



GREAT BRITISH INVENTIONS

A special 24-page **RadioTimes** magazine inspired
by the BBC2 season **GENIUS OF INVENTION**

MICHAEL MOSLEY

A nation founded on invention



Sir James Dyson once told me that he believed part of the reason the British are so good at inventing things is

because we are an island race. I'm not so sure I can point to any one particular British characteristic that has encouraged such a great inventing tradition, but our geography certainly has helped. It created its own pressures, separated us intellectually as well as physically from the rest of Europe. It made our relatively affluent, well-educated nation turn to science at a time when the rest of the world did not. It gave us a head start.

The result is that we have an enormous amount of history that we can draw on for inspiration. We led the Industrial Revolution, and I can look back with huge respect at all those steps in our engineering and inventive past that make my life today so easy.

That past – which BBC2 is celebrating this year with a season of programmes called *Genius of Invention* – can also fuel the next generation of scientists and inventors. Our universities are world class, with a great history of technology behind them. We turn out a phenomenal number of Nobel Prize winners, and our heritage has made us a very open place, ready to embrace talent from around the world.

But there is a downside. Perhaps because we are used to getting there first, we constantly fail to commercialise British invention. Tim Berners-Lee, the father of the worldwide web, is rightly applauded for giving his invention to the world – yet on another level it would have been nice if he could have benefited from his

work in the way Google's founders have done. Richard Trevithick – the inventor of my choice in this supplement (see page 7) – is a great example of a man who doesn't get the recognition he deserves because he failed to commercialise his invention.

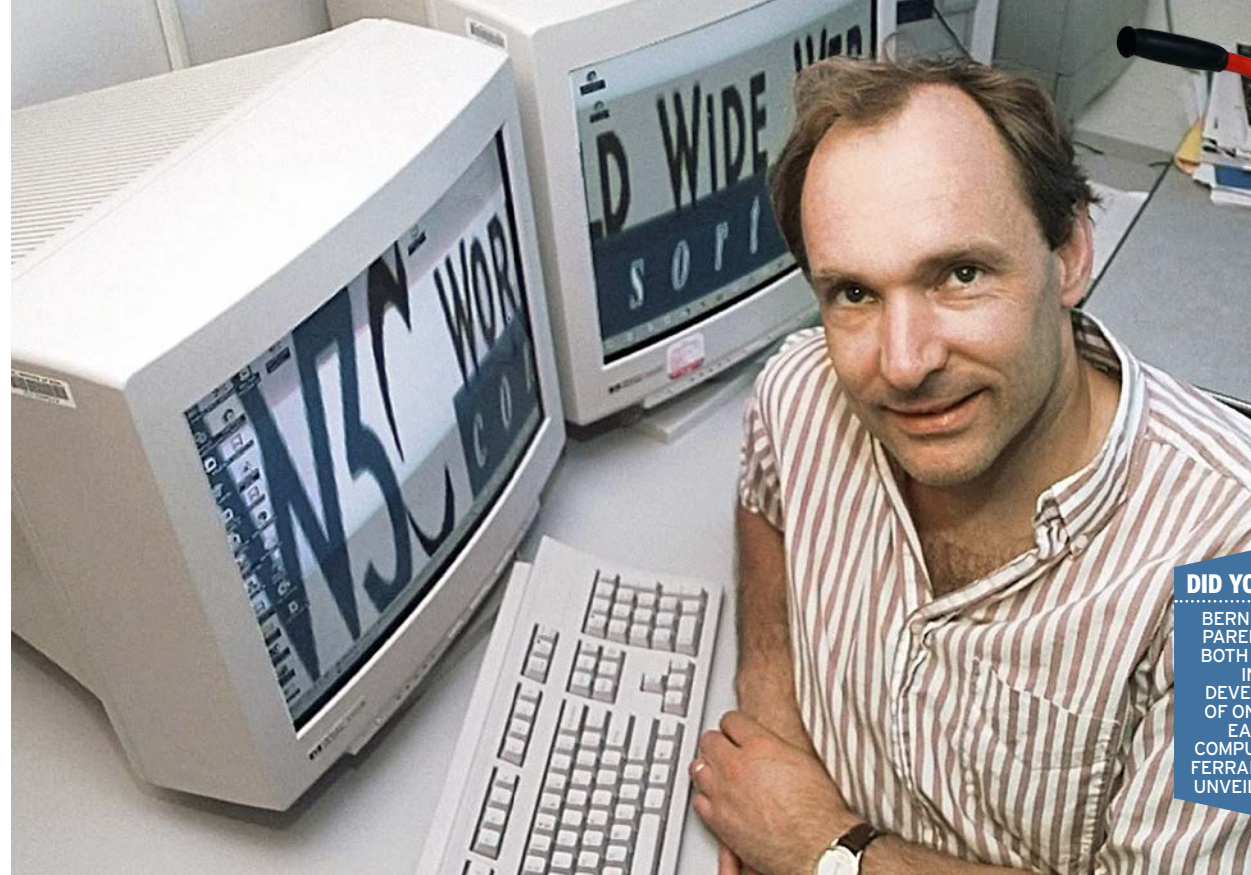
Attitudes are changing, and I have absolutely no doubt that our economic future lies in tapping into British inventiveness. Programmes such as *Dragons' Den* and figures like Steve Jobs and James Dyson have certainly inspired my children. They want to make things, but they also want to sell things. They want to be entrepreneurs.

We need invention now to help pull us out of our current morass, and I'm very hopeful our next generation of inventors is going to do it. To achieve this, we must reconnect with a culture of innovation that served these islands so well in the past: where scientists and inventors are appreciated, and where people see things that inspire them and want to make them even better.

Have your say

Which of the following 50 inventions, compiled for RT by a group of BBC science experts, is your favourite? And are there any from the randomly displayed list that they've missed out? Vote now at radiotimes.com/inventions

Michael Mosley presents a new series, *The Genius of Invention*, which starts on BBC2 next week



DID YOU KNOW?
BERNERS-LEE'S PARENTS WERE BOTH INVOLVED IN THE DEVELOPMENT OF ONE OF THE EARLIEST COMPUTERS, THE FERRANTI MARK 1, UNVEILED IN 1951.

2 Worldwide web

INVENTED 1989 INVENTOR TIM BERNERS-LEE

Not to be confused with the internet, which is a system of linked computer networks, the worldwide web was invented by British computer scientist Tim Berners-Lee. It was while working at Cern, the European particle physics lab, that he wrote a proposal showing how "hypertext" – a way of sharing information via links – could be married with the internet to create a system for fellow scientists to share data.

He created the first server in late 1990 and, on 6 August, 1991, the web went live, with the first page explaining how to search and how to set up a site. One critical innovation was that web users could link their page to another without the need for the other user's approval. And Berners-Lee gave his invention to the world for free. ■



1 Thermos flask

INVENTED 1892 INVENTOR SIR JAMES DEWAR

This humble invention was the brainchild of Sir James Dewar, an eminent professor of chemistry at Cambridge and leading light of the Royal Institution. Dewar didn't invent it to keep tea hot on picnics, but to help his experiments on cooling gases, like air and oxygen, to such low temperatures that they would liquefy.

The flask was actually two flasks, one inside the other, touching only where they joined at the top, and with a vacuum in between. Its purpose was to keep its contents either warmer or cooler than the ambient temperature outside.

Sadly for Dewar he never patented his invention. When the German Thermos Company did, he sued them – and lost. ■

3 Lawnmower

INVENTED 1827 INVENTOR EDWIN BEARD BUDDING

What could be more quintessentially British than a perfectly mown lawn in summer? Until inventor Edwin Beard Budding came up with the lawnmower in 1827, this was the preserve only of the very rich, who could afford an army of people to cut their lawns with scythes. Budding already had a reputation for inventiveness: he devised a repeating pistol that predated Samuel Colt's, a cotton carding machine of a design that is still used today, and the first screw-adjusted spanner.

His first mower was 19in wide, had a box that collected the clippings as they were thrown forward by the blades and allowed the user to adjust the height of the cut. It was, at first, still a fairly exclusive item: Oxford colleges and the Royal Zoological Society were among his first customers. But its popularity spread as more British homes came to have gardens. And because it made lawns more affordable, it gave an important boost to sports that were played on grass, such as cricket, rugby and football. ■



4 Float glass

INVENTED 1959 INVENTOR ALASTAIR PILKINGTON

When we think of inventions, it's machines and gadgets that usually come to mind. But what about all the processes needed to create and manufacture the materials the modern world is made of? Take glass: almost all the glass we use today is made using the "float" process, devised by Alastair Pilkington in 1959.

Molten glass is poured from a furnace onto a shallow bath of molten tin: the glass floats on the tin, and under its own weight it spreads out to form a level surface. As it gradually cools on the tin, the glass is drawn off in a continuous ribbon. This process made it far easier and cheaper to make high-quality glass, without the need for grinding and polishing. ■



5 Chocolate bar

INVENTED 1847 INVENTOR JS FRY & SONS

The first chocolate bar was created by JS Fry & Sons of Bristol in 1847. It was sold to the public as chocolate "delicieux à manger" – delicious to eat – because, until this point, chocolate had been exclusively consumed as a drink.

Fry's company, originally an apothecary, had been selling drinking chocolate since the 1750s, but the breakthrough came about when the company decided to combine cocoa powder with sugar and cocoa butter to make a product that could be moulded into a solid bar. It was the cocoa butter – the oil extracted from cocoa beans – that was the key: it's melting point matches the temperature of the human body, so it stays solid at room temperature but melts in the mouth.

When other chocolate-makers copied the bar, Fry's upped the ante by introducing the first cream-filled bar in 1866. More innovations followed and by the First World War, Fry's was one of the largest employers in Bristol. ■

DID YOU KNOW?

FRY'S MERGED WITH CADBURY IN 1919, THEIR ASSETS COMBINED IN A NEW HOLDING FIRM, THE BRITISH COCOA AND CHOCOLATE COMPANY.

