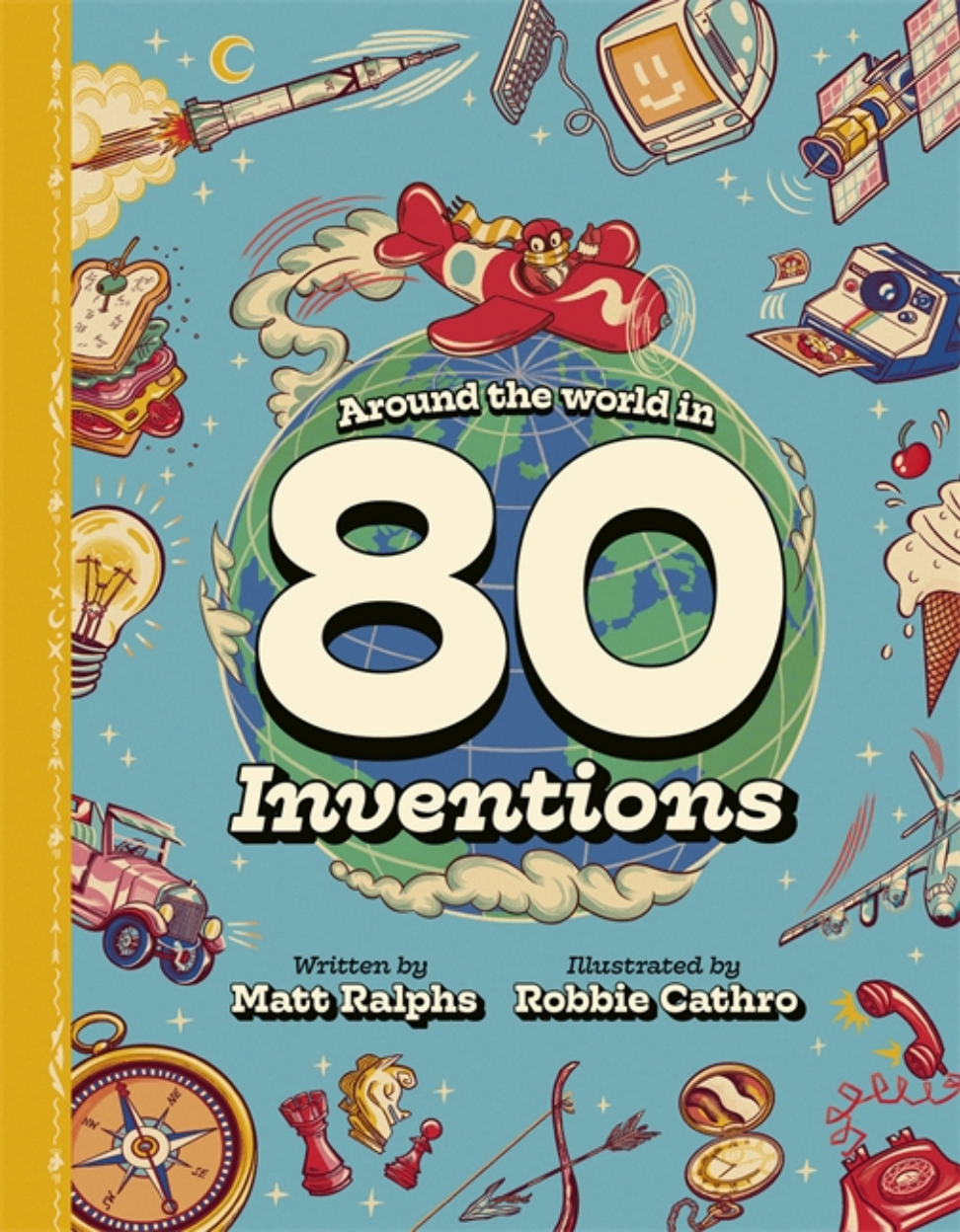
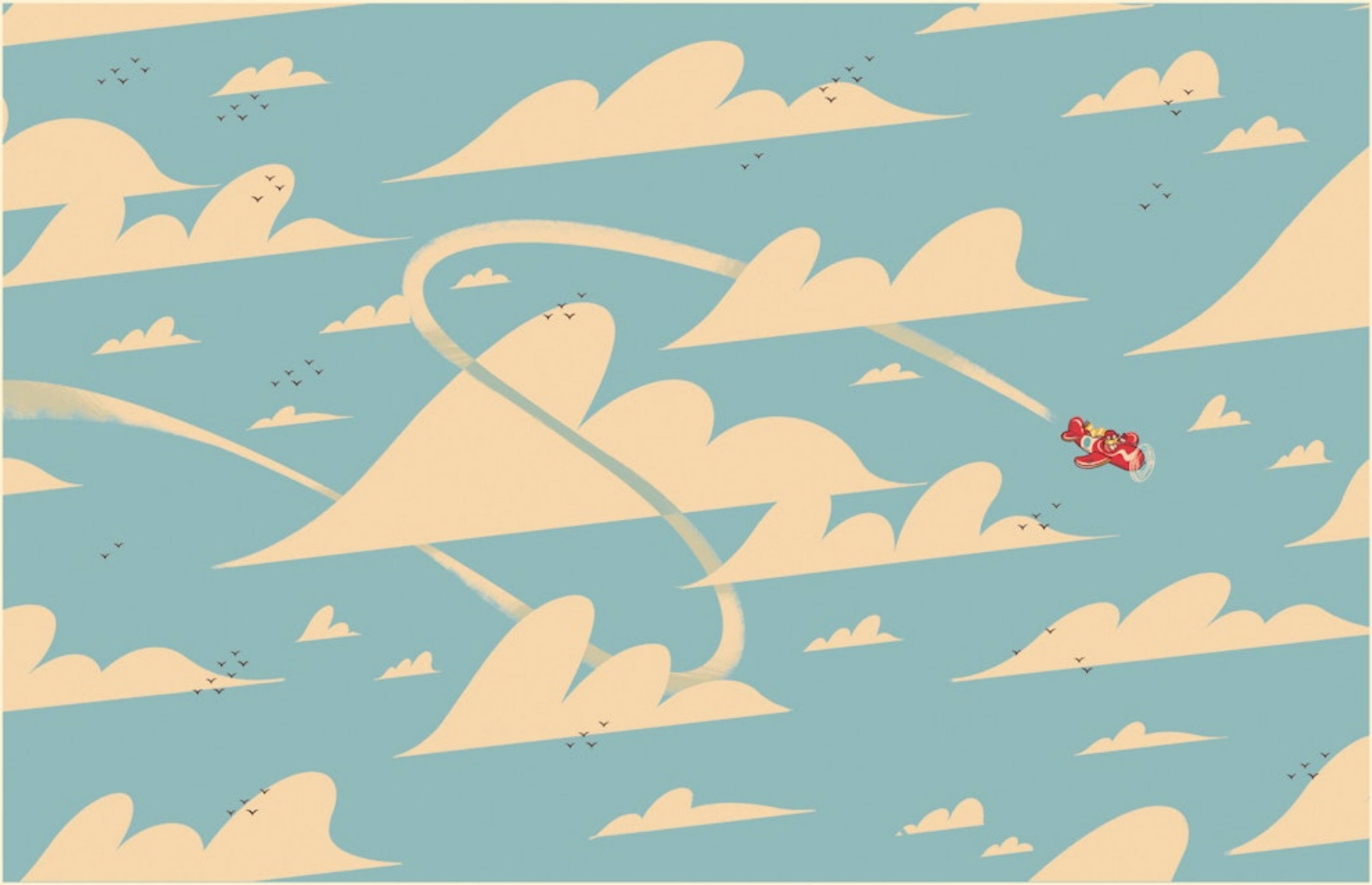

Around the world in
80
Inventions
Written by
Matt Ralphs
Illustrated by
Robbie Cathro



For Dad,
a collector of objects.
-R.C.

For Breege, an
extraordinary friend
-M.R.

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Consultant: Anne Rooney
Edited by Carly Blake and Tayabah Khan
Designed by Ted Jennings
Production by Nick Read

Printed in China

Written by
Matt Ralphs

Illustrated by
Robbie Cathro

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Contents

Stone Age Tools

"Ingenious early implements"

01

The Stone Age is a period of **prehistory** when early humans used stone tools. It lasted about 2.5 million years and ended roughly 5,000 years ago when humans first began using metal tools. The Stone Age is split into three periods: the Palaeolithic period (Old Stone Age), when people used early stone tools; the Mesolithic period (Middle Stone Age), when tool technology improved, and the Neolithic period (New Stone Age), when farming began.

