of females aged 13-20, up from 23% in 2007. The #MeToo movement has produced chilling accounts of actors being intimidated into taking their clothes off on camera. Salma Hayek wrote a harrowing article in the *New York Times* in which she alleged that Mr Weinstein pressured her into a lesbian-sex scene in “Frida”, a film about Frida Kahlo, an artist. (Mr Weinstein “does not recall” pressuring her into the scene.)

Nobody thinks sex is going to vanish from screen. After all, women enjoy erot-

ica, too. “Women are just as game as men are,” says Ms Jacobson; “it’s just a matter of who gets to tell the stories.” But the Weinstein convulsions are spurring a rethink. The change won’t mean “purifying” entertainment, says a senior movie agent, but will mean films offer a more “balanced” view of sexuality. Figures in the industry whispered to the *Hollywood Reporter* that executives have become skittish about greenlighting films with gratuitous sex.

Like a better equilibrium between male and female roles, a less pornographic approach to sex might actually be good for business. Data suggest female viewers are turned off by the exploitative sexualisation of women and girls. Nick Meaney of Epagogix, a consultancy that evaluates screenplays algorithmically to predict box-office takings, says that sex scenes can indeed help films make money, but only when they fit organically into the story.

Hollywood, the sequel

If sex on screen is under scrutiny, so is misogynistic violence. Films portraying women in distress are unlikely to go out of fashion, but they might be made in a style that is less crass and demeaning. As it happens, says Mr Meaney, that would also help at the box office. ‘Woman in peril’ films fare best, he finds, when the woman fights back and wins at the end. This advance from primitive victimisation may already be under way. Keira Knightley recently said that, reviewing scripts set in the present, she had noticed a welcome uptick



Making up for lost time

in women who “aren’t raped in the first five pages and aren’t simply there to be the loving girlfriend or wife”.

Another, more concrete ramification of Hollywood’s Weinstein moment, observes Ms Jacobson, is that fewer careers of ambitious young women will be crushed by harassment. Fewer abusive men will mentor acolytes in their image. In time that will mean more women taking decisions. Two big agencies have pledged to achieve equal representation in senior posts by 2020. Some redistribution has already begun. The former boss of Amazon Studios, who left under a cloud, has been replaced by a woman, Jennifer Salke.

Change has begun in the director’s chair as well. Martha Lauzen of San Diego State University found that, for the top 100 films in 2017, 8% of directors were women. That seems paltry, but in 2016 the figure was 4%; in 2010, it was 2%. Greta Gerwig, one of that minority, has been nominated for the best-director Oscar for “Lady Bird”. A female cinematographer has been nominated for the first time (Rachel Morrison for “Mudbound”). The link between more female artists and more rounded pictures is hard to quantify, but it is real. John Landgraf, president of FX, a network that has raised its share of female and non-white directors to around a half, notes that “broadening the diversity of our roster” has “yielded a wider and often times more surprising range of choices”.

All this matters beyond Hollywood because of the example it sets to viewers everywhere. To take one small but telling instance of that influence, after the release of “The Hunger Games” there was a surge in girls’ interest in archery, the heroine’s speciality. Almost two-thirds of women say that watching a strong role model on screen made them more ambitious or assertive, says Rachel Pashley of J. Walter Thompson, a marketing firm. Women report seeing greater possibilities in the real world if their avatars realise them on celluloid: “What they said was, ‘if we saw more female scientists or female leaders or female politicians on screen, it would make it easier for that to happen in real life.’”