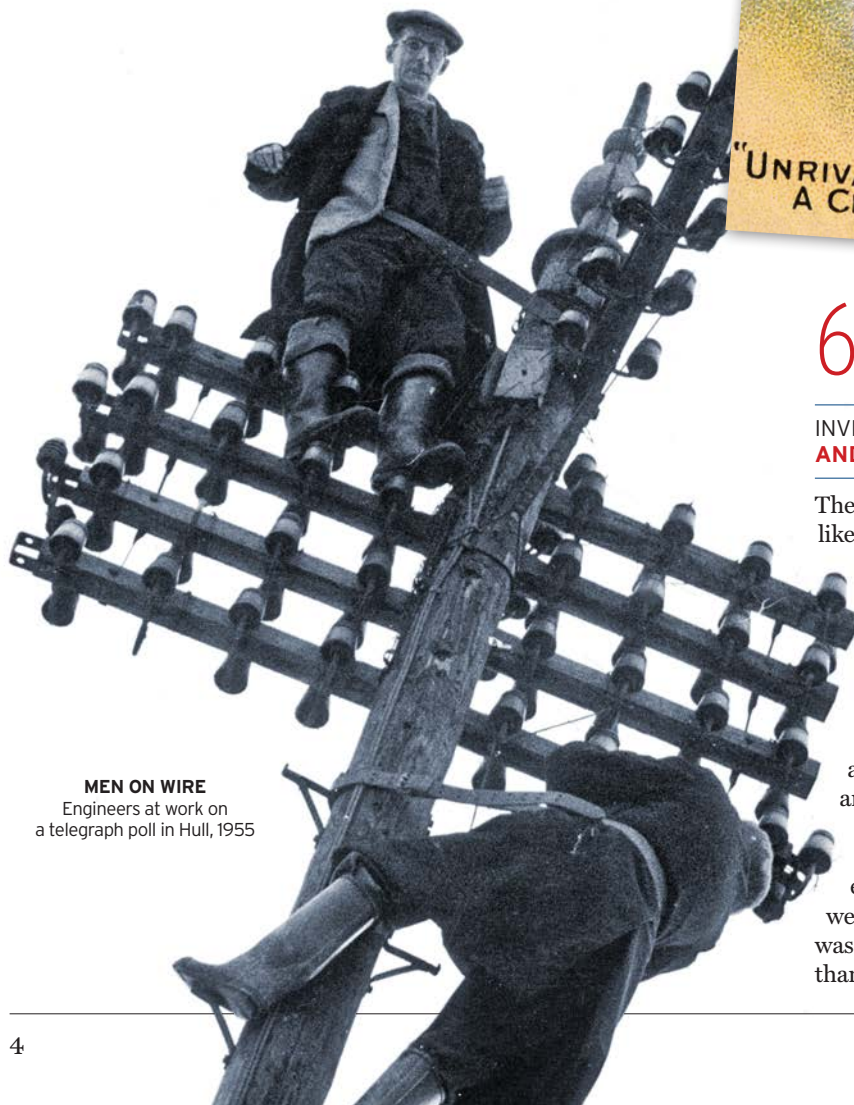


6 Electric telegraph

INVENTED 1837 INVENTORS CHARLES WHEATSTONE AND WILLIAM COOKE

The electric telegraph was a world-shrinking technology like no other. The first working system was demonstrated in 1837 by the British physicist Charles Wheatstone and his young engineer partner, William Cooke. The first fully operational telegraph ran from 1839 between Paddington and West Drayton railway stations in London, but at first it was slow to catch on. That is until New Year's Day, 1845. John Tawell, who had just murdered a lady of his acquaintance, jumped on a train at Slough and made his getaway. But when the police arrived, the station clerk was able to telegraph Paddington, where Tawell was arrested when his train pulled in.

It was a sensation, and from here on the technology exploded. Morse Code made it efficient; telegraph cables were soon everywhere – in 1858 the first transatlantic cable was laid – and by the end of the century there were more than 150,000 miles of cable connecting the globe. ■



MEN ON WIRE
Engineers at work on a telegraph pole in Hull, 1955

7 Modern fire extinguisher

INVENTED 1818 INVENTOR GEORGE WILLIAM MANBY

The first recorded fire extinguisher was invented and patented by a London chemist called Ambrose Godfrey in 1723. Godfrey's invention was perhaps motivated by his line of business – he was a successful manufacturer of the highly flammable chemical phosphorus. His gadget rather surprisingly used gunpowder to scatter the fire-extinguishing liquid, but there's at least one contemporaneous newspaper report of its success in putting out a blaze.

The first modern extinguisher, the "Extincteur", was invented by naval captain George William Manby in 1818. It's said he was inspired by the sight of firemen struggling to fight the flames on the top floors of a house fire in Edinburgh. His solution was a portable copper cask containing three to four gallons of potassium carbonate, which was dispersed by compressed air via a stopcock. ■

DID YOU KNOW?

GEORGE WILLIAM MANBY IS MOST FAMOUS FOR HIS MANBY MORTAR, WHICH FIRED A LINE TO STRUGGLING SHIPS OFF SHORE, ENABLING PEOPLE TO BE RESCUED.



8 Light bulb

INVENTED 1880 INVENTOR JOSEPH SWAN

Cheap and reliable electric lighting was a holy grail for 19th-century inventors. But didn't Thomas Edison get there first? No! He was beaten to it by Britain's very own Joseph Swan, working out of his private lab at his house in Gateshead. Swan got his patent – and started manufacturing and selling his bulbs – in 1880. He developed a tiny filament that used specially treated cotton, and set it inside an oxygen-free vacuum so that it wouldn't catch fire when it glowed white-hot.

Swan's first bulbs lasted little more than 12 hours but, unlike gas lamps, there was no flame or dirty smoke and they soon caught on. The impresario Richard d'Oyly Carte seized the opportunity to make his new Savoy Theatre in London stand out – and when it opened the following year it was the first public building in the world to be lit electrically throughout. D'Oyly Carte even took to the stage himself – holding a glowing bulb aloft, he ceremoniously broke it in front of the audience to prove it was safe. ■



Coming soon... highlights of the BBC2 season throughout 2013

Why the Industrial Revolution Happened Here Monday 9.30pm Investigating why Britain became the world's most powerful industrial nation.

The Flying Scotsman at 90 Marking the anniversary of the great London-Edinburgh steam train.

The Railway: Keeping Britain on Track Behind the scenes of the nation's rail network.

Murder on the Victorian Railway Investigating the first murder on a passenger train.

Newton: the Last Magician The life and work of the physicist, mathematician, astronomer.

Speed King The life and career of record-breaking Donald Campbell.

Turner: Man of Iron Examining the artist's fascination with science and technology.

Science Britannica Brian Cox celebrates British science and re-creates his heroes' experiments.

The Genius of Josiah Wedgwood AN Wilson tells the story of the man who revolutionised British ceramics.

Challenger: Final Flight Fact-based drama about the 1986 space shuttle disaster.

Horizon: Reinventing Invention Liz Bonnin reveals the ideas and technologies set to transform our lives.

Stephen Fry's Planet Invention Fry explores the triumph of consumer capitalism and mass production.

The Hairy Bikers: Rebuilding Industrial Britain Si and Dave visit heritage groups restoring old mechanical wonders.



9 Pneumatic tyre

INVENTED 1887
INVENTOR JOHN BOYD DUNLOP

In 1845, railway engineer Robert William Thomson patented the world's first pneumatic tyres at the age of just 23. He demonstrated his "aerial wheels" – a belt of air-filled rubber fitted inside a leather casing – on horse-drawn carriages in London's Regent's Park. Unfortunately there was no real market for them – the automobile and bicycle hadn't been invented yet.

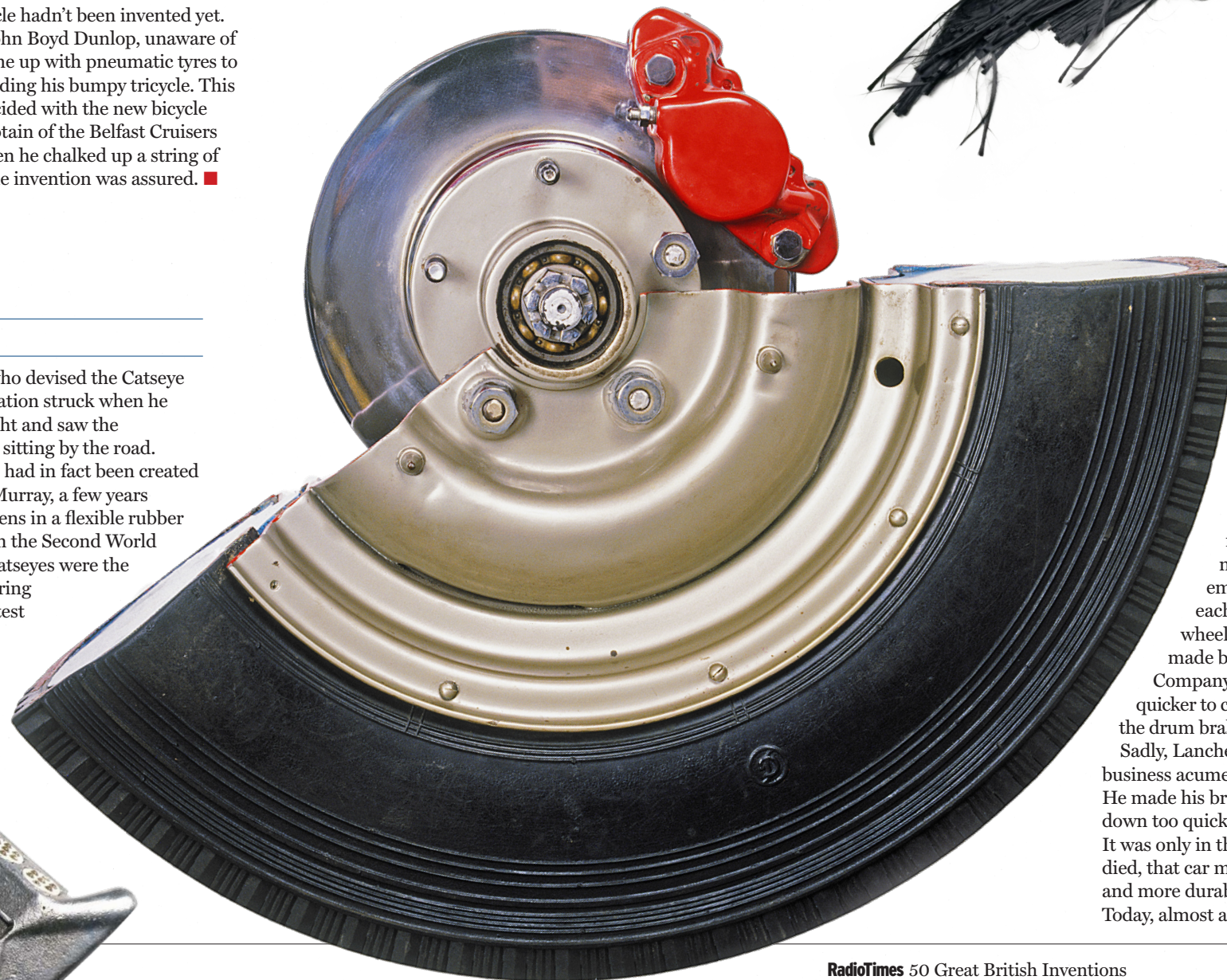
Forty years later, Belfast vet John Boyd Dunlop, unaware of Thomson's earlier invention, came up with pneumatic tyres to stop his son getting headaches riding his bumpy tricycle. This time around, the invention coincided with the new bicycle craze. Dunlop persuaded the captain of the Belfast Cruisers Cycling Club to try his tyres: when he chalked up a string of racing victories, the success of the invention was assured. ■

10 Catseye

INVENTED 1933 INVENTOR PERCY SHAW

Percy Shaw was a Yorkshire road contractor who devised the Catseye reflector in 1933. He liked to claim that inspiration struck when he was driving home from the pub on a foggy night and saw the reflection of his headlights in the eyes of a cat, sitting by the road.