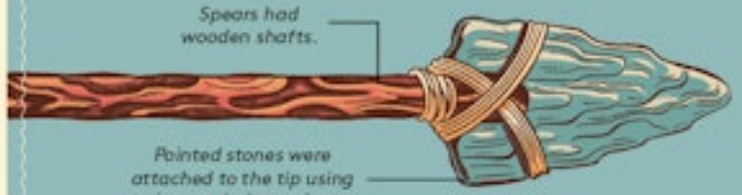
Deadly Tool

As far back as 500,000 years ago, Stone Age humans were using spears to hunt bison and gazelles for their meat, bones and hides, and to defend themselves against fearsome, now-extinct animals such as sabre-toothed cats and cave bears.

Palaeolithic Tools

The Palaeolithic period lasted from 2.58 million to 11,700 years ago. A wide variety of tools were developed during this time. Some of the earliest, found in Kenya, include sharpened hand-sized rocks, which were used to cut flesh from animals and break bones to extract the marrow inside. From around 1.76 million years ago, humans began making stone hand axes for chopping, digging and possibly defence, and flint scrapers for skinning animals. Towards the end of the Palaeolithic, humans were making smaller and more specialised tools from flakes of flint.

Stone Age humans hunted woolly mammoths.



Cave Painter's Toolkit

From at least 45,000 years ago, Stone Age humans expressed themselves by carving sculptures of animals from bone, stone and ivory. They also mixed paint using **minerals**, charcoal, blood and berries, then applied it to cave walls using their hands, brushes made from animal hair, or by spraying it through hollow bones. These colourful and often beautiful works of art show us how they lived, survived and saw their world.

Mesolithic Tools

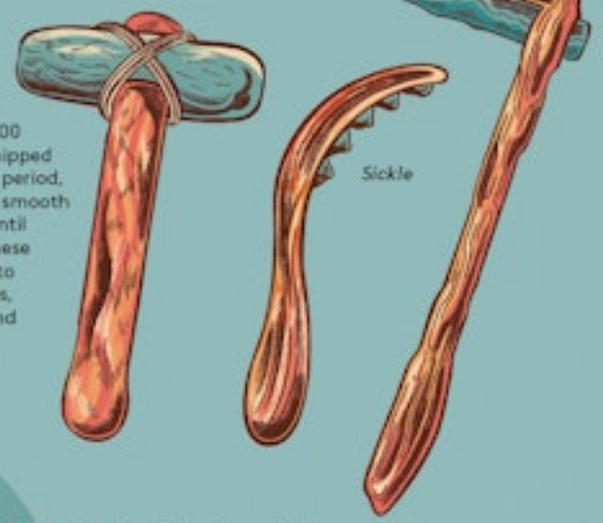
By the Mesolithic period (10,000–8,000 BCE), humans were using ever-more specialised tools for various uses. They butchered animals and chopped wood using small axes with wooden handles and sharp stone heads. They also used small, pointed tools called awls made from bone, to bore holes in animal hides to make clothes and shelters.

Microliths

Microliths are small pieces of sharpened flint. They were used to tip spears, javelins, harpoons and arrows, and have been uncovered all over Africa, Asia and Europe. Although made in a wide variety of shapes and sizes, microliths were small. Some are no longer than the width of a finger, proving just how skilled Stone Age toolmakers were.

Neolithic Tools

Tool-making techniques continued to be refined in the Neolithic period (10,000–3,000 BCE). Stone axe-heads and blades were chipped into shape just like during the Palaeolithic period, but Neolithic people used abrasive rock to smooth out the chip marks and polish the edges until they were razor-sharp. Toolmakers used these techniques to make weapons, heavy axes to cut down trees, hoes to clear land for crops, and woodworking tools to make canoes and simple buildings.



Tools to Farm

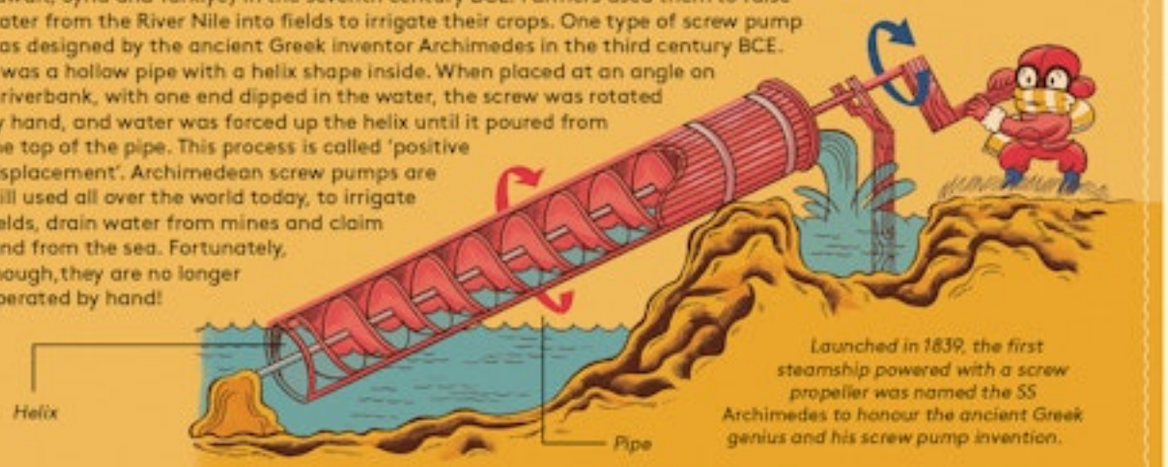
Stone Age tools completely changed human history. They gave humans a huge advantage by allowing us to kill much larger and more ferocious creatures in order to survive. These tools also enabled humans to begin farming – by felling trees to create fields and pastures, and preparing the ground to cultivate the land for crops – which provided a more stable and regular source of food than hunting and gathering only.

Screw Pump

"The ancient water raiser"

02

Water always flows downhill. But what if you want to force it uphill? That's where this ingenious invention comes in. The earliest screw pumps probably appeared in ancient Egypt and **Assyria** (parts of modern-day Iraq, Iran, Kuwait, Syria and Türkiye) in the seventh century BCE. Farmers used them to raise water from the River Nile into fields to irrigate their crops. One type of screw pump was designed by the ancient Greek inventor Archimedes in the third century BCE. It was a hollow pipe with a helix shape inside. When placed at an angle on a riverbank, with one end dipped in the water, the screw was rotated by hand, and water was forced up the helix until it poured from the top of the pipe. This process is called 'positive displacement'. Archimedean screw pumps are still used all over the world today, to irrigate fields, drain water from mines and claim land from the sea. Fortunately, though, they are no longer operated by hand!



Launched in 1839, the first steamship powered with a screw propeller was named the SS Archimedes to honour the ancient Greek genius and his screw pump invention.

Ballpoint Pen

"The notable note-maker"

03

Manufacturing company BIC has sold over 100 billion ballpoint pens since 1950.

The humble ballpoint pen revolutionised writing by making it easier, cheaper and **portable**. In 1888, American John Loud came up with the idea of a pen that used a tiny ball in the nib to roll ink onto the page. It wrote well on wood and leather, but not on paper, so it's no surprise it didn't take off! Hungarian inventor László Bíró realised the problem was that the ink took too long to dry. So he invented a thicker ink that dried in seconds and in 1944 production was underway in Argentina to manufacture his ballpoint pen. However, his metal design was expensive. It was French manufacturer Marcel Bich who created the cheap, mass-produced plastic BIC pen that we use now. They've hardly changed in 70 years and today one costs about 15 pence and produces two kilometres of writing!

Aquarium

"A window to watery worlds"

04

The first aquarium was invented in 1832 by a French marine biologist. Jeanne Villepreux-Power designed a watertight glass box that could keep marine plants and animals alive. Her invention allowed her to study marine life from the comfort of her own home. Villepreux-Power earned great respect from other marine biologists for the research she gathered from her aquarium. Her achievements are especially remarkable given the time in which she lived. In nineteenth-century Europe, society was not equal – women were considered less capable than men and were given fewer opportunities to use their talents to reach their potential. It took resourceful and inventive women like Villepreux-Power to disprove such sexist ideas.

The word 'aquarium' comes from Latin. 'Aqua' means water, 'arium' means 'a place for relating to'. So, an aquarium is a place to study water-based life.