A new kind of storytelling does not mean homogenising men and women, or eliminating sex and violence. It means telling much the same stories, but with a different eye. Recent television provides a template. “Big Little Lies” is in part a saga of domestic abuse. “The Handmaid’s Tale” is a parable of women being systematically controlled. But they are told from the perspective of the women. Similarly, “Wonder Woman” was a superhero film in more than name. Some people who went to see it waited with trepidation for the scene in which the heroine is reduced to a fetish object; that scene never came. Instead women and girls walked out of screenings ready to conquer the world. ■

A requiem for the factory

When giants ruled the world

Behemoth: A History of the Factory and the Making of the Modern World. By Joshua Freeman. *W.W. Norton & Company*; 448 pages; \$27.95 and £22

WHEN it was built in 1721 beside the River Derwent, in Britain's East Midlands, Lombe's silk mill became something of a tourist attraction. Daniel Defoe, one of its many visitors, described its "vast bulk" as "a curiosity of a very extraordinary nature". Employing some 300 people, mostly children in ghastly conditions, the mill was not large by modern standards. But it is widely regarded as the first successful mechanised factory, an innovation that over the next 100 years transformed the way people lived and worked.

Lombe's mill is the natural starting-point for Joshua Freeman's lively chronicle of the factory, which as the title of his book "Behemoth" implies, concentrates on the largest specimens of their time. Mr Freeman, a historian at Queens College in New York, travels from Britain's textile mills, which centralised tasks that were previously carried out in homes and small workshops, to monster steel and carmaking factories in 20th-century America, Europe and the Soviet Union. His journey ends in southern China at Foxconn's city-sized plant, which makes iPhones and other electronic gadgets.

Mr Freeman rolls up his sleeves and delves into the nitty-gritty of manufacturing. He successfully melds together those nuggets with social history, on the shop

floor and beyond the factory walls, from union battles to worker exploitation and, in the case of Foxconn, suicides. Consider, for example, his account of one of the most famous factory bosses of all.

Henry Ford launched his Model T in 1908, turning the car from a luxury into a mass-manufactured product. Ford's original factory, just outside Detroit, used standardised parts and fitted them to vehicles as they travelled along a moving assembly line. By 1914 this cut the labour time needed to assemble a Model T from 12.5 hours to 93 minutes. Before long the nearby River Rouge complex became the centre of a vertically integrated empire, designed to produce everything required to make a car.

The Model T, however, soon became obsolete. As Mr Freeman describes, this exposed the weakness of the Ford system: it is extremely expensive and slow to switch a giant factory from one product to another. In 1927 Ford halted production and laid off 60,000 workers, causing a social crisis in the Detroit area. After six months 15,000 machine tools had been replaced and 25,000 others rebuilt, so that the Rouge was ready to make the new Model A. At its zenith the factory employed 100,000 people. But it was a brutal place to work, with employees subject to harsh discipline and tyrannical foremen. "A man checks 'is brains and 'is freedom at the door,'" one Rouge worker complained.

As the switch from Model T to Model A plunged Ford into loss, Alfred P. Sloan, president of General Motors, presciently observed that carmakers would need to "adopt the 'laws' of Paris dressmakers". That meant bringing out new models more often. The shortening of product cycles and the fickle nature of modern markets has duly seen manufacturing atomise into smaller, nimbler, more specialist factories.

The Rouge, for instance, lives on, but with just 6,000 workers making pick-up trucks.

Some see offshoring to low-wage countries, particularly in Asia, as the mega-factory's last hurrah. Yet long supply chains and distant plants are leaving producers vulnerable to rapid changes in their home markets, so production has been trickling back. Meanwhile new materials and manufacturing methods, such as 3D printing, are demolishing the economies of scale that giant factories have relied on. Although Mr Freeman is not ready to write off his behemoths, he has probably written their obituary. ■