The lens that reflects light back at its source had in fact been created by another British inventor, Richard Hollins Murray, a few years earlier. Shaw's masterstroke was to wrap this lens in a flexible rubber casing and set it into the centre of the road. (In the Second World War, the Ministry of Transport realised that Catseyes were the perfect way to keep roads safely lit at night during blackouts.) Shaw's Catseye was voted the greatest design of the 20th century. ■



11 Carbon fibre

INVENTED 1963
INVENTORS ROYAL AIRCRAFT ESTABLISHMENT ENGINEERS

This marvellous material is one of many inventions developed by the military that are incredibly useful for us all. In 1963, engineers at the Royal Aircraft Establishment's research station at Farnborough worked out how to reinforce plastics with carbon filaments to produce a material that was strong, lightweight and could be mass-produced.

Early on, there were setbacks – carbon fibre was used for the turbine blades for the Rolls-Royce RB-211 jet engine, but the lightweight blades just weren't strong enough. They failed the bird-strike test – they shattered when a frozen chicken was fired into them at high speed – and the engine had to be scrapped at huge cost. But the inventors at Farnborough found other uses for the material and today the material has thousands of applications in boats, cars, motorbikes, sports equipment, and even in the fuselages of jumbo jets. ■



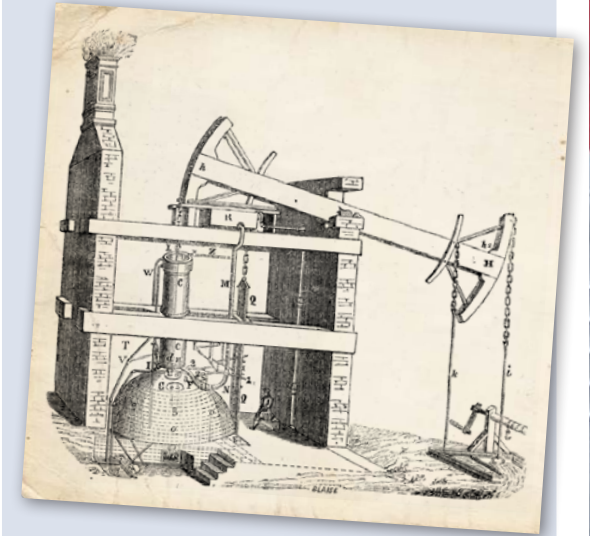
DID YOU KNOW?

THE RAE TEAM IMPROVED UPON EXPERIMENTS WITH CARBON FIBRE PREVIOUSLY CONDUCTED BY AMERICAN AND JAPANESE RESEARCHERS.

12 Disc brakes

INVENTED 1902 INVENTOR
FREDERICK WILLIAM
LANCHESTER

Frederick William Lanchester was one of Britain's first motorcar designers and manufacturers. Disc brakes employ brake pads that squeeze each side of the rotor turning a wheel, and they were fitted to the cars made by his Lanchester Engine Company in Birmingham. They were quicker to cool down and to dry out than the drum brakes used in most cars at the time. Sadly, Lanchester lacked the money and business acumen to develop them properly. He made his brakes using copper, which wore down too quickly, and they didn't catch on. It was only in the 1950s, after Lanchester had died, that car makers decided to use stronger and more durable materials, like cast iron. Today, almost all cars use his invention. ■



MICHAEL MOSLEY 13 Steam engine

INVENTED 1801
INVENTOR RICHARD TREVITHICK



The high-pressure steam engine is the most extraordinary invention of all time. It made the Industrial Revolution possible; it made the modern world possible.

For most of history, empires ran on one thing: slave power. During Richard Trevithick's time we had wind power and water power to a very limited extent, but it wasn't portable: you had to build your generator next to a stream if you wanted to tap into it. What Trevithick did with high-pressure steam was to take power, in this case in the form of coal, and turn it into workable energy.

Everybody believes that James Watt was responsible for the modern engine, but he wasn't. What he did was improve on another invention called the atmospheric engine (devised by Thomas Newcomen in 1712). It was the size of a house, could never have been portable and operated on a completely different principle to the modern steam engine. It could pump water, but basically it was dead-end technology.

Trevithick's invention, however, would become the father of the steam train and the father of portable steam power. On Christmas Eve 1801 he tested a steam car, known as the *Puffing Devil*, which successfully climbed Camborne Hill in Cornwall.

In doing so, Trevithick became the first person to power a piston using high-pressure steam. It had been attempted for 2,000 years, but every time people had tried, it had blown up and usually killed whoever was nearby. Trevithick managed it: he had the materials and the know-how, and his invention reduced the steam engine from the size of a house to the size of a modern car. He liberated power, and in doing so transformed the world. ■

Michael Mosley's four-part series, *The Genius of Invention*, begins next week on BBC2

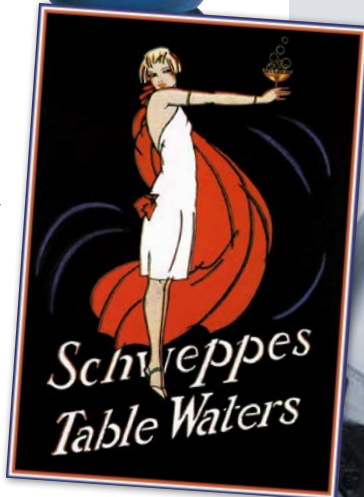


14 Soda water

INVENTED 1772
INVENTOR JOSEPH PRIESTLEY

Joseph Priestley was an 18th-century clergyman and scientist fascinated by chemistry, electricity, optics and many other subjects. As well as being possibly the first person to isolate oxygen, he invented carbonated water (later known as soda water) when he suspended a bowl of water above a beer vat at a brewery near his home in Leeds. The carbon dioxide gas given off by the fermenting vat was known as "fixed air". Being heavier than air, it stayed above the vat rather than dispersing. Priestley found he could dissolve the gas in the water and that it made a refreshing drink – of a kind that met the approval of his clean-living, religious-minded friends.

In 1772, he published a description of how to make carbonated water, using sulphuric acid and chalk, and just a few years later the Swiss fizzy drinks pioneer Johann Schweppe set up his Schweppes drinks company in London to manufacture carbonated mineral water using Priestley's method. ■



15 Hypodermic syringe

INVENTED 1853 INVENTOR ALEXANDER WOOD

Alexander Wood was an eminent Edinburgh doctor who co-invented the first true hypodermic syringe. The syringe itself had been known since ancient times; and the hollow needle had been invented a few years before, but Wood's innovation was to combine them into a means of penetrating the skin of his patients to deliver drugs intravenously without having to cut the skin first. It is said he found inspiration in the sting of the honeybee.

He initially used the syringe for morphia and other opiates – and he used a glass syringe so he could see how much medicine had been used. He also later came up with the idea of adding a scale. This was a great breakthrough in anaesthetics, and helped advance the procedure of giving blood transfusions. ■

16 Reflecting telescope

INVENTED 1668 INVENTOR ISAAC NEWTON

The first known successful reflecting telescope was built in 1668 by a man who is remembered by most people for identifying the effects of gravity. Sir Isaac Newton, then a fellow at Trinity College, Cambridge, took the idea of a reflecting telescope, which had been around for decades, and turned it into reality. It gives as much credence to his engineering skills as to his scientific mind.

He built it to prove his theory that white light, the visible part of the electromagnetic spectrum, is made up of many different colours. Newton's design consisted of a spherical-shaped mirror, made of a copper-tin alloy, above which he placed a second flat mirror at a 45 degree angle, which reflected the light into an eyepiece mounted on the side of the telescope. This huge leap forward in telescope technology made astronomical observation much more accurate. ■



DID YOU KNOW?

THE 36IN YAPP TELESCOPE, PICTURED HERE, WAS ONE OF THE LARGEST IN THE WORLD WHEN IT OPENED AT THE GREENWICH OBSERVATORY IN 1934.



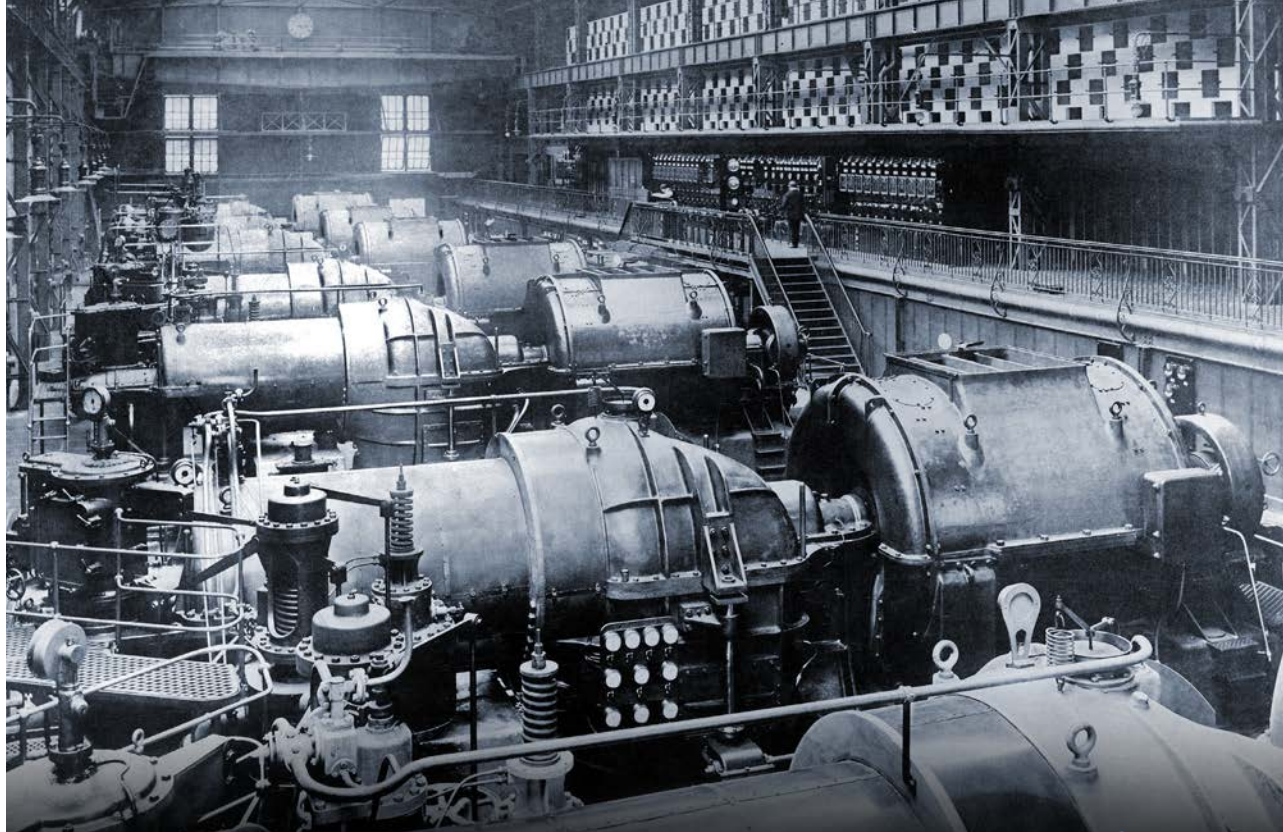
17 Collapsible baby buggy

INVENTED 1965 INVENTOR OWEN MACLAREN

In 1965, engineer Owen Maclaren was delighted to be visited by his daughter and his first grandchild, but watched with frustration as his daughter struggled with an unwieldy pushchair. Fortunately for her – and for new parents ever since – Maclaren had been the man in the Second World War who helped design the folding undercarriage for the Spitfire.

Now he decided to apply his knowledge to the pram problem. Within two years he had designed, manufactured and launched the first collapsible buggy, the classic B-01, made using lightweight aluminium tubing. It folded up into something no bigger than a large umbrella. Today, the most modern version is sold in more than 50 countries. ■





18 Steam turbine

INVENTED 1884 INVENTOR CHARLES PARSONS

After the invention of the electrical motor – which transforms rotation into electrical power – the next step was to find a device to drive it. Piston engines vibrated too violently, so the steam turbine, invented by Newcastle-based engineer Charles Parsons in 1884, was the answer.

The turbine is like a windmill – steam blasts the turbine blades and turns them round. What Parsons came up with was a means of extracting every last ounce of

power from the steam. He made the gaps between the blades very small so that the steam would accelerate through the turbine. He also realised you could channel the steam through multiple sets of blades in sequence, each one capturing the steam from the one before. Three quarters of the world's power stations still use steam. Whether steam-powered or not, every station uses the theory behind Parsons's innovation. ■

DID YOU KNOW?

THE TURBINIA (1894), THE FIRST SHIP POWERED BY A STEAM TURBINE, WAS THE FASTEST IN THE WORLD AT THE TIME. SEE IT AT NEWCASTLE'S DISCOVERY MUSEUM.

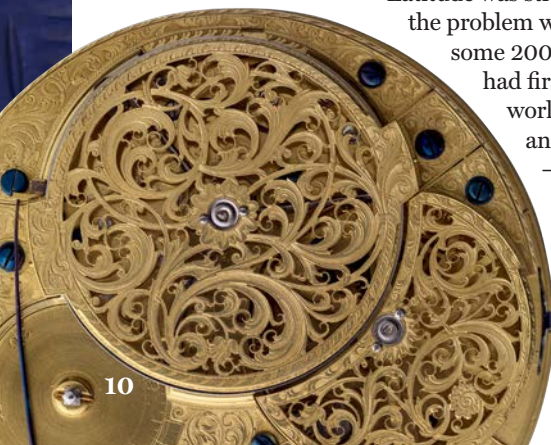
19 Marine chronometer

INVENTED 1761 INVENTOR JOHN HARRISON

Accurate navigation at sea has always been critically important but, until the invention of the marine chronometer, it was extremely difficult, if not impossible. Latitude was straightforward to measure; the problem was longitude. In 1714, some 200 years after sailing ships had first circumnavigated the world, the British government announced a £20,000 prize – worth almost £3m today – for anyone who could solve the problem.

The key to it was making a clock that could somehow keep

accurate time despite being pitched around by wind and waves and exposed to great variations in temperature and humidity. John Harrison, a self-taught clockmaker, devoted his life to the task. He began building his first attempt in 1730, but 30 years went by before he cracked it. The H4 timepiece lost just five seconds between England and Jamaica and contained numerous horological innovations. After lengthy disputes with the Board of Longitude, Harrison finally got his reward in 1773. His clocks were carried by the likes of James Cook and William Bligh, and safe long-distance travel was now possible. ■



20 Synthetic dye

INVENTED 1856
INVENTOR WILLIAM PERKIN

In 1856, William Perkin was a precocious 18-year-old studying at the Royal College of Chemistry when he discovered how to make the world's first synthetic dye – mauveine.

The search for how to make synthetics was at the cutting edge of chemistry at the time, and Perkin was assisting his professor's hunt for an artificial way to make the anti-malarial drug quinine. Working in his makeshift lab at home one day during the university holidays, he was using alcohol to clean out some chemical residue from a flask when he suddenly saw an

intense purple colour appear. At the time, dyes were made from natural extracts, and were expensive and faded easily.

Purple came only from the glands of particular species of molluscs and was among the priciest. Perkin worked out how to reproduce his new colour, then, keeping it secret from his professor, he patented the method and set up a company to produce it.

Mauve, as it came to be known, and other synthetic dyes that followed it transformed the fashion and the textile industry. And the chemistry of dyes would have many uses in medicine, too. ■



DID YOU KNOW?

IT WAS SAID THAT THE GRAND UNION CANAL WOULD CHANGE COLOUR DEPENDING ON WHAT PERKIN WAS WORKING ON IN HIS NEARBY WEST LONDON DYEWORKS.

21 Hip replacement

INVENTED 1962 INVENTOR JOHN CHARNLEY

British surgeon Sir John Charnley pioneered the idea that a human hip joint could be replaced. He designed the joint and, in 1962, performed the first successful hip-replacement operation, at Wrightington Hospital in Lancashire. Charnley's design used a femoral stem and ball made of steel and a hip socket made of Teflon – later replaced with harder-wearing polyethylene. Both parts were glued to the bone using an acrylic bone cement.

Charnley also introduced important new improvements to surgical

procedure to reduce the chances of infection: clean air enclosures, suits for the surgical team that covered their entire bodies, and a system of sterile instrument trays. He also taught surgeons from all over the world.

Although many improvements have been made since – to the design of the joint, the surgical method and the ways of fixing the replacement joint to the bone – Charnley set the standard. Today, 80,000 hip replacements are performed in Britain each year, and almost a million a year worldwide. ■

DAN SNOW

22 Passenger railway

INVENTED 1825
INVENTOR GEORGE STEPHENSON



One of my favourite British innovations is George Stephenson's passenger railway. Stephenson's parents were illiterate, his mother dying of TB when he was a child and his father later blinded in an industrial accident. It was a

remarkable background for a man who would forge a communications revolution.

While working as a miner, Stephenson enrolled in night school where he learnt to read and write, at age 18. He established an aptitude as a mechanic and was allowed to build machines at his colliery. At the time, carts on tracks, pulled by horses, were used to take coal from the many collieries around Newcastle to the Tyne, from where it could be exported by ship. Stephenson started to innovate. He improved the design of cast-iron rails to strengthen them, but above all he used steam engines to replace horse power.

Machines that harnessed the power of steam to push, lift or pull had been around for a while; Stephenson improved them and developed workable solutions to ensure that rather than remaining static, these steam engines could actually run on tracks. The result was a rapid succession of world firsts: the first "flanged-wheel adhesion locomotive". The first trackway or railway using only locomotives – no horses at all. The first purpose-built passenger car, which ran on the world's first regular passenger-carrying railway, the Stockton and Darlington. The world's first intercity railway, between Liverpool and Manchester.

Stephenson's system of train coupling became the European standard and his chosen gauge, or distance between the two rails, of 4ft 8½in (1.435m) has become the world's standard gauge, adopted nearly universally. We are still carried along by the revolution that he began. ■

Locomotion: Dan Snow's History of Railways starts on Tuesday at 9.00pm on BBC2



23 Telephone

PATENTED 1876
INVENTOR ALEXANDER GRAHAM BELL

The telephone is a classic example of how inventions are often the culmination of work done by many individuals, sharing and borrowing each other's ideas. What's for sure is that Edinburgh-born Alexander Graham Bell patented his telephone model in 1876, filing his patent just hours before a rival inventor.

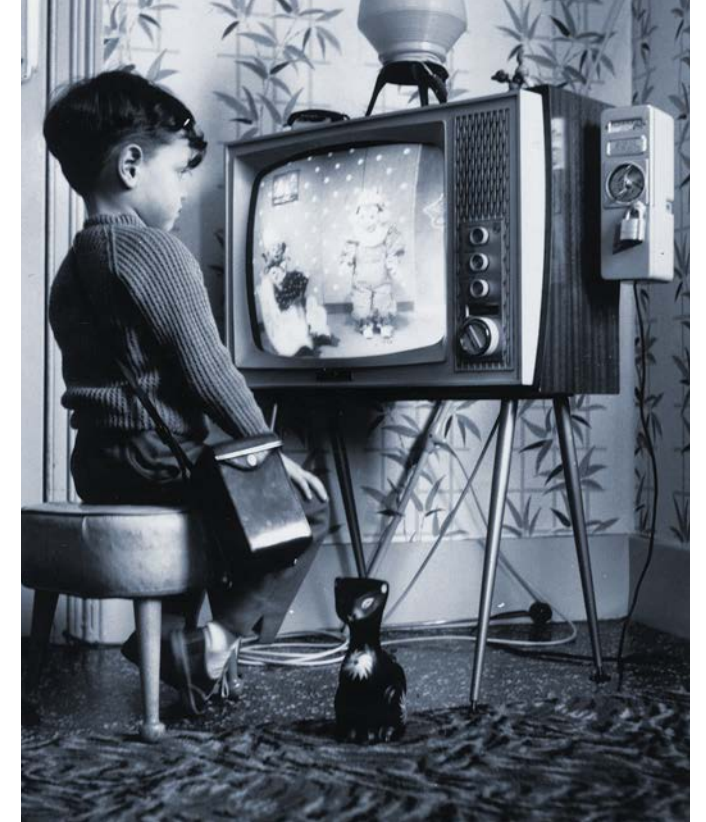
The telephone came about thanks to the discovery that a thin metal sheet vibrating in an electromagnetic field produces an electrical waveform that corresponds to the vibration and can be acoustically reproduced.

It's also pretty likely that Bell made the first telephone call: "Mr Watson, come here - I want to see you," he barked down the phone to his assistant in the next room. They first publicly demonstrated their invention at the Centennial Exhibition in Philadelphia in 1876, and made their first long-distance call - over ten miles, between their respective homes in Canada - a month later. In 1877, Bell set up the Bell Telephone Company, and 150,000 households in the US had telephones within a decade. ■



DID YOU KNOW?

BELL'S INDUSTRIOUS MIND WAS ALSO RESPONSIBLE FOR THE LOUDSPEAKER (1876) AND THE FORERUNNER OF THE METAL DETECTOR (1881)



26 Television

INVENTED 1925 INVENTOR JOHN LOGIE BAIRD

It's hard to credit just one person with the invention of television, but it's indisputable that John Logie Baird was the first to transmit moving pictures. In October 1925, he transmitted a greyscale image of ventriloquist's dummy Stooky Bill. He publicly demonstrated his system the following January and, in 1928, broadcast the first transatlantic television signal, between London and New York.