The Creator of Aquariums

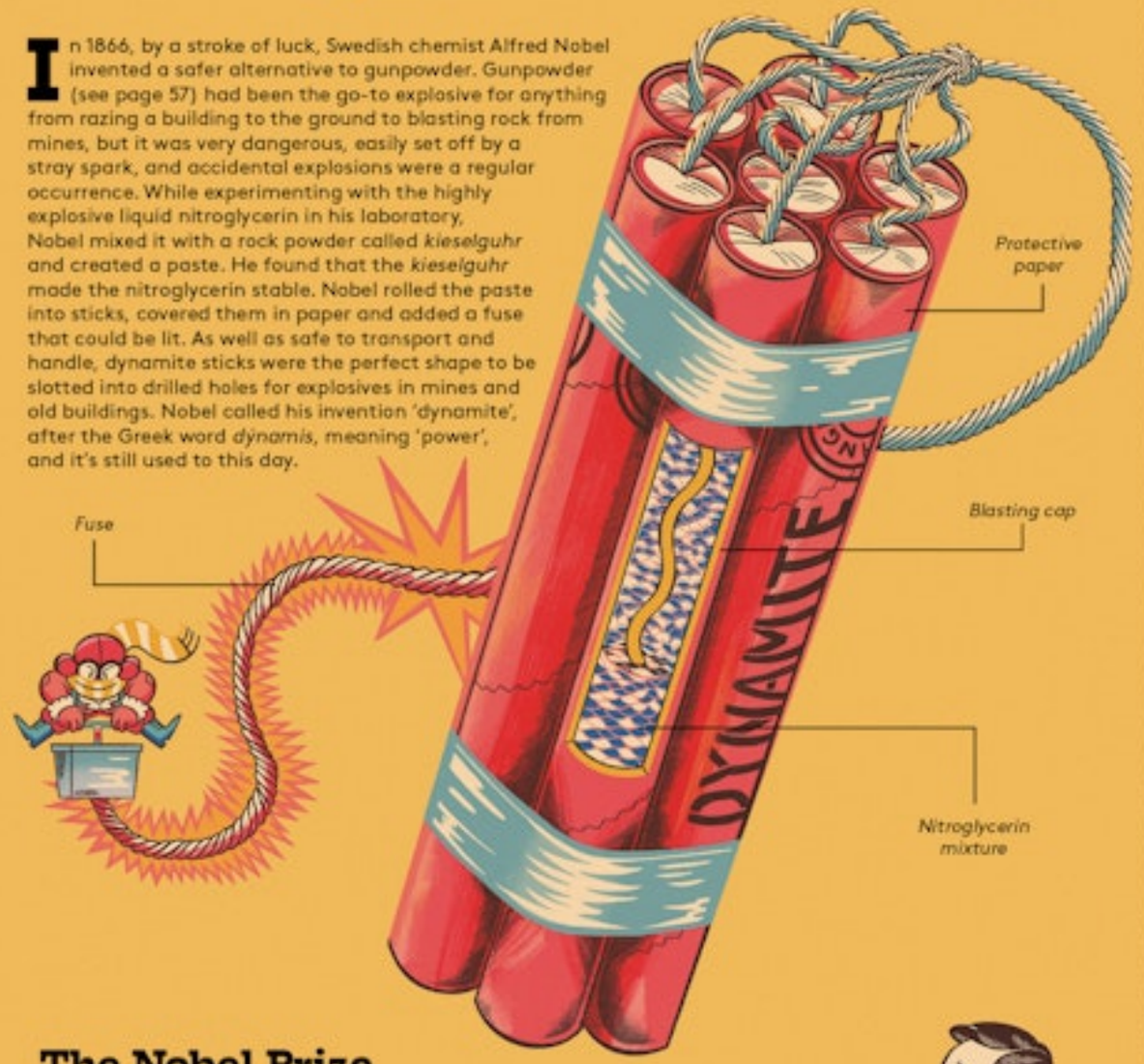
Villepreux-Power's aquarium inspired other inventors to create their own designs, including heated aquariums for tropical fish dependent on warm water. The first public aquarium was built in London Zoo in 1853, and it still welcomes visitors today. Modern public aquariums are big and technologically advanced enough to house large marine animals such as rays and sharks. Millions of people all over the world have aquariums in their homes, and research has shown that looking at fish is soothing and can reduce anxiety and stress.

Dynamite

05

"Explosive but safe"

In 1866, by a stroke of luck, Swedish chemist Alfred Nobel invented a safer alternative to gunpowder. Gunpowder (see page 57) had been the go-to explosive for anything from razing a building to the ground to blasting rock from mines, but it was very dangerous, easily set off by a stray spark, and accidental explosions were a regular occurrence. While experimenting with the highly explosive liquid nitroglycerin in his laboratory, Nobel mixed it with a rock powder called *kieselguhr* and created a paste. He found that the *kieselguhr* made the nitroglycerin stable. Nobel rolled the paste into sticks, covered them in paper and added a fuse that could be lit. As well as safe to transport and handle, dynamite sticks were the perfect shape to be slotted into drilled holes for explosives in mines and old buildings. Nobel called his invention 'dynamite', after the Greek word *dynamis*, meaning 'power', and it's still used to this day.



The Nobel Prize

In 1888, a French newspaper mistakenly thought Alfred Nobel had died. The article they published about him was called 'The Merchant of Death is Dead' and accused him of making 'a fortune by finding ways to kill more people faster than ever before'. Nobel was upset that this might be how he'd be remembered after his (actual) death, so he decided to put the money he'd made from dynamite to good use. In his will, he left his fortune to set up the Nobel Prize, which every year awards people who have made great achievements in physics, chemistry, medicine, literature and peace.

Chess

06

"Ancient entertainment"

A battle of strategy, kings, queens and castles, chess is a really old game. It is thought to have been adapted from a similar board game called *chaturanga*, that was popular in India 1,500 years ago. Just like chess, *chaturanga* used a board with 64 squares and had playing pieces – including infantry, cavalry, elephants and chariots – that could be moved in different ways. Pilgrims (people journeying to religious places) and traders spread the game far and wide. The ancient Persians called it *shatranj* (the phrase 'checkmate' comes from the Persian *shah mat*, which means 'the king is frozen'). The game of chess we recognise now was developed in Medieval Europe around 1300, and more than 170 countries enjoy the game today.

A Knight's Game

Chess was a popular pastime of knights and nobles in Medieval Europe, for fun and for gambling. It was even said to be among the seven skills that a good knight must acquire. The pieces they used were often beautifully carved and decorated.

Bow and Arrow

07

"A deadly long-distance weapon"

Imagine you're a Stone Age human fighting a sabre-toothed cat with a sharpened stick: death is only one mistake away. Now think of the difference a bow and arrow would make. You could fight from a distance and maybe kill it before it even sees you. Arrowheads dating from between 71,000–60,000 years ago were found in South Africa and are the earliest evidence of archery we have. However, it's possible prehistoric humans were using arrows with flint head arrows even earlier. Bronze Age (3,300–600 BCE) armies in Mesopotamia (modern-day Iraq), Africa, Persia (modern-day Iran), Japan, China and India had field archers that used flint or bronze arrowheads when fighting on foot or on chariots. Evidence suggests some indigenous people in South America were using bows and arrows around 1300 BCE, and in North America by around 600 CE.

The bow used by Mongol warriors in the thirteenth century could shoot arrows double the distance of those used by competing armies.

Prehistoric Battle

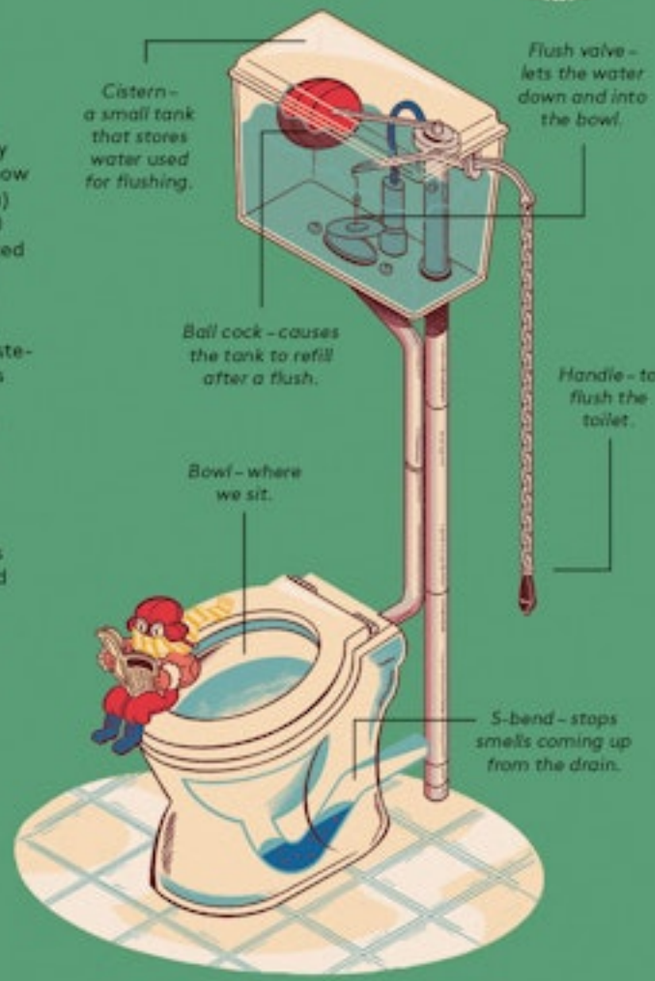
An incredible piece of prehistoric cave art in Morella la Vella in Spain appears to show a battle between two groups of people. Possibly painted around 7,000 years ago, the image includes seven archers drawing their bows and preparing to shoot at each other. It might depict an ambush, with one group surrounding another and attacking them. This image, and others like it, prove that as far back as prehistoric times, bows were used to kill people as well as animals.

Flushing Toilet

08

"The waste disposal wonder"

Toilets have been around since ancient times. At first, they were deep holes in the ground. But with the invention of pipes, it became possible to wash waste quickly away. The Indus Valley Civilisation (in what is now modern Afghanistan, Pakistan and North India) built the first-known flushing toilets over 3,000 years ago. In their houses, toilets were connected to underground sewers and water was poured down to wash the waste away. In many places around the world, different kinds of flushing toilet caught on. But despite these ancient waste-disposing wonders, few people before the 1850s had them in their home. Instead, they made do with chamber pots (which were sometimes emptied right onto the street!), wooden outhouses with a seat placed over a deep pit, or even just a good old hole in the ground. In the 1590s Englishman Sir John Harington invented the first modern flushing toilet. It was a bowl connected to a raised water tank, called a cistern, but it didn't become popular because most houses didn't have plumbing or running water. A few hundred years and numerous improvements later, including the S-bend, the flushing toilet really caught on.



The toilet has had many names over the years, including house of easement, jakes, latrine, privy, garderobe, lavatory, commode, john, head and water closet.

Ancient Roman Communal Commodes

The ancient Romans built public toilets all over their empire to stop their towns and cities from filling up with filth, but they were very different to modern loos. These large, dimly-lit rooms had no privacy at all! There were several long rows of seats, with holes placed over running water to wash waste into underground sewers. When the person finished, they used a wet sea sponge on a stick (called a *tersorium*, which means 'a wiping thing') to clean themselves. They rinsed the sponge in a trough of water which also had salt or vinegar in it, ready for the next person.

Aeroplane

"Up, up and away"

09

People have always dreamed of flying. Bamboo and cloth kites appeared around 2,500 years ago in China, and the art spread to Japan, India and Polynesia. Small hot air balloons were also invented by the ancient Chinese. The first balloon capable of lifting a person was invented by the French Montgolfier brothers in 1783, with the first engine-powered balloon, invented by Brazilian aviator Alberto Santos-Dumont, successfully taking flight in 1899. Unpowered winged 'gliders' appeared in the 1850s, and great advancements towards powered aeroplanes were made by German glider pilot Otto Lilienthal.

First Powered Aircraft

On 17 December 1903 in South Carolina, USA, American brothers Wilbur and Orville Wright took to the air in *Wright Flyer*, their 4hp (horsepower) petrol-powered propeller aeroplane. It was the first of its kind. Constructed from wood, muslin and bicycle-spoke wire, *Flyer* may not have flown very high or far, but it kickstarted the age of powered flight.

Monoplanes, Biplanes and Triplanes

Aircraft developed quickly after the *Flyer*, becoming faster, more reliable and more manoeuvrable. Governments realised how useful aeroplanes could be so began founding their own air forces. Although further developed during the **First World War** (1914–18), fighter, bomber and **reconnaissance** planes really came into their own during the **Second World War** (1939–45).

The Golden Age of Flight

Enthusiasm for flying skyrocketed in the 1920s and 1930s. Sleek metal replaced wood and canvas. Small passenger aircraft allowed people who could afford it the chance to travel the world without having to spend weeks on ships. Many speed and distance records were broken, including the first male transatlantic flight by Charles Lindbergh, in the monoplane *Spirit of St Louis* in 1927, and the first female transatlantic flight by Amelia Earhart, in a Lockheed Vega in 1932.

Wright Flyer

Sopwith Camel Biplane

Spirit of St Louis

Bell X-1

de Havilland Comet

Lockheed SR-71 Blackbird

AC-130 Hercules

Harrier Jump Jet

Supersonic Aircraft

During the 1930s and 40s, English and German engineers led the way in developing two new types of aircraft engine: the jet (see page 84) and the rocket. The first fighter jet aircraft was the ME 262 Schwalbe. The first fighter rocket aircraft was the ME 163 Komet. In 1954, the American rocket-plane Bell X-1 was the first to break the sound barrier (1,127 kilometres per hour).

Commercial Airliner

Jet engines allowed planes to go faster, and also get bigger. Engineers designed aircraft large enough to carry hundreds of passengers. The *de Havilland Comet* (1952) was the first commercial jet airliner. The Concorde (1969) was the fastest at 2,160 kilometres per hour. The Airbus A380 (2005) is currently the biggest with a capacity of 853 passengers.

Stealth Aircraft

The Lockheed SR-71 Blackbird (1964) was the first stealth aircraft. Its narrow shape and the materials it was built from made it nearly invisible to RADAR (see page 86) so it could fly undetected in enemy territory. It could fly as high as 26,000 metres and at speeds of 3,530 kilometres per hour.

Cargo Aircraft

Soon after their invention, aircraft were being used to carry the mail. However, it wasn't until the 1940s, when engines became more powerful and planes got bigger, that specialised **cargo** planes were designed. These days, planes such as the AC-130 Hercules and the massive Antonov An-225 provide the quickest way to transport **cargo** over long distances.

VTOL Aircraft

VTOL stands for 'Vertical Take-Off and Landing'. Like helicopters, VTOL aircraft don't need a runway to operate from so can land and take-off anywhere, including car parks, forest clearings and ships. The first VTOL aircraft was the Hawker Siddeley Harrier Jump Jet (1969), which was a British military aircraft used for **reconnaissance**.

Calendar

10

"A way to track time and seasons"

Since ancient times, people used the Earth, Sun and Moon to keep track of the seasons and longer periods of time. A day is measured as one rotation of the Earth. A lunar month is one lunar cycle (just over 29 days). A year, also called a 'solar year' (just over 365 days), is one Earth orbit around the Sun. For tens of thousands of years, the indigenous people of Australia have used detailed knowledge of the stars, weather patterns and life, including migration cycles of animals and plants, to create a seasonal calendar. The ancient Egyptians (3100–332 BCE) used two calendars. The lunar calendar was used to plan religious ceremonies and festivals. The civil calendar was used to organise the collection of taxes and censuses. By the fifth century BCE, the ancient Mayans had their own calendar system. In fact, it was a three calendar system that worked together as interlocking wheels. The *haab* was used to plan farming. The *tzolkin* was used for religious events. The long count tracked longer time periods, called 'universal cycles', and was used for dating historical and mythical events.

The tzolkin had 260 days, each of which was identified using a combination of 13 numbers and 20 names.

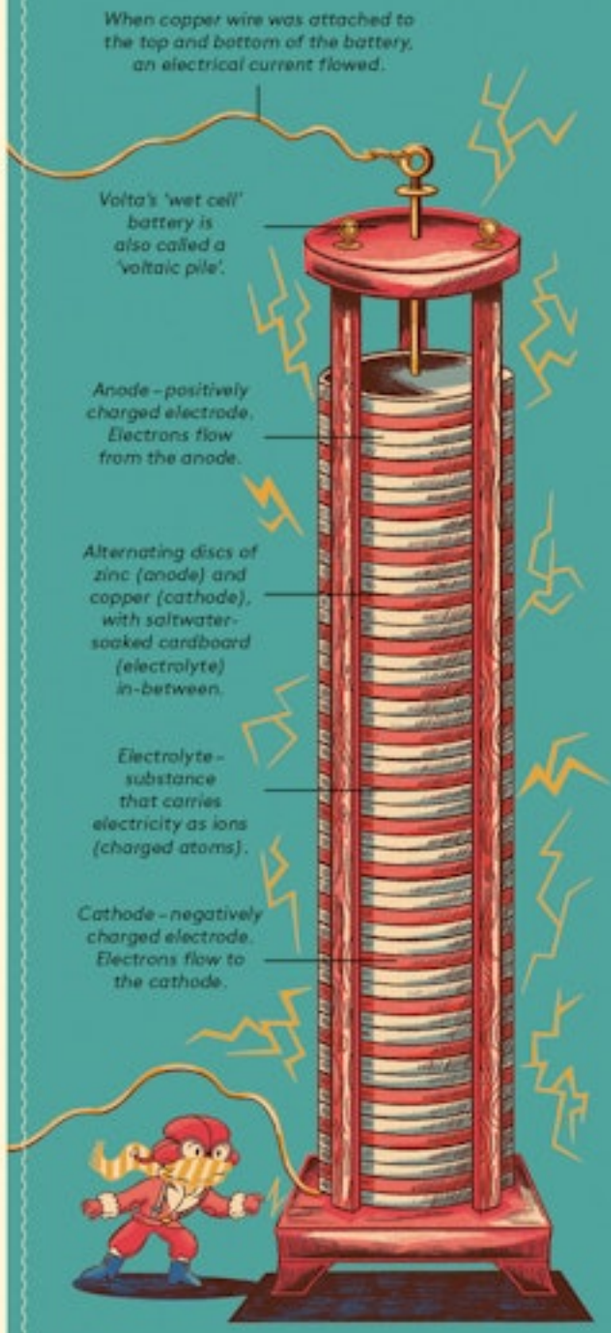
Julian and Gregorian Calendars

Ancient Roman leader Julius Caesar introduced the Julian calendar in 45 BCE. It lasted 365.25 days, 11 minutes longer than an exact solar year. To accommodate the quarter day, a day was added to February every fourth year, which was called a leap year, but the calendar still lost a day every 100 years. The Gregorian calendar, introduced in 1582, corrected this by skipping a leap year every 100 years. Over the centuries, more and more countries adopted the Gregorian calendar, and it is now the most widely used in the world.

Battery

11

"Power to the people"



Some batteries, like a watch battery, are small enough to sit on your fingertip. Others, like those used in most modern submarines are several metres long. Batteries store energy in a chemical form as charged atoms, called ions, which can be released as electricity. Before power stations and plugs, batteries were the only source of electricity people had. In 1791, Italian scientist Luigi Galvani demonstrated the power of electricity by making a dead frog's legs move. By touching them with metal, he generated electricity in them. Alessandro Volta, another Italian scientist, took Galvani's discoveries in electricity further, and created the first battery in 1800. Volta's 'wet cell' battery produced a steady electric current, but only for a short time. Over the following decades, scientists tried different metal-and-chemical combinations, and batteries became more powerful, longer-lasting and rechargeable. By 1887, the 'dry-cell' battery had been invented; one type in Germany, another in Japan. They're safer than wet-cell batteries because they use paste instead of water, so they don't leak. Today some of the most common battery types are alkaline, zinc-carbon, lead-acid and lithium-ion, powering everything from phones to hearing aids to cars and homes.

Essential Electricity

Lithium-ion batteries are used in their billions in electronic devices such as smartphones, laptops and electric vehicles – including the Mars rover! Moroccan scientist Rachid Yazami spent many years studying and experimenting with battery technology, and in 1980 invented the graphite anode – a vital component in most lithium-ion batteries today. Using graphite as the anode (the negative electrode) improved power, efficiency and lifespan. In 2021, his pioneering work led him to break the world record for recharging a car battery in only ten minutes, several times faster than ever before.

Deep-Sea Diving Suit

12

"Allowing us to venture into the abyss"

Would you like to search shipwrecks for treasure? A few centuries ago, people did, and they went about finding a way that would allow them to safely dive to the seafloor and discover its watery secrets. The first diving suit was invented by French **aristocrat** Pierre Rémy de Beauve in 1715. It had a material suit, a metal helmet and two flexible hoses – one fed in fresh air pumped by bellows and the other removed exhaled air. Much later, in the 1830s, German-born engineer Augustus Siebe created a suit that consisted of a brass helmet, an oxygen hose and a weighted canvas suit. This design was used for decades and made the dangerous tasks of underwater salvage, engineering and exploration much safer. The most advanced modern diving suits can reach depths of 600 metres, keep the diver warm and oxygen-fed for four hours at a time, and also have thrusters to make movement easier.

The First Diving Machine

In need of money to look after his large family, English wool merchant John Lethbridge decided to create a deep-sea diving machine so that he could search shipwrecks for sunken treasure. So, in 1715, he built a two-metre-long waterproof wooden barrel, strengthened with iron hoops, which he tested in a pond in his garden. Inside his 'diving machine', Lethbridge could look down through a porthole and use two armholes to move around and pick up objects. His invention worked perfectly – even at the maximum depth of 22 metres – and Lethbridge used it to raise valuables from several sunken ships and make himself a rich man.

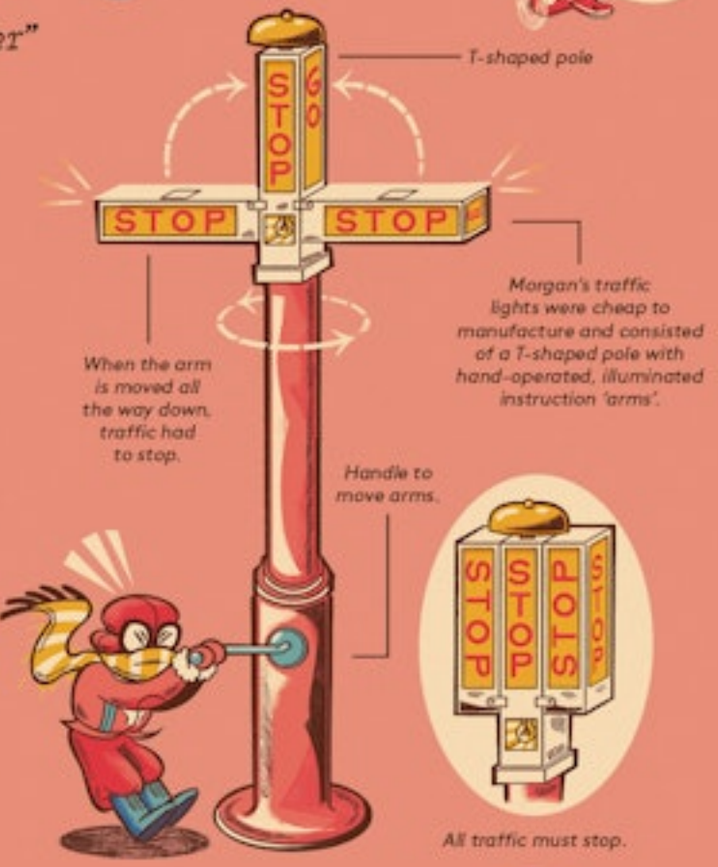
Canvas 'body' – lightweight and flexible enough for the diver to move their limbs and walk on the seabed.

Three-Position Traffic Signal

13

"Roadside lifesaver"

The idea that led to modern traffic lights came about from a road accident. In the early 1920s, African-American inventor Garrett Morgan witnessed an automobile colliding with a horse-drawn carriage at a road junction. Shaken by the carnage, Morgan decided to find a way to stop similar accidents from happening. Traffic signals had been in use for many years (the first appeared in London in 1868) but they only had two instructions: 'Stop' and 'Go'. This meant vehicles moving off too quickly at a 'Go' signal sometimes collided with traffic that was still crossing. To solve this problem, Morgan added a third signal to instruct all traffic to stop. This paused traffic from all directions between one lane coming to a halt and another proceeding, making junctions safer for motorists and pedestrians. By 1923, Morgan's traffic signals were being used in the United States, Canada and the United Kingdom. Today's orange light on traffic lights is thanks to Garrett Morgan.



All traffic must stop.

Life-saving Inventor

Garrett Morgan's mother and father were free Black people who had been enslaved, and he faced disadvantages and racial discrimination his entire life. In 1914, he invented the Safety Hood and Smoke Protector, an early type of gas mask. However, he knew people wouldn't buy it if they knew the inventor was Black. So, at public demonstrations, he hired white actors to pretend to be him. In 1916, Morgan bravely entered a damaged tunnel while wearing one of his gas marks and rescued eight workers. Because he was Black, Morgan did not receive the plaudits his heroism deserved during his lifetime, but he is now recognised as a brilliant inventor who saved countless lives.

Half-mast warns drivers to go slow and drive carefully.

Ice Cream

14

"Dreamy frozen dessert"

Our love of ice-based sweet treats goes back a long way. Around 200 BCE, the ancient Chinese packed a mixture of milk and rice into snow to make an ice-cream-like food. The Egyptians, Romans, Greeks and Indians all mixed ice and snow with fruit or flavourings to create refreshing desserts. Around the thirteenth century, possibly in the Middle East, it was discovered that cream could be frozen when surrounded (but not touched) by an ice-and-salt mixture. The ice melts, but the salt makes it melt at a lower temperature – the ice draws heat from what it's touching, keeping it colder for long. Suddenly, ice cream making got easier! This delicious idea spread through Europe and became especially popular in Italy and France. By the late 1600s, ice cream, which had been a luxury only enjoyed by the rich, become more affordable and the flavours more varied. Chocolate, pineapple and pistachio, and more unusual ones like chestnut and jasmine were enjoyed.

Vanilla is the world's most popular ice cream flavour, and most of the vanilla pods used to make it come from Madagascar and Indonesia.

It's said that King Charles I of England (1600–1649) paid his chef £500 per year to keep his ice cream recipe secret, so only he could enjoy it!

Easy Ice Cream

Stirring the cream, sugar and flavourings to make ice cream takes a long time. In 1843, American inventor Nancy Johnson came up with the first ice cream maker for home use to make the job easier. An outer container, or 'pail', contained the ice and salt. An inner metal cylinder contained the ingredients, which were mixed with a hand-cranked stirrer. A job that had once taken hours now only took about 45 minutes. Johnson's invention made ice cream easier to produce, and cheaper too, meaning anyone could afford it. Modern electric ice cream makers are even more convenient because they stir and freeze the ingredients automatically.

Bicycle

15

"Freedom on two wheels"

Did you know that the first bicycle was banned from the roads? People thought it looked too dangerous. After all, the *Laufmaschine* (which means 'running machine' in German) had no pedals or brakes. Invented by German Karl von Drais in the early 1800s as a quick method of travel for people who couldn't afford horses, his wooden contraption was the first human-powered, two-wheeled steerable vehicle. Other designs soon followed, but they were very expensive. The age of the bicycle truly began in the 1890s with the invention of the cheap, mass-produced Safety Bicycle, which gave everyone the ability to travel far and wide using only their legs.

A brake on the front wheel, operated by a lever on the handlebars, allows the rider to slow down safely.

Light and strong triangular frame – this is one of several features still used on modern bikes.

Same-size wheels allow the rider to touch the ground with their feet – a major safety advantage over the taller Penny-Farthing.

Chain – connects the pedals to the back wheel.

Perilous Penny-Farthing

If you like a bit of danger, mount up on the iconic Penny-Farthing. Invented before the Safety Bicycle in 1869 by Frenchman Eugène Meyer, the Penny-Farthing or 'high wheeler' was the first mass-produced bicycle. Perched high up on a leather saddle, a rider had to keep their balance while rotating the oversized front wheel using the pedals attached to it (this is a 'direct drive' system, which means without the use of cogs and a chain) and steering it with handlebars. Serious injury was common among riders as it was easy to lose control and tumble over the handlebars, also known as 'taking a header'!

Steam Locomotive

16

"Coal-fired, heavy-metal machines"

Transporting **cargo** took ages before the steam locomotive. Animal-hauled wagons rumbled down roads. Canals were first built in China in the seventh century BCE, and later in Europe in the eighth century CE. Journeys could take days, weeks even, which meant most people rarely travelled far from their hometown. Everything changed in the early 1800s. Bridges were built. Tunnels and cuttings were carved through the landscape. Steel tracks were laid down, and along them thundered a new kind of vehicle – coal-fired steam locomotives hauling people and **cargo** faster than ever before.

Steam Engine Evolution

Inventors had tried for centuries to harness the power of steam, but it wasn't until the eighteenth century, when the ability to make carefully engineered metal tanks, pipes and pistons existed, that this really became possible. The first steam locomotives were small, unreliable, strange-looking inventions. But as the decades passed and engineers improved the designs, steam locomotives became bigger, better and faster. By the early 1900s, millions of kilometres of track had been laid all over the world, and on them sped elegant passenger express engines and lumbering freight locomotives.

Trevithick's steam locomotive

Pioneers of Steam Locomotion

British engineer Richard Trevithick invented the first steam locomotive to run on rails. In 1804 his car-sized engine set off from the Welsh town of Penydarren hauling 10 tonnes of iron and 70 people on wagons. It took four hours to travel 16 kilometres. Word spread of Trevithick's achievement, and the race to design better steam locomotives began. Twenty-five years later, engineer Robert Stephenson stunned the world with his speedy and reliable Rocket, the first practical steam locomotive (average speed: 20 kilometres per hour). For the next 150 years nearly every steam engine copied his design.

Smoke created by the coal in the firebox is blasted out of the chimney.

Steam from the boiler is used to drive the engine.

The heat from the fire boils the water in the boiler.

Most steam locomotives have a two-person crew: the driver is in charge, and a fireman makes sure the firebox is well fed with coal.

Signals tell the driver if it's safe to continue along the track. If the arm is horizontal it means: Danger! Stop!

MALLARD

Nº4468

CLASS

LNER

The A4 express engine Mallard holds the world speed record for steam locomotives. In July 1938, Mallard reached 126 kilometres per hour on England's East Coast Mainline between London and Edinburgh.

The Real McCoy

Steam engines need to be regularly oiled to work well, and it was African-American engineer Elijah McCoy who came up with the solution. At 15, McCoy went to study mechanical engineering in Scotland, but upon returning to the United States he faced racism and was turned down for job after job. Undeterred, in 1872, McCoy invented an automatic engine lubricator, called the oil drip cup, which greatly extended the working lives of steam locomotives and other steam machines. His invention was so reliable it's thought that the phrase 'The Real McCoy' (meaning 'the original and best') was named after him.

Wheel

17

"The revolutionary design that makes the world go round"

Can you imagine a world without wheels? Apart from sledges and ships, there would be no vehicles – no carts, cars, bikes, buses, trucks, trains, trams or aeroplanes. The first wheeled vehicles were animal-drawn carts with solid wooden wheels. They were invented in Mesopotamia (modern-day Iraq) around 3200 BCE, 300 years after the horizontal potter's wheel. These carts carried **cargo** to market and heavy loads, such as stone and timber for building projects. The horse-drawn chariot came next. In about 2500 BCE, chariot wheels were spoked rather than solid like a cartwheel, so they were faster and lighter. The wheel may be one of the simplest inventions, but without it our world would be completely different.

Many early inventions were inspired by things in nature. However, apart from some animals that use rolling to move, there are no wheels found in the natural world.

The ancient Romans raced chariots as a sport.

A chariot was drawn by a team of two horses.

Roman chariots had wooden wheels.

Potter's Wheel

The very first wheels were used to make pottery. The art of pottery began around 30,000 years ago. Originally, potters would shape clay into pots with their hands, but this took a long time. The Mesopotamians invented a better method in around 3500 BCE. The potter's wheel was a large stone disc balanced on a stick called an 'axle', which could be spun. By putting clay on the wheel and spinning it, the potter could shape the clay quickly into pots. We don't know for sure, but it seems likely that the potter's wheel led to the invention of the vehicle wheel.

Internet

18

"The world at your fingertips"

The invention of the Internet – a network of computers that 'speak' to each other – was a concentrated effort in the United States. The first computers were connected to each other in 1969, but scientists first began developing the Internet in the early 1960s during the **Cold War** (1947–1991), a time of heightened hostility between the **USSR** and the United States and when computers were the size of an entire room. The United States government wanted a communication system that couldn't be destroyed in a single attack, so they created ARPANET (Advanced Research Projects Agency Network): a series of linked computers across different locations, which allowed information to be relayed along telephone lines. The first message was sent in 1969. It was a single word: LOGIN, but only the 'L' and the 'O' got through before the network crashed. By the end of the same year four computers were connected on the ARPANET. It took years to create the 'network protocol' that allows computers to transfer data and 'speak' to each other. From the 1970s this network grew into the global Internet, which now links billions of devices. Today, whatever you want – books, food, holidays, cars – with the Internet you simply click a button and wait for it to arrive. Social media sites allow people all over the world to communicate instantly. We can consume films, television shows, music and video games, and even do our banking online.

World Wide Web

The World Wide Web (WWW) is a gateway to the Internet. It's made up of search engines like Google and Safari, the Internet addresses (also called URLs) we type in, and the websites that appear on our screens. It was invented by a British computer scientist called Tim Berners-Lee in 1989 while working at CERN, a science research laboratory in Switzerland. The WWW made the Internet accessible to everyone, not just scientists and academics.

Tin Can

19

"Keeping your food fresh for longer"

Before tin cans, food was difficult to keep fresh on land, but it was impossible at sea. By the eighteenth century, sea voyages could last for months. The food preservation method of 'canning' was invented by Frenchman Nicolas Appert in the early 1800s. Appert filled glass bottles with foods like meat, soup and casseroles, then boiled the sealed bottles in water. This killed off **bacteria** and ensured the food lasted for months. In 1810, English merchant Peter Durand took Appert's method and **patented** a metal container, which was easier to make and harder to break. From then on, sailors and explorers could take food with them that lasted years, and ordinary people could cook nutritious, affordable meals in moments.

Before the invention of the can opener in 1855, cans had to be broken open using hammers, chisels and knives.

Match

20

"Instant fire-starters"

Controlling fire is a powerful ability. For at least 800,000 years, humans have used fire for heat, light, cooking and fending off predators. However, it wasn't until 1826 that a simpler way to create fire was invented, which happened quite by chance! One day, while carrying out experiments, English chemist John Walker accidentally scraped a wooden splint tipped with a **combustible** mix of chemicals including sulphur against some metal and was amazed to see it fizz into flame. This allowed Walker to create the first self-lighting matches, which he called Friction Lights. In 1831, French chemist Charles Sauria added white phosphorus to match tips, making them even easier to light.

*Safety matches have **combustible** (red) phosphorus on the matchbox's striking surface, not the match head itself. This means the match cannot be lit when struck against another surface.*

The use of white phosphorus in matches was eventually banned in 1906. The fumes it produced gave match factory workers a terrible bone-decaying disease called 'phossy jaw'.

Writing

21

"How we record and share our ideas"

Without writing, this book would not exist! Writing is language set down and preserved, a combination of letters, symbols or pictures used to create words. Like speaking, it's another way we can communicate with each other. It can record our history, stories, thoughts and ideas, and can be copied and shared with anyone who can read the language it's written in. The concept was invented separately by several ancient civilisations. Around 5,500 years ago, the Mesopotamians (who lived in what is now modern-day Iraq), used wedge-shaped styluses to press symbols into clay tablets. This type of writing is called cuneiform, meaning 'wedge-shaped'. The ancient Egyptians wrote in hieroglyphs (a writing system using pictograms) from 3200 BCE and used paint, ink and carving tools to record daily life on tablets, temple walls and papyrus (a type of paper made from plants). Ancient Chinese writing (from around 1200 BCE) used thousands of symbols, each representing single words or syllables. From around 400 BCE the ancient Mesoamericans (who lived in what is now Central America) used glyphs and symbols to represent words.

Many cultures, such as First Nations Australians, indigenous Americans and the Inuit of Greenland, Canada and Alaska, have for centuries passed on information, history, traditions, laws and stories by word of mouth, rather than relying on writing.

Mesoamericans made paint by crushing plants and mixing them with water.

Glimpses of the Past

Thanks to archaeology, we've been able to read the words of people who lived thousands of years ago. The Sumerian (modern-day Iraq) poem 'The Epic of Gilgamesh', written in the Akkadian language in the second millennium BCE, is the oldest discovered written story. It involves kings, gods, goddesses and dangerous journeys to strange lands. The famous ancient Egyptian Rosetta Stone is a large slab containing a pharaoh's decree written in ancient Greek, Demotic and hieroglyphs. The first writings in the Ge'ez language of Ethiopia, which uses letters to create words, appeared in the third and fourth century BCE and is still used today.

Microscope

22

"Revealing invisible worlds"

Look into this amazing invention and you'll see an invisible miniscule world revealed. It's thought that the light microscope (or optical microscope – the sort you might use in science lessons) was invented by a Dutch spectacle maker called Zacharias Janssen sometime around 1600. He noticed that by looking at an object through two magnifying lenses, it appeared about nine times larger. Amazing as this discovery was, his lenses were not smooth enough to provide a crystal-clear view. In the 1660s, Dutch scientist Antonie van Leeuwenhoek created lenses that magnified objects up to 270 times their actual size. This achievement kindled a new age of scientific discovery. In 1665, English scientist Robert Hooke published a book called *Micrographia*, filled with detailed illustrations of tiny things he'd observed through his microscope including fleas, lice and plants. Scientists have used microscopes to study the effect of antiseptics, antibiotics and vaccines on **bacteria** and germs, helping to combat disease. It's impossible to calculate how many lives have been saved by the amazing microscope, and the scientists who use them.

*Antonie van Leeuwenhoek was the first to observe single cell organisms in a drop of pond water, **bacteria** on tooth plaque and human blood cells.*

Magnified image of red blood cells.

The flame is from oil burning on a wick. The flame's light spreads through the water to shine through the glass lens. The light then falls on the specimen, illuminating it so it can be seen through the microscope.

Even Smaller

Light microscopes are great – but electron microscopes are even better! Invented in 1931 as a way to see even smaller objects, the first electron microscope could magnify up to 400 times. Instead of light, an electron microscope uses a beam of electrons, and instead of glass lenses it uses electromagnets. Images of the object are projected onto a screen, which can be zoomed in on even further. The best modern microscopes can magnify up to 100 million times.

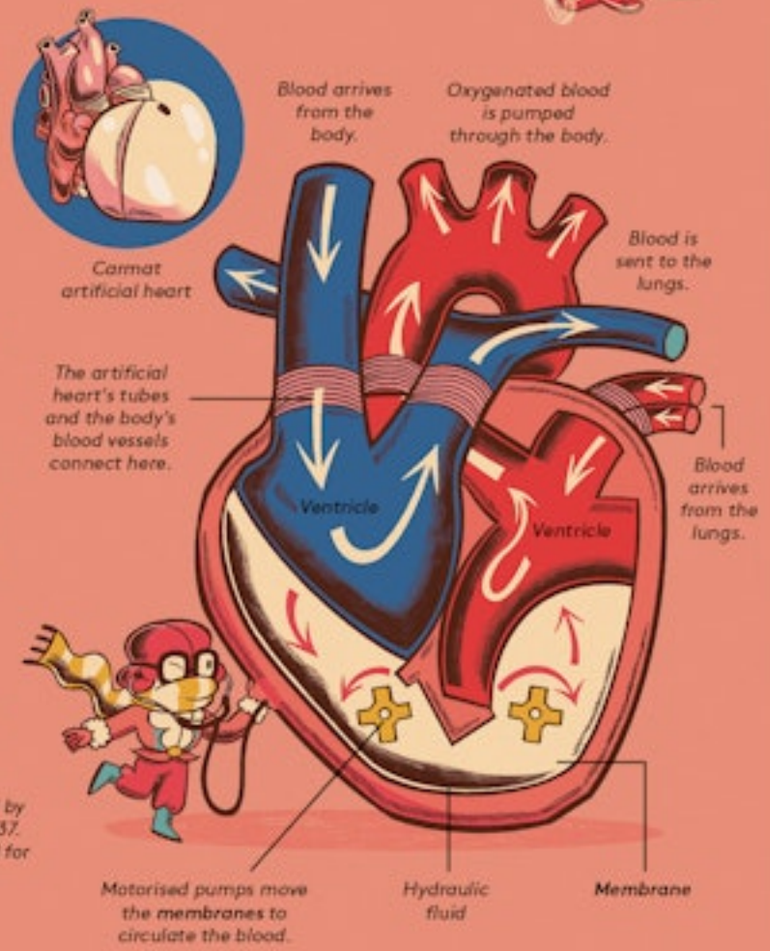
Artificial Heart

23

"Mechanical life preserver"

Your heart is like an engine, keeping you alive. It pumps around an incredible 100,000 times every day and never takes a break. The blood it circulates feeds vital oxygen to your brain, organs and muscles, and takes away the waste carbon dioxide. If the heart stops, death quickly follows. Inventors tried to create a mechanical heart for about a century before they were successful. The idea was this blood-pumping device could help people with serious heart problems while they waited for a transplant. Early experimental artificial hearts were implanted inside animals. As the technology improved and the doctors perfected their surgical techniques, the animal test subjects lived for longer. In 1969, an artificial heart, created by Argentinian inventor Domingo Liotta, was implanted into a human ... and it worked! Although the patient died soon after receiving their real donor heart, Liotta proved that artificial hearts could prolong a patient's life at least for a short time.

The very first artificial heart was invented by Russian scientist Vladimir Demikhov in 1937. He implanted it into a dog, which survived for two hours after the operation.



Heartbeat Breakthrough

In 1982, an artificial heart called the Jarvik-7 was implanted into a dentist called Barney Clarke. Scientists Robert Jarvik (American) and Willem Kolff (Dutch) had designed Jarvik-7 as a permanent heart replacement, not just something to keep the patient alive until a donor heart became available. After a seven-hour operation, Clarke's mechanical heart was beating inside his chest. It kept him alive for 112 days. The next patient survived an amazing 620 days. However, even modern artificial hearts can't keep a patient alive indefinitely, so nowadays they are usually only used until a real one can be transplanted.

Camera

24

"Say cheese"

Although it only takes an instant to snap a photograph, it took decades for the camera to be perfected. Before the camera there was the 'camera obscura'. Invented in China around 400 BCE, camera obscuras were dark rooms with a small hole in one wall. Light coming through the hole projected an image of the outside world onto the opposite wall. In 1826, French inventor Joseph Nicéphore Niépce recorded the very first photograph using a handheld camera obscura with a light-sensitive metal plate inside. The image was a view of rooftops from his window. (The knowledge about light-reactive chemicals, which facilitated the first permanent photograph, had been known for a long time before the camera came about.) Louis Daguerre, another Frenchman, discovered how to create sharper photographic images than Niépce by using salt and gold chloride solutions to permanently 'fix' images onto light-sensitive silver-plated copper sheets. His 'daguerreotype' camera went on sale in 1839 and gave people the miraculous ability to capture images of their lives.

A light-sensitive metal plate is inserted into the camera. The image is developed using the vapours from heated mercury.

The lens cover is removed to let light into the camera.

Daguerrotype camera

The first-known photograph of a person was taken in 1838 by Louis Daguerre. It shows a man having his shoes shined on a street in Paris.

Lens

After the camera's invention many painters moved away from creating realistic works of art and instead used abstract and surrealist styles to express themselves.

Developed to Perfection

Many improvements to the camera followed. From around 1840 photographs could be transferred to paper instead of the less practical metal plates. Film negatives stored photographic images and could be developed many times over. Single Lens Reflex (SLR) cameras were invented in 1861 and produced high-quality photographs. The first cheap and easy-to-use cameras (the 'Kodak' in 1888 and the 'Brownie' in 1900) opened up the art of photography to everyone. Then came the Polaroid camera which took, developed and printed photos instantly. Towards the end of the twentieth century, the digital camera arrived. Without the need for film, instead it records photos and video clips onto a memory card.

Polaroid camera

High-Speed Train

"Hi-speed worldwide"

25

By the 1960s the golden age of the railway was long gone and people thought trains were slow and inconvenient, especially compared to the speedy automobile (see page 50) and commercial jet (see page 84). However, a new railway revolution began when the Japanese government decided to build the very first High Speed Train (HST). It was a massive task, 500 kilometres of track had to be laid between the cities of Tokyo and Osaka. On top of that, a ground-breaking, super-swift electric train had to be invented too. Flying over the rails at 220 kilometres per hour (twice as fast as any other train at that time) these trains were called Shinkansen, which means 'New Main Line', but they are commonly known as Bullet Trains. The first Shinkansen line opened in 1964 and was an immediate success. Since then, it's had a staggering 10 billion passengers. There are now High Speed Train networks all over the world, and they keep getting faster. The world speed record for a train was broken in 2007 when a French TGV service reached 575 kilometres per hour.

Incredibly, it only took five years for the Tokyo-Osaka high-speed railway line and the Shinkansen Bullet Trains to be developed and completed, and they worked brilliantly from day one.

Shinkansen trains are hardly ever late, and when they are it is only ever by a few seconds.

Like poles repel each other, pushing the train forward.

Opposite poles attract each other and pull the train forward.

Marvellous Maglevs

There is a vehicle that's even faster than the HST: the incredible floating maglev. Maglevs use electromagnetic fields created by electromagnets to float about 1.5 centimetres above the rail. This means there's no friction to slow the maglev down or cause vibrations (unlike a track-borne train). As the maglev reaches its top speed, passengers can enjoy a smooth journey, even though they're travelling faster than any other land vehicle in the world. In Japan, the experimental L0 Series maglev train set a land speed record of 603 kilometres per hour for rail vehicles.

Computer

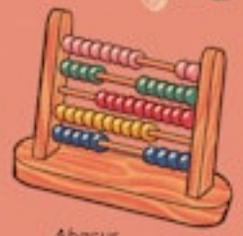
"The programmable machine we can't live without"

26

The computer – a digital electronic machine that can be programmed to perform many different functions – is a modern invention, but humans have been using devices to 'compute' sums for over 4,000 years. Here are some notable devices and machines that have formed milestones in computing history.

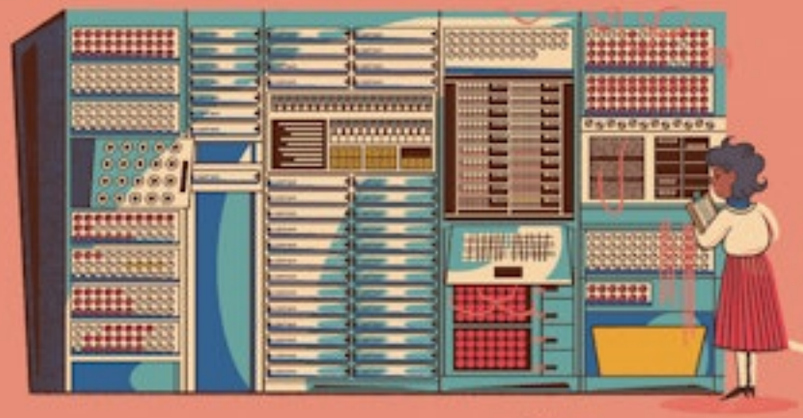
Early Devices

The abacus, which uses movable beads on a frame, is the oldest-known calculating device, used from around 2400 BCE in Mesopotamia (modern-day Iraq), and later in ancient Greece, India, China and Italy. Calculating aids became more complex and able to compute harder number problems. In 1642 French mathematician Blaise Pascal invented a mechanical calculator called the Pascaline that could add and subtract when the operator turned dials. A huge stride forward was made in the 1840s when English inventor Charles Babbage designed (but never built) the Analytical Engine, the first programmable computing machine. Incredibly, it included several components that are still essential to modern computers: the Mill worked like a central processing unit (CPU), the Store worked like memory, and the Reader was an input device that worked like a keyboard.



Abacus

Pascaline



Colossus

The first computer programme was written for Babbage's Analytical Engine by English mathematician Ada Lovelace in 1843. She also correctly predicted that computers in the future would do far more than just crunch numbers – something even Babbage didn't foresee.

First Generation

The move towards modern computers began during the first half of the twentieth century, in part prompted by the need to crack enemy codes during the **Second World War**, and the more widespread use of electricity. Mechanical computers were replaced by electromechanical computers, which used mechanical and electronic processes to perform calculations. This first generation of computers were bulky, noisy machines that could run thousands of calculations per second – many times faster and with more accuracy than a human brain (but much slower than modern computers). During the **Second World War** (1939–45) the **Allies** developed computers such as the Turing Bombe (which was based on the earlier Polish device 'the bomba') and Colossus to break enemy codes and read their top-secret messages.

Harwell CADET

Second Generation

The second generation of computers appeared in the late 1950s: fully electronic, no longer room-sized, and more powerful thanks to the invention of the transistor (see page 52). Early designs used glass vacuum tubes as big as lightbulbs to amplify the electric current and control the computer's processes. The problem was these tubes were prone to overheating and had to be constantly replaced. However, the introduction of transistors fixed this overheating problem, and the first fully transistorised computer, the Harwell CADET, appeared in 1956.

Third Generation

Even smaller and faster, third generation computers functioned using cheap and mass-producible integrated circuit boards (ICs) and covered silicon chips. The cabinet-sized IBM 360, introduced in 1964, was capable of processing huge amounts of data and could be linked to form networks. Created in 1970 and sold until 1990, the PDP-11 (also cabinet-sized) could be **mass produced**, and its design influenced many computers that came afterwards.

IBM 360

PDP-11

Commodore 64

Fourth Generation

Appearing from the early 1970s, fourth generation computers are the ones we use today: desktop PCs, laptops and tablets. The first PC, the Altair 8800, arrived in 1975 and had to be built from a kit. The Commodore 64, introduced in 1982, was the world's best-selling computer, with more than 22 million units sold. Introduced in 1998, the colourful Apple iMac G3 showed the world that practical computers could also look stylish. Modern fourth generation computers are cheap to build, reliable and can be highly **portable** (battery-powered laptops and tablets). They function and store data using silicon memory chips, transistors, hard drives, and microprocessors made up of thousands of integrated circuits – they are getting faster and more powerful all the time.

Apple iMac G3

Modern laptop

Plough

"Ancient harvest helper"

27

Farmers have been growing crops for 11,000 years in a ceaseless cycle of ploughing, planting and harvesting. (To grow crops, soil was worked, turning it over to bring nutrients to the top, and loosened so seeds could set their roots. After millenia of elbow grease and handheld tools, the plough was invented.) The first ploughs – called 'ards' or 'scratch ploughs' – were powered by people pushing them along. They were simple wooden devices that used a sharp stick to dig furrows in the ground for seeds to be sown into. However, scratch ploughs were too lightweight to clear weeds or dig deep into dry, stony ground. This problem was solved with the invention of heavier, animal-hauled ploughs that prepared fields faster and with less effort. The ancient Celts added wheels (see page 26), which made the plough easier for the farmer to control as they tramped up and down through the mud.

Using a plough was hard work, even with an animal's help. The farmer had to guide the plough up and down the fields in straight lines, as well as push downward to help it cut through the soil.

We can't be sure exactly when ploughs were first used. However, the earliest evidence of a ploughed field was found in the Czech Republic in Central Europe, and dates from between 3500–3600 BCE.

Ploughing On

Amazingly, in 4,000 years, the essence of the design has changed little – except in size and speed! Most modern farms use tractors to haul their ploughs. Tractors can cope with much bigger ploughs, and are capable of working faster and for longer than animal teams. Modern ploughs usually have around six to seven blades – but the maximum is a whopping 18! The angle and depth of each blade, plus the width between them, can be adjusted from the tractor cab depending on the condition of the soil and the type of crop being planted.

Compass

"Helping you find your way"

28

The ancient Chinese invented the compass sometime during the Han Dynasty (second century BCE to second century CE) when they discovered that a mineral made from magnetized iron ore (called 'lodestones') moved on their own – as if by magic. They called them 'south pointing fish' and used them to tell people's fortunes, and plan the positions and locations of buildings (an art called 'geomancy'). However, sometime between the tenth and eleventh centuries, the Chinese began using compasses to navigate. These first navigating compasses were wooden sticks with magnetized iron tips floating in bowls of water. When the stick came to rest, the magnetized end always faced north. We now know that Earth is surrounded by a magnetic field, which is created by the liquid iron and nickel found in Earth's outer core. It's this magnetic field that causes a compass needle to always point north. The sort of compass you'd probably use now when out for a hike has a freely rotating magnetized pointer suspended over a 'compass rose', which is marked with the four 'cardinal points' of North, South, East and West.

The compass needle always points due north.

Compasses have a glass dome to protect the needle.

These days we can navigate accurately using GPS (see page 65). However, explorers and travellers often carry a trusty compass as a back-up in case of emergencies.

Early Explorers