The reality of war

Fragments and ruins

Eat the Apple. By Matt Young. *Bloomsbury*; 272 pages; \$26 and £14.99

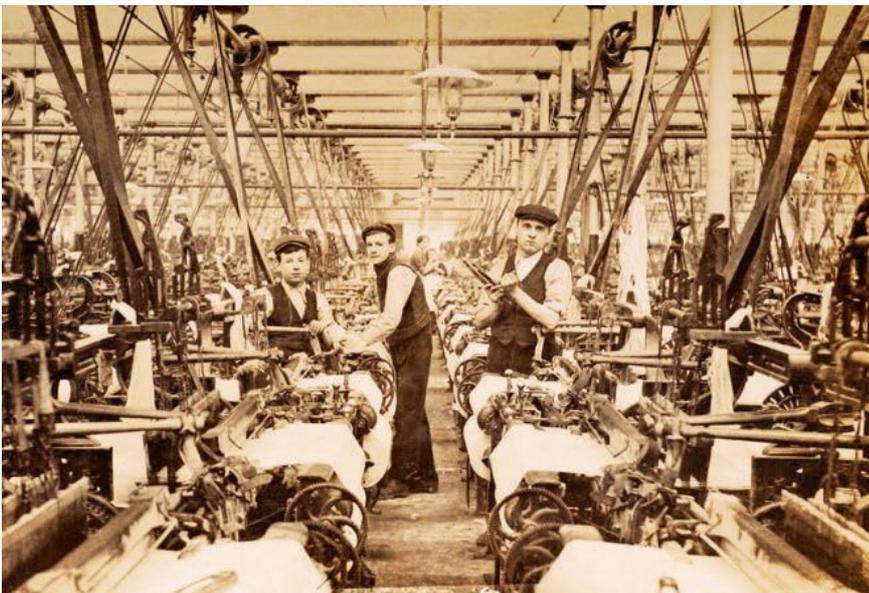
WHAT is it like to wage war? Correspondents and film-makers try to depict it, while veterans often struggle to convey the reality. Matt Young manages to answer better than most.

As an alienated young man he joined the Marines in 2005 and served three tours in Iraq during the bloodiest years of the American occupation. In "Eat the Apple" he offers a series of vignettes drawn from his experience, changing tone and voice with each. Sometimes he refers to himself as "this recruit", at others he is "the boy". Rarely does he write as "I", more often referring to "we" and "us". Here he narrates with cold distance, there he is close and grisly. Some pages are tender and wistful, others repulsive, still others funny.

The experimental, jagged account matches the disjointed life of the soldier: long periods of boredom, interspersed with terror and confusion in battle, and drunken brawls on leave. The comradeship of men at arms becomes a refuge from the incomprehension of family. The Marines' dog-tags become talismans, both remnants of fallen friends and "a foretelling of violent anonymous death".

Mr Young draws, too. One sketch describes how, with a towel and rubber glove, a serviceman can fashion a homemade aid to onanism. "Masturbation is a means of survival. Jerking off has saved countless lives through countless wars," he writes, noting how it helps keep men awake on long nights of guard duty.

His scenes recall the body- and soul-deadening training; the urge to desert on the eve of his first deployment to conflict; the exhilaration and struggle to survive amid the heat and insects. Violence explodes on the pages suddenly, like impro- ▶▶



In the belly of the beast

vised explosive devices (IEDs). After a car-bomb blasts his Humvee, he becomes a “person-thing”. Confronting the Iraqi on-lookers, he steps on a fleshy pile, which turns out to be the suicide-bomber’s face. “The person-thing thinks it is wonderful and hilarious and physically amazing. It holds the bomber’s face in front of his own and screams at the crowd through plump, blood-flecked lips, watching the crowd’s reaction through empty eyeholes.”

He has an eye for the absurd. After his patrol is blown up by an IED, he recovers in a field hospital, upset that the doctors are cutting away his favourite boots. At a strip

club back home, he emphasises the “undulating stretch marks and caesarean scars” of the naked girls.

On occasion he reflects on America’s wars. A night patrol prompts the observation that: “There is no light pollution in Iraq. There might’ve been once, but not any more. Bombs dropped, buildings collapsed, people died. But now there are stars.” He imagines a letter to a dark-skinned taxi-driver he punched. Recalling that many cabbies are Somalis, he asks, “Are you one of them?...It seems I can’t go anywhere without running into someone whose country the Marine Corps has

fucked over.”

“Eat the Apple” is not a treatise on grand strategy. It offers no lessons on defeating insurgencies or the intricacies of countries in which America fights. This is a grunt’s story, of the world seen through gun-sights and the reinforced glass of armoured vehicles. The enemy is unknown and generic: *muj, hajji* and “raghead”.