But his system ultimately failed. It was mechanical, using a rotating disc embedded with lenses, one per line, to scan the image. A rival system - scanning purely electronically, with no moving parts - was being developed at the same time and was deemed more reliable and, with far more lines per picture, visibly superior. Baird, it was said at the time, was "doomed to be the man who sows the seed but does not reap the harvest". ■

27 Automatic kettle

INVENTED 1955 INVENTOR PETER HOBBS

The automatic kettle - one that switches itself off when the water reaches boiling point - was the brainchild of Peter Hobbs, one of the two founding members of appliance company Russell Hobbs. (He had previously invented the world's first coffee percolator.)

Hobbs's 1955 K1 kettle had at its heart a simple piece of technology - the bimetallic strip. This acted like an internal switch. It was made from two strips of different metals - usually steel and copper - joined together along their length; the two metals were chosen because of the difference in their rate of expansion when heated. As the water boiled, the steam was funnelled past the bimetallic strip and, as the two metals expanded at different rates, the combined strip would bend, breaking a circuit and switching off the kettle. ■



24 Toothbrush

INVENTED C. 1770 INVENTOR WILLIAM ADDIS

William Addis was a rag trader who got caught up in a riot in 1770 and was sent to Newgate Prison. While there, and with time on his hands, he felt that the way most people were cleaning their teeth, which was to rub soot and salt over them with a rag, could be improved on. Possibly inspired by the design of a broom, he saved a small animal bone left over from a meal and drilled small holes in it. Then he obtained some bristles, tied them in small tufts and poked them through the holes. He glued it all together and - hey presto - a toothbrush.

After his release, Addis set up a business in 1780 to make what became the world's first mass-produced toothbrushes. They made him very rich. Cheap brushes used pig bristle; more expensive ones badger hair. His company, Wisdom Toothbrushes, is still going strong today, though it now uses plastic and nylon. ■

25 Linoleum

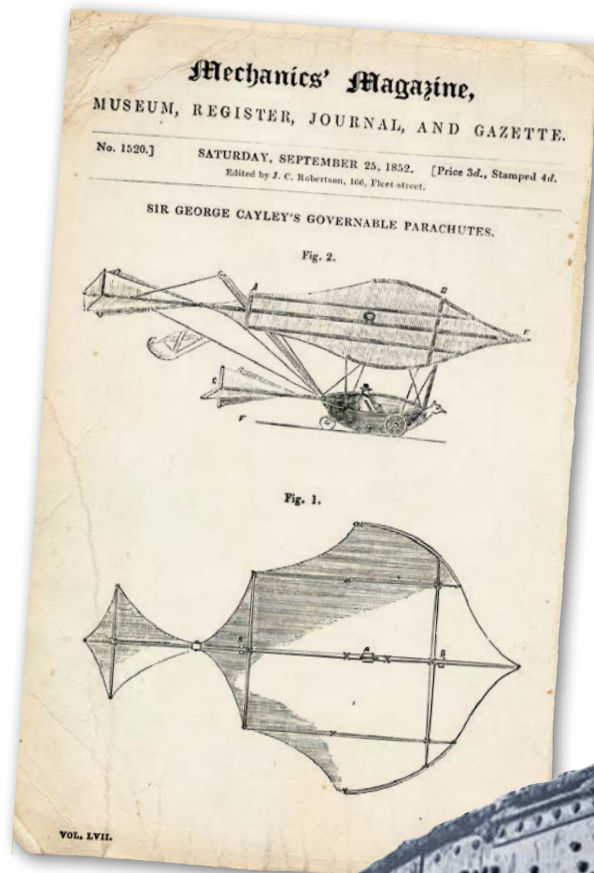
INVENTED 1860 INVENTOR FREDERICK WALTON

The idea for Frederick Walton's wipe-clean floor covering came to him around 1855, when he noticed that a rubbery, flexible skin of solidified linseed oil had formed on a can of oil-based paint. He was fascinated by the thought that linseed oil might be made into a waterproof material to rival expensive India rubber.

After trying to produce and sell a varnish product, he realised that if he could apply the varnish to a backing himself, he could sell flooring directly - cue linoleum.

For almost a century, until cheaper vinyl flooring became popular in the 1960s, linoleum was the ideal material for hallways, passages and kitchens: natural, hygienic and, in its more expensive "inlaid" versions, even beautiful. ■





28 Glider

INVENTED 1804 INVENTOR **GEORGE CAYLEY**

One of the greatest inventors in the field of aviation was Yorkshireman George Cayley. The first-ever sustained manned glider flight was made in a craft of his design at Brompton Dale in 1853. (Cayley also invented the tension-spoked wheel – see page 17.)

Cayley first designed an unmanned glider in 1804, and he was the first to move away from the idea that a man-made flying machine must have wings that flapped like a bird's. Instead, he laid down the concept of a fixed-wing aircraft, subject to the forces of weight, lift, drag and thrust, for which he became known as the father of aeronautics. His first pilot is unknown, but it may have been his 12-year-old grandson, also George. ■



30 Modern torpedo

INVENTED 1866 INVENTOR **ROBERT WHITEHEAD**

It was Giovanni Luppis, an officer in the army of the Austrian empire, who first came up with the idea of a self-propelled anti-ship weapon, but it was the British engineer Robert Whitehead who really made Luppis's concept work.

Whitehead was working for the Austrian navy when Luppis met him and suggested his idea for a prototype "coast saver" that used a clockwork motor to traverse the surface of the water and that was steered by ropes from the land. Whitehead was captivated by the idea, though didn't think much of Luppis's designs.

Over the next two years he came up with his own design for a "mineship" – a torpedo launched from a ship in an underwater tube, powered by compressed air and with an internal mechanism of his own invention that adjusted itself to stay at a constant depth. He presented it to the Austrian navy in 1866, improved the range, speed and accuracy and had a factory making and selling them worldwide.

The first ship to be sunk by Whitehead's invention was the Turkish steamer *Intibah* in 1878, after being hit by a torpedo launched from a Russian warship. ■

29 Military tank

INVENTED 1914 INVENTOR **ERNEST SWINTON**

In November 1914, the British Army was using crawler tractors to pull artillery on the Western Front, when Britain's official war correspondent, Ernest Swinton, saw them in action and realised that they could perhaps be adapted into bullet-proof and power-driven offensive weapons that could storm the enemy lines and take out their guns.

The idea was taken up and "landships" were developed: the "tank" description was meant to shield their true purpose from enemy spies. Because it was the Royal Navy rather than the Army that first developed them, naval terms

were used for some of its parts, hence terms such as the "hatch" and "turret".

The first proper tank battle took place at Cambrai, France, in November 1917, when some 400 tanks penetrated almost seven miles behind the front lines, but they weren't supported by infantry and soon had to retreat. These tanks had the capability to climb a five-foot obstacle, span a five-foot trench, were resistant to small arms fire and could travel at 4mph. Although the tank helped end the stalemate of trench warfare, it came too late to have much impact on the First World War. ■

DID YOU KNOW?

GEORGE CAYLEY APPLIED HIS GENIUS TO MANY FIELDS. HIS IDEAS INCLUDED AN INTERNAL COMBUSTION ENGINE THAT WAS POWERED BY GUNPOWDER.

31 Jet engine

INVENTED 1937 INVENTOR **FRANK WHITTLE**

Frank Whittle was a 24-year-old RAF fighter pilot in 1930 when he patented a new kind of aircraft engine – the turbojet.

Whittle's new design had no propeller and no pistons, using a gas turbine instead. With a rotating turbine and air compressor – and powered by thrust alone from the back – his new design was so radical that the military wouldn't fund it, nor would any manufacturers.

However, in 1937 Whittle found a few private backers. After two more years of development, it was reliable enough for the Air Ministry, and on 5 May 1941 at RAF Cranwell in Lincolnshire, a 17-minute test flight went ahead. It was a revolution. ■



32 Safety bicycle

INVENTED 1885 INVENTOR JOHN KEMP STARLEY

The bicycle as we know it today was originally developed as the "safety bicycle", because other bikes at the time were extremely dangerous. Riders of the penny-farthing perched above a huge front wheel, steered indirectly using the tiny back wheel, and couldn't touch the ground with their feet; only a few daring young men would go near them. The key to the new bicycle was the chain drive, which meant you could still go fast even though both wheels were the same size.

Together with front-wheel steering and back-wheel drive, this made it much more stable and easier to control. The safety bicycle was perfected by Coventry engineer John Kemp Starley, who in 1885 exhibited the Rover (right): the first recognisably modern bicycle. Light and cheap, it caught on quickly and brought cycling to the masses. For most people, and women in particular, it was arguably the most liberating invention of all time. ■

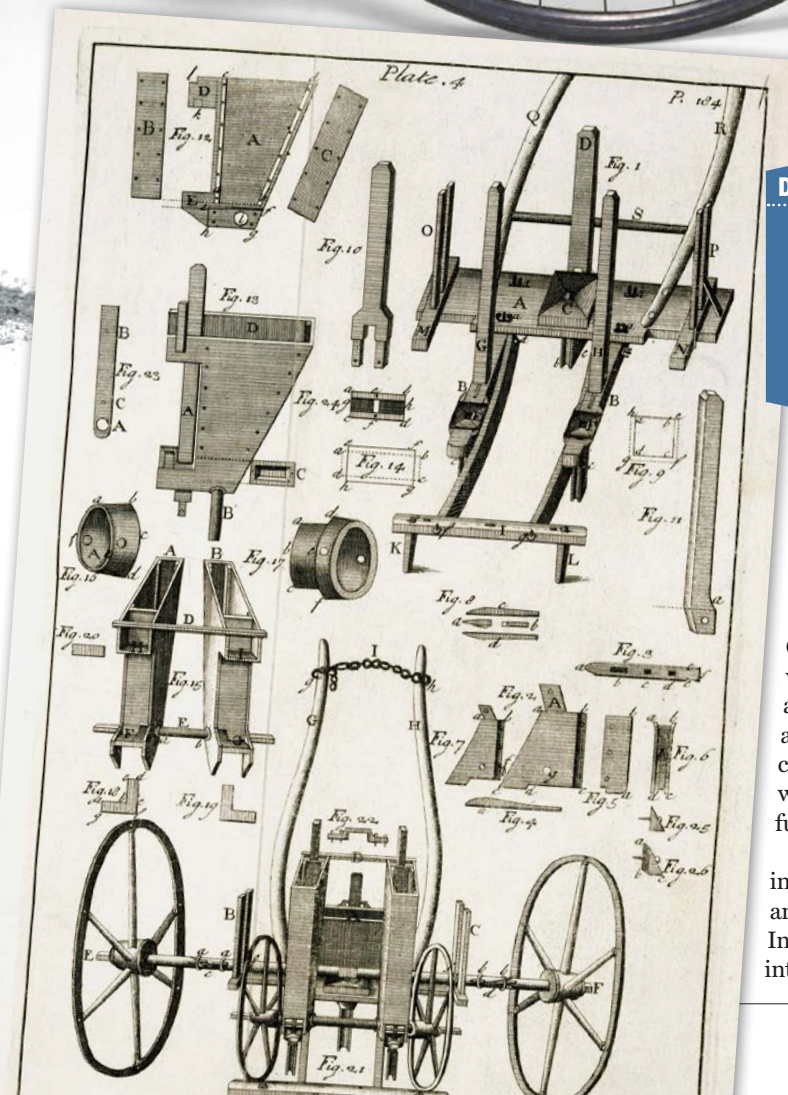


34 Cement

INVENTED 1824 INVENTOR JOSEPH ASPDIN

In 1824, Leeds bricklayer Joseph Aspdin invented and patented a method of making what he called Portland Cement – the type that's most widely used today. The process involved burning limestone, mixing it with clay and burning it again; the burning produced a much stronger cement than just mixing limestone and clay. Aspdin called it "Portland" as he claimed the set mortar resembled the best limestone quarried from Portland in Dorset.

However, to make it he needed a ready supply of limestone, and to acquire it he even took to levering up entire paving blocks at night – which twice landed him in court. His son, William, moved the business to north-east Kent, where there were limitless supplies of limestone. William also tweaked the formula, using more limestone and a higher burning temperature to produce cement that set more slowly, but developed strength more quickly, meaning it could be used in concrete. ■



DID YOU KNOW?

JETHRO TULL INTRODUCED OTHER FARMING INNOVATIONS, INCLUDING THE INVENTION OF A HORSEDRAWN HOE AND A MUCH-IMPROVED PLOUGH.

35 Tension-spoked wheel

INVENTED 1808 INVENTOR GEORGE CAYLEY

As well as inventing the glider – see page 14 – George Cayley also reinvented the modern wheel. He wanted wheeled landing gear for his gliders, but wheels with solid or wooden spokes were just too heavy. His innovation was to shift the balance of forces in the wheel from compression to tension. No more would the wooden spokes hold the rim up: now the rim itself would bear all the weight, and its shape would stay true thanks to spokes made of tight cord, which pulled from the sides when weight was placed on the top.

It was an extraordinary breakthrough, which was first described by Cayley in 1808, although it really took off much later when tension-spoked wheels using wire spokes were adopted for bicycle wheels. The elegant design has been used ever since. ■



36 Seed drill

INVENTED 1701 INVENTOR JETHRO TULL

Oxfordshire farmer Jethro Tull's seed drill, which he perfected in 1701, was a landmark in a new scientific approach to agriculture. Pulled by a horse, the drill dug a straight groove into the soil at the right depth and dropped into it seeds that were regularly spaced. It made planting crops far more efficient: previously, seeds had been scattered by hand, which meant that lots were wasted when they didn't fall into the furrow, and that they were planted too sparsely or too close together.

Tull's invention had three drills side by side and is estimated to have increased productivity eightfold. It was a milestone in what became an agricultural revolution in Britain that, hand in hand with the Industrial Revolution, helped both population and life expectancy into a steady upward climb for the first time in history. ■

33 Wind-up radio

INVENTED 1991
INVENTOR TREVOR BAYLIS

In 1991, Trevor Baylis saw a television programme about Aids in Africa that said one way to stop its spread was for people to hear educational information on the radio. So Baylis designed one that needed no batteries, running off an internal generator powered by a mainspring wound by a hand crank. It really took off when he displayed it on *Tomorrow's World* in 1994. In 1996, his Freeplay radio was awarded the BBC Design Award, and Baylis was able to demonstrate it to Nelson Mandela. Since then, the radio has been distributed all over Africa. ■



37 Spinning frame

INVENTED 1768 INVENTOR RICHARD ARKWRIGHT

Richard Arkwright's spinning frame – more than James Hargreaves's better-known spinning jenny – was the cornerstone invention of the industrial revolution in textiles that transformed northern England and lay behind Britain being named the “workshop of the world”. The spinning jenny made the spinning of yarn more efficient, but the spinning frame spun thread that had a tighter weave and was considerably stronger.

Unlike the jenny, the frame was too big to be operated by hand, so Arkwright had to build what's often said to be the world's first factory in Cromford, Derbyshire, to house the machines. Now the workers had to come to his premises where, under one roof, a water mill and, later, steam engines, powered the machines.

It was the cotton threads produced by the spinning frames that were turned into the cheap “calicoes” that were exported in huge quantities all over the world. ■



39 Electric motor

INVENTED 1821 INVENTOR MICHAEL FARADAY

Michael Faraday was employed by the Royal Institution, where he investigated the connections between electricity, magnetism and motion. In 1821, he demonstrated electromagnetic rotation for the first time. A free-hanging wire was dipped into a pool of mercury that had a fixed magnet in it. When an electric current was passed through the wire, it rotated around the magnet – the electricity produced a magnetic field around the wire, which interacted with the magnet in the mercury. This was the world's first electric motor.

Ten years later, Faraday made an incredible intellectual leap: if electricity and magnetism could create motion, could the reverse be true – could motion and magnetism create electricity? Faraday proved it could with the world's first electric generator, a copper disk that rotated between the poles of a magnet and generated a current in a wire attached to it by a spring. ■



LEARN MORE

VISIT THE ROYAL INSTITUTION'S MICHAEL FARADAY MUSEUM IN LONDON TO SEE FARADAY'S MAGNETIC LABORATORY AS IT WAS IN THE 1850s.

38 Bessemer process

INVENTED 1856 INVENTOR HENRY BESSEMER

Sheffield steelmaker Henry Bessemer didn't invent steel production. But his method for simplifying it and greatly reducing the cost makes the Bessemer process rank as one of the most important breakthroughs of the industrial era.

Steel is a combination of iron and a small amount of carbon. But the process of adding carbon to iron was extremely time-consuming and used up a huge amount of fuel. Steelmakers wanted to use “pig iron”, a cheap and plentiful product that had too much carbon in it, but they couldn't work out how to get the carbon out. Bessemer managed to do that by pumping high-pressure air through the molten pig iron. It was assumed the air would cool the iron, but the oxygen in the air actually burnt off carbon in the iron and, in doing so, it raised the temperature. This accelerated the process and the result was hotter, purer iron that could be converted to steel much more easily. ■



DID YOU KNOW?

JOSEPH BRAMAH'S OTHER INVENTIONS INCLUDE FOUNTAIN PENS, PAPER-MAKING MACHINES, HAND PUMPS FOR BEER AND THE FLUSHING TOILET.

40 Hydraulic press

INVENTED 1795 INVENTOR JOSEPH BRAMAH

Locksmith Joseph Bramah made famously unpickable locks and was also a keen inventor. Of all his developments, the one that has had the most impact was the hydraulic press, which he patented in 1795.

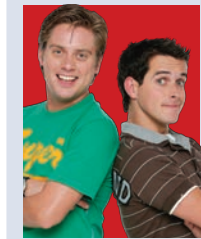
In a hydraulic press, two piston cylinders, with different cross-sectional areas, are connected with a tube and filled with fluid – oil, for example – so that moving one piston will cause the other one to move, too. According to Pascal's principle (originated

by French mathematician Blaise Pascal), the pressure inside a closed system is constant, so a small force applied to move the small piston a large distance translates to a large force pushing the large piston a small distance. Bramah used the press to make parts for his locks: by pushing the small piston, he could slowly flatten metal with the large piston. The hydraulic press is today one of the most useful and widespread machine tools. ■

DICK AND DOM

41 Sewage system

INVENTED 1865 INVENTOR JOSEPH BAZALGETTE



There are certain inventions and creations that people are aware of every day. There are very few creations that we use our whole lives without ever thinking about or even seeing. But that

is exactly what the London sewers are.

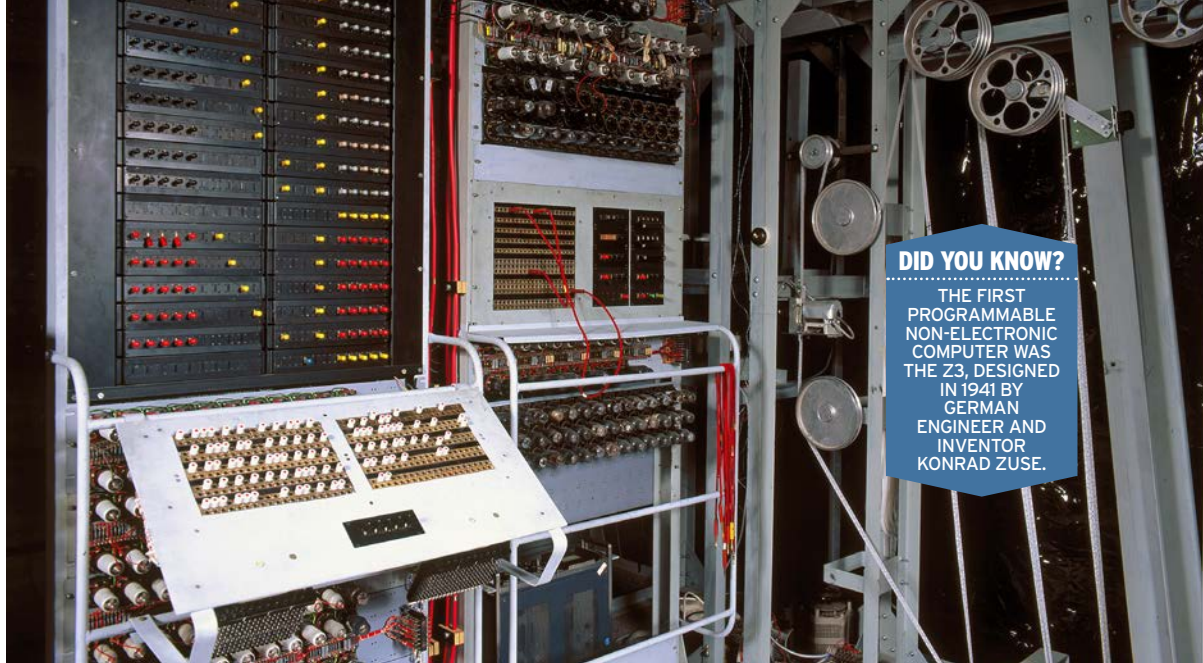
Their creator, Joseph Bazalgette, may be remembered as more of an engineer than an inventor, but what he developed in London – the largest and most forward-thinking sewage system the world had ever seen – changed life in the city completely.

There was a sewage system in place beforehand, but all it did was transfer waste straight into the Thames. It was basically one massive open sewer pipe. By all accounts it created a truly awful smell, reaching its peak during the Great Stink of 1858. Even more worryingly, it caused serious health problems, such as cholera, because it contaminated the city's drinking supply. Something had to be done, and Bazalgette was the man to do it.

His solution was phenomenal: a new waste system that would divert the sewage eastwards away from the river and pump it out to sea. By 1865 most of the system was working, the main intercepting sewers used 318 million bricks and measured over 80 miles in length. To do all that work above ground would have been one thing, but to create it underground was something else altogether. We got the opportunity to go down there, and even though we saw and smelt things we couldn't describe in a family magazine, the intricate maze of sewer pipes more than 100 years old was just unbelievable. And the most amazing thing is that it still functions today.

The reason is that when Bazalgette designed the tunnels, he estimated how much the population of London would increase in the next 100 years and worked out how large the tunnels would need to be to meet the needs of the future and keep the system flowing. Which is why the sewers are still in working order today, and why in our eyes it should be seen as a huge inventing achievement. ■

Watch *Absolute Genius with Dick and Dom* on CBBC later this month



DID YOU KNOW?

THE FIRST PROGRAMMABLE NON-ELECTRONIC COMPUTER WAS THE Z3, DESIGNED IN 1941 BY GERMAN ENGINEER AND INVENTOR KONRAD ZUSE.

42 Electronic programmable computer

INVENTED 1943 INVENTOR **TOMMY FLOWERS**

Alan Turing and his Bletchley Park computers became famous for cracking the supposedly unbreakable Enigma cipher in 1941. But Turing's Bombe machines were electromechanical, and in 1943 they were surpassed by the arrival of the Colossus at Bletchley.

Built and designed by brilliant Post Office engineer Tommy Flowers, the machine was conceived to crack the German Lorenz cipher, which was even more complex than Enigma. Constructed using 1,500 vacuum tubes,

the Colossus was the first truly electronic, digital and programmable computer. Initially, however, bosses at the Post Office didn't believe it could be done, and Flowers had to build it in his spare time using his own money.

Ten Colossi were built, all extraordinarily successful. Sadly for Flowers, the technology that could easily have formed the basis for a computer industry was reserved for military intelligence and remained top secret. Every Colossus machine was dismantled after the war. ■

43 Stainless steel

INVENTED 1913 INVENTOR **HARRY BREARLEY**

Harry Brearley, the son of a Sheffield steel smelter, left school at 12 to go to work in one of the city's steelworks. He was an ambitious chap and started to study metallurgy at home and in evening classes. He gradually built a reputation for expertise, and still in his 30s was chosen to run a new research facility funded by two of Sheffield's largest steel companies. In 1912, he was tasked by a small-arms manufacturer to find a material that could prolong the life of their gun barrels. He set out to find erosion-resistant steel, but found corrosion-resistant steel instead.

The story goes that in 1913 he threw out some experimental steel made of 12.8 per cent chromium and 0.24 per cent carbon. A few weeks later, he found it in the yard still shiny as new. This apparently serendipitous discovery led to the transformation of the already established cutlery industry in Sheffield. Stainless steel is now used in everything from surgical instruments and turbine blades to architectural cladding. ■

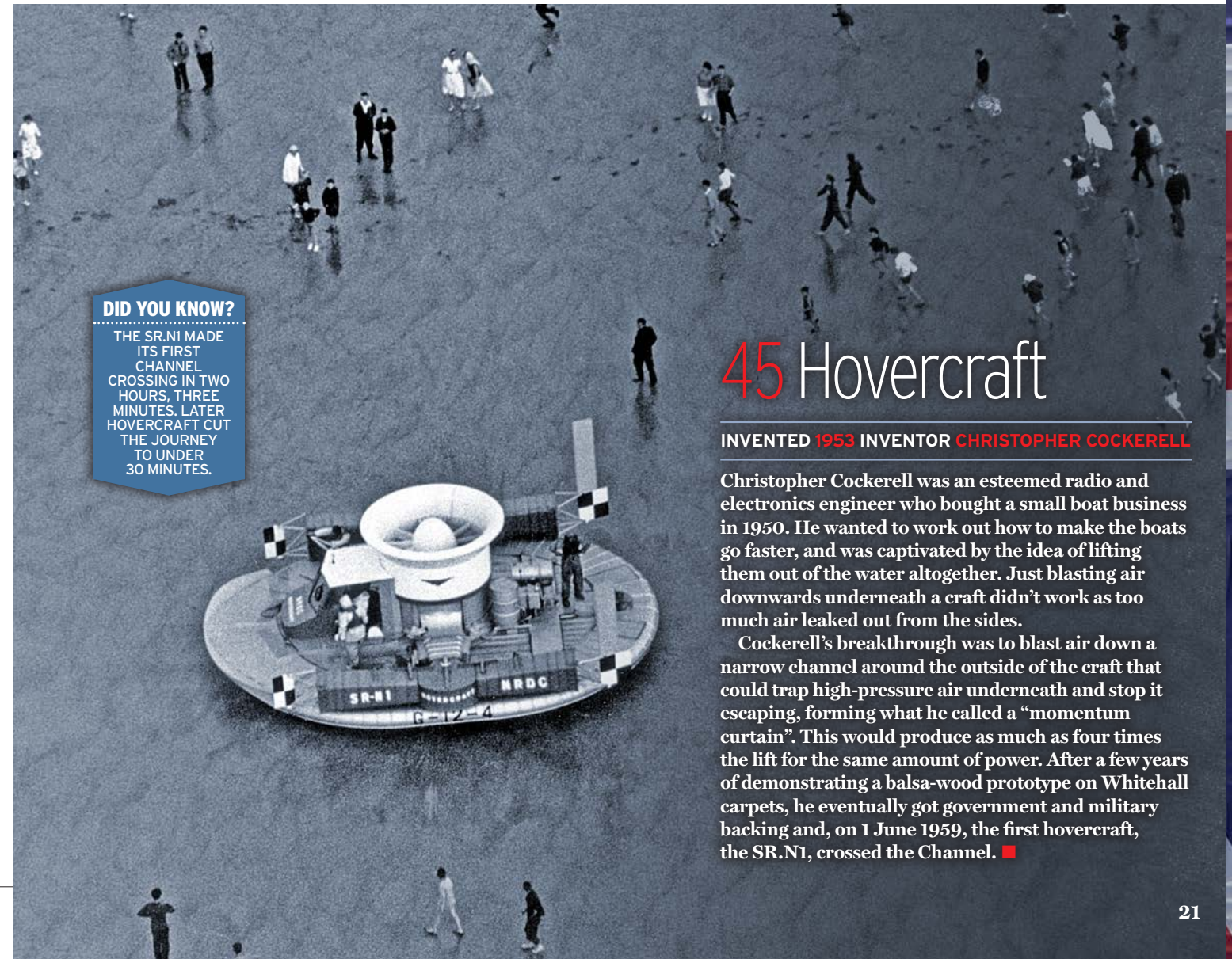


44 Photography

INVENTED 1835
INVENTOR **WILLIAM HENRY FOX TALBOT**

Who was the inventor of photography? It's hard to say. The first fixed image was made by a Frenchman, Joseph Niépce, in 1826, using a coating of light-sensitive bitumen on a pewter plate, which took about eight hours to expose an image. His collaborator, Louis Daguerre, continued working with silver iodide, and discovered that if it was exposed to light for just a few minutes, the image could be "developed" later with mercury vapour.

In 1835, British inventor William Henry Fox Talbot made another breakthrough. He used silver iodide on paper, and found a way to produce a translucent negative that – unlike Daguerre's images – could be used to make any number of positives by contact printing. Fox Talbot patented his system and forced any photographer who used his system – which was most of them – to pay him a royalty. But his positive/negative system has been the basis of all photography since – at least until the advent of digital cameras. ■



DID YOU KNOW?

THE SR.N1 MADE ITS FIRST CHANNEL CROSSING IN TWO HOURS, THREE MINUTES. LATER HOVERCRAFT CUT THE JOURNEY TO UNDER 30 MINUTES.

45 Hovercraft

INVENTED 1953 INVENTOR **CHRISTOPHER COCKERELL**

Christopher Cockerell was an esteemed radio and electronics engineer who bought a small boat business in 1950. He wanted to work out how to make the boats go faster, and was captivated by the idea of lifting them out of the water altogether. Just blasting air downwards underneath a craft didn't work as too much air leaked out from the sides.

Cockerell's breakthrough was to blast air down a narrow channel around the outside of the craft that could trap high-pressure air underneath and stop it escaping, forming what he called a "momentum curtain". This would produce as much as four times the lift for the same amount of power. After a few years of demonstrating a balsa-wood prototype on Whitehall carpets, he eventually got government and military backing and, on 1 June 1959, the first hovercraft, the SR.N1, crossed the Channel. ■

46 ATM

INVENTED 1967
INVENTOR JOHN SHEPHERD-BARRON

John Shepherd-Barron was lying in the bath one night in 1965. Earlier he had failed to get to a bank and was wondering how to get money outside bank hours. He hit on the idea of a cash dispenser and, as he worked for banknote manufacturer De La Rue, he secured a meeting with Barclays. It signed up, and the first ATM was installed outside its branch in Enfield, north London, in 1967. The first cash was taken out by TV star Reg Varney (below).

As plastic bank cards hadn't been invented, customers inserted special cheques that the machine could recognise. It gave out a maximum of £10 – at the time, enough for a wild weekend.

Users also had to enter a PIN number – Shepherd-Barron claimed that it was thanks to his wife, who said she could only remember a maximum of four digits, that we all use four-digit PINs today. ■



DID YOU KNOW?

AMONG BOOTH'S OTHER CLIENTS WERE WILHELM II OF GERMANY, NICHOLAS II OF RUSSIA AND THE HOUSE OF COMMONS. HE ALSO DESIGNED FERRIS WHEELS.

47 Tin can

INVENTED 1810 INVENTOR PETER DURAND

Frenchman Nicolas Appert – working for Napoleon's army – figured out in 1810 how to preserve food by packing it into sealed containers and then cooking it for hours to sterilise it. But Appert used glass jars; it was British merchant Peter Durand who, in the same year, adapted Appert's method to a new container – the tin can.

Once the first cannery was set up in Bermondsey, a couple of years later, the British Army found itself as well equipped – better, in fact – than the French. There were a few problems at the start: many early cans were sealed with lead solder, which could be dangerous. In Sir John Franklin's Arctic expedition in the 1840s, some of the crew suffered from severe lead poisoning after three years of eating canned food.

Initially, a hammer and chisel were required to open the cans: the tin opener wasn't patented until 1855. ■



49 Waterproof material

INVENTED 1823
INVENTOR CHARLES MACINTOSH

Charles Macintosh, an amateur chemist, was experimenting with coal-tar naphtha, a chemical waste product, and realised that it was a powerful solvent that could make a solution from rubber. He coated a thin fabric with this solution but, because it was so sticky, he sandwiched it between two layers of the fabric to make a practical waterproof material.

His family company started selling the coats as the "Mackintosh". But they had a tendency to melt in hot weather. Another British inventor, Thomas Hancock, later improved the product and was made a partner in the firm. ■

48 Electric vacuum cleaner

INVENTED 1901
INVENTOR HUBERT CECIL BOOTH

In 1901, a young engineer called Hubert Cecil Booth was watching a railway carriage being cleaned at St Pancras Station by a machine that simply blew dust off the fittings. Booth thought it would be better to suck the dust up. To test his theory, he placed a handkerchief on a restaurant chair, sucked through it and found an impressive amount of dust collected on the other side.

Booth's first vacuum cleaner, which came to be known as the "Puffing Billy", used a piston engine driven by an electric motor to suck air through a filter that was mounted on a horse-drawn cart. He set up a company that sold cleaning services. His operators would haul long hoses from his bright red vans through the windows of buildings. It was a huge success; he was even hired to clean Westminster Abbey for Edward VII's coronation. But when it came to small, household vacuum cleaners, the Hoover Company became the market leader. ■



DEBORAH MEADEN

50 Steri-spray

INVENTED C. 2008 INVENTOR IAN HELMORE



The British are very good at working out how to overcome obstacles. I do think it's within our DNA. As long as we've got people coming up with ideas and trying to get them off the ground, we'll survive as a nation.

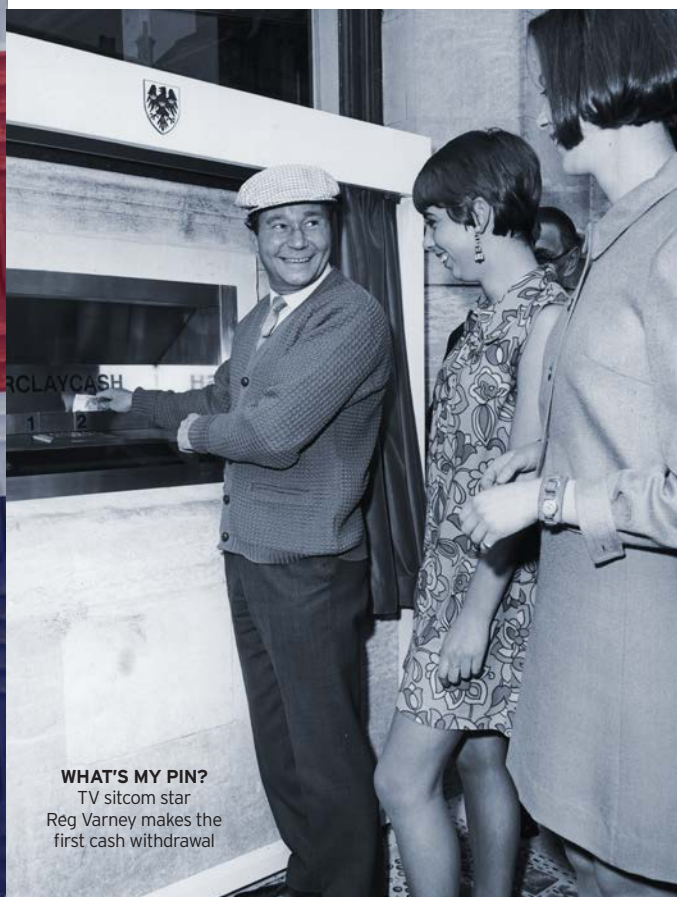
For any idea to be picked up, there has to be a market, but as an investor on *Dragons' Den* I'm not just looking for ideas; I'm looking for business propositions. I don't need a 100-page business plan; I just need to know what the problem is, how many people it affects, and how the invention solves the problem. It can be as simple as that.

My favourite invention underlines just that point. Plumber Ian Helmore sterilised water tanks to prevent legionella breeding in them, and believed there had to be a wider application of the technology. Because the bacteria can live in the last two inches of pipework, he decided that putting a UV lamp into a tap or showerhead would deal with the problem. And it works, at a very high level. It has taken us three years to get it from prototype to actual physical product, but now it is out there in NHS hospitals, hopefully saving lives.

When we're asked to invest in inventions, there has to be a big enough market and they have to be capable of being produced at a price people are prepared to pay. We all have a value system. We might not know how much we will pay for something, but we definitely know how much we won't pay.

Personally, the invention that's changed my life is the inflatable riding jacket. As I get older I'm much more aware of the dangers of riding, and now there's a jacket that's like an airbag. You attach yourself to the saddle and, if you become unattached at great force, the jacket inflates so that when you hit the ground, you've got your neck and back protected. It's made me more confident and has enhanced the value of my leisure riding. ■

Dragons' Den will return in late summer. If you're seeking investment for a business idea or invention, visit bbc.co.uk/dragonsden/apply or email dragonsden@bbc.co.uk



WHAT'S MY PIN?
TV sitcom star
Reg Varney makes the
first cash withdrawal



Places to visit

Explore your passion for invention
– from coal mines to code-breakers



3 The Big Pit

WALES

- 1 Techniqest, Cardiff** Hands-on science centre, with over 100 activities from launching a rocket to driving electric cars.
- 2 The National Waterfront Museum, Swansea** tells the story of industry and innovation in Wales over the last 300 years.
- 3 The Big Pit, National Coal Museum Blaenavon, Tofaen** Take an underground tour of the mine, led by a former miner and find out all about the history of coal-mining, once the area's mainstay.

SCOTLAND

- 4 National Museum Scotland, Edinburgh** The Science and Technology gallery looks at scientific advances and innovation in Scotland and beyond.
- 5 Glasgow Science Centre** Interactive centre where children are encouraged to get involved with the magic of science.
- 6 Museum of Transport, Glasgow** See the world's oldest bicycle, and find out why Glasgow was once known as the workshop of the British Empire.
- 7 Satrosphere Science Centre, Aberdeen** Get hands on with over 50 scientific activities.
- 8 Museum of Communication, Burntisland, Fife** Explore the history of radio, radar, television and IT.
- 9 Museum of Lead Mining, Wanlockhead, Dumfries & Galloway** Take a guided tour of the 18th-century Lochnell Mine.

NORTHERN IRELAND

- 10 Titanic Dock and Pump House, Belfast** Set in the heart of the Harland and Wolff shipyard, where *Titanic* was built.
- 11 W5 Science and Discovery Centre, Belfast** Get to grips with more than 250 interactive exhibits.
- 12 Ulster Folk and Transport Museum, Hollywood, Co Down** Explore a collection that features horse-drawn carriages to cars.

ENGLAND: NORTH

- 13 Bradford National Media Museum** A feast of film, TV and radio history, as well as the UK's first IMAX cinema.
- 14 Manchester Museum of Science and Industry** The Power Hall houses a vast collection of working steam mill engines as well as gas, oil, hot-air and diesel engines.
- 15 Discovery Museum, Newcastle** Find out more about Tyneside inventions that had an impact on the world we live in.
- 16 Cragside, Morpeth, Northumbria** The first house to be lit by hydro-electricity is crammed full of ingenious Victorian gadgets, most of which are still working.
- 17 National Railway Museum, York** Quite simply, the largest railway museum in the world.
- 18 Stephenson Railway Museum, North Shields** See locomotives including George Stephenson's *Billy*, a forerunner of the world-famous *Rocket*.
- 19 Quarry Bank Mill and Styal Estate, Wilmslow** features a cotton mill that's powered by Europe's most powerful working waterwheel.
- 20 National Waterways Museum, Ellesmere Port** brings together a unique fleet of historic boats telling the story of Britain's canals and waterways.
- 21 National Coal Mining Museum, Wakefield** The 200-year history of mining is brought to life.
- 22 World of Glass, St Helens** including tours of the tunnels under the Cone House, the 19th-century glass-making furnace.

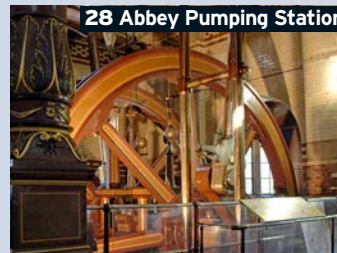


17 The National Railway Museum

- 23 Millennium Gallery, Sheffield** The Designed to Shine exhibition forms part of a celebration of the centenary of Harry Brearley's discovery of stainless steel.
- 24 Magna Science and Adventure, Rotherham** The four elements – earth, air, fire and water – explored through a range of activities.

MIDLANDS

- 25 Thinktank, Birmingham Science Museum** The city's industrial heritage is on display in the Millennium Point exhibition.
- 26 Coventry Transport Museum** How the city became the birthplace of the British cycle and motor industry.
- 27 Midland Air Museum, Baginnton, near Coventry** The story of the jet age told at the Sir Frank Whittle Heritage Centre.
- 28 Abbey Pumping Station Museum, Leicester** The 200-year history of science and technology, from the early days of steam and industry.



28 Abbey Pumping Station

- 29 Ironbridge Gorge Museums, Shropshire** Ten award-winning museums along the Severn Gorge explain the area's importance in the Industrial Revolution.
- 30 Black Country Living Museum, Dudley** Visit one of the country's largest open-air museums that celebrates the innovations of the Black Country.
- 31 Heritage Motor Museum, Gaydon, Warwickshire** Home of the world's biggest collection of historic British cars.

EAST

- 32 Woolthorpe Manor, near Grantham** Visit the birthplace of Britain's greatest scientist, Sir Isaac Newton.

- 33 Science Alive, Harlow** A fun, interactive centre that brings science to life, combined with the Living History section where you can find out more about our world.

SOUTH

- 34 Bletchley Park, Milton Keynes** Historic site of secret British code-breaking activities during the Second World War, and birthplace of the modern computer.
- 35 Eastney Beam Engine House, Southsea** View a pair of magnificent James Watt beam engines, housed in their original high Victorian engine house of 1887.
- 36 The Farnborough Air Sciences Trust Museum, Hampshire** Exhibits from the early years of aviation, including research models of Concorde.
- 37 Beaulieu, National Motor Museum, Brockenhurst** The history of the motor car, plus home to the world's largest collection of original James Bond vehicles.
- 38 Bovington Tank Museum, Wareham** One of the largest and most comprehensive collections of armoured fighting vehicles.

WEST

- 39 Crofton Pumping Station, Marlborough** houses the oldest working beam engine in the world, open from March 2013.
- 40 The Steam Museum – Museum of the Great Western Railway, Swindon** tells the story of the men and women who built and operated the Great Western Railway.
- 41 Lacock Abbey, Fox Talbot Museum, Lacock, near Chippenham** The museum celebrates William Henry Fox Talbot and his contribution to the invention of photography.
- 42 At Bristol** is one of the UK's biggest interactive science centres.
- 43 SS Great Britain, Bristol** Built by Isambard Kingdom Brunel, it was the first propelled steam ship to cross the Atlantic.
- 44 Porthcurno Telegraph Museum Porthcurno valley** in the far west of Cornwall was the hub of international cable communications from 1870–1970.
- 45 Levant Mine and Beam Engine, Cornwall** Enter this copper and tin mine and see the beam engine that's been restored after 60 years lying idle.

LONDON

- 46 Design Museum** From 30 January there is an exhibition featuring key designs that have changed the world.
- 47 Michael Faraday Museum – Royal Institution** Explore the world-changing science that's happened at the Royal Institution since 1799.
- 48 Science Museum** The Codebreaker exhibition celebrating the centenary of the birth of Alan Turing, is open until June 2013.
- 49 Brunel Museum, Rotherhithe** tells the story of the Thames Tunnel, the first in the world to be built under water.
- 50 Royal Observatory, Greenwich** is the home of Greenwich Mean Time and also to London's only planetarium.

Check venue websites for full details. For more ideas on places to observe British inventiveness go to bbc.co.uk/thingstodo