Instead, Mr Young’s is a tale of pathos. A young man tries to find himself by going to war, but fails. “I didn’t even get to kill anyone,” he laments. He has only shot dogs, guiltily at that. Yet, in writing about war, he has found a purpose and his voice. ■

Johnson | For whom, the bell tolls

In the court of common usage, an old pronoun is losing its case

LAST week *The Economist* considered the new South African president’s in-tray, advertising our advice on the cover with the words “Who Cyril Ramaphosa should fire”. Some readers might have wondered whether someone should fire our proofreaders. Shouldn’t that be “Whom Cyril Ramaphosa should fire”?

It wasn’t a cock-up. On its face, our editors agreed, the grammar was clear. It should be *whom*. *Who* is used for subjects, *whom* for objects, including direct objects such as that of the verb *to fire*. “He fires him”, not “He fires he”. Thus, “He fires whom”.

The issue is not as simple as that. *Whom* is one of the few remaining vestiges of case in English. At the time of “Beowulf”, the great monster-slaying Anglo-Saxon epic, English nouns, pronouns and adjectives, plus words like *the*, all had an ending showing case. Four different cases in Old English tell you whether a word is a subject, direct object, indirect object or possessor. Other languages, from Ancient Greek to Russian to Estonian, have far richer case systems still.

More than 1,000 years later, that system has vanished almost entirely—probably fatally weakened by foreign invaders. When foreign speakers learn a second language, as the Vikings and then the Normans did when they conquered England, cases are tricky to pick up, as any student of Russian knows. If they can be dispensed with, they often will be. Those Vikings and Normans feebly learning Old English helped turn it into Middle English, in which case was far less often visible.

Yet fans of *whom* might ask, how can you dispense with case without throwing out intelligibility? It’s important to know what word in a sentence is the subject, which the direct object, and so on. That is true—so true that every language on Earth



has a way of solving the problem, whether it has cases or not. In English and other case-poor languages, from Swedish to Vietnamese, the solution is word order.

In Old English, Latin or Russian subjects, objects and other words can appear in different orders; this gives speakers and writers a way to play with rhythm and emphasis. The loss of case in modern English means that word order must be relatively fixed, usually subject, verb and object in that sequence. *Steve loves Sally* means that Steve is the lover, Sally the loved. This could be reversed in Old English, with the meaning unchanged, because the case-endings would show who loved whom.

In English today just six words still show a distinction between subject and object: *I, he, she, we, they* and *who*. For the first five, making the case-distinction is mandatory nearly all of the time. You cannot say “I love she and she loves I”. Admittedly, some people say “between you and

I”. (It should be *between you and me*, because both *you* and *me* are objects of the preposition.) But this is a marginal mistake, made mostly by educated people taking to excess the childhood lesson not to say “you and me” in sentences such as “you and me are going to be friends.” Regardless, that children say “you and me are going” and grown-ups say “between you and I”, and both are perfectly understood, illustrates the point: case just isn’t important to meaning in English.

Whom is special. It is used in questions and relative clauses, which are rarer and more complex than “he saw him” type sentences. It is not always obvious whether the relevant word is a subject or an object, as in sentences such as, “He’s the candidate *who(m)* we think will win”. (It should be *who*.) Perhaps because these sentences are tricky, and swapping *who* and *whom* rarely causes confusion, the two words have been collapsing into just one combined form: *who*, which is used, just like *you*, as both subject and object.

Whom is stuffer in some places than in others. The pomposity of Sideshow Bob from “The Simpsons” is clear when he asks his audience “Whooom do you love?” By contrast Twitter recommends “Who to follow”. (Changing the site language to British English oddly changes this to “Whom to follow”, though Britons do not actually use *whom* any more than Americans.) After a preposition, *whom* still feels necessary: “people for whom a holiday is a far-off dream”. But in cases like our cover flash, “Whom Cyril Ramaphosa should fire” felt so unacceptably stilted that our editors decided against it.

The case, as it were, is getting stronger against *whom*. Except in the most formal language—think courtrooms and prayers—this little word may not survive. For whom, the bell tolls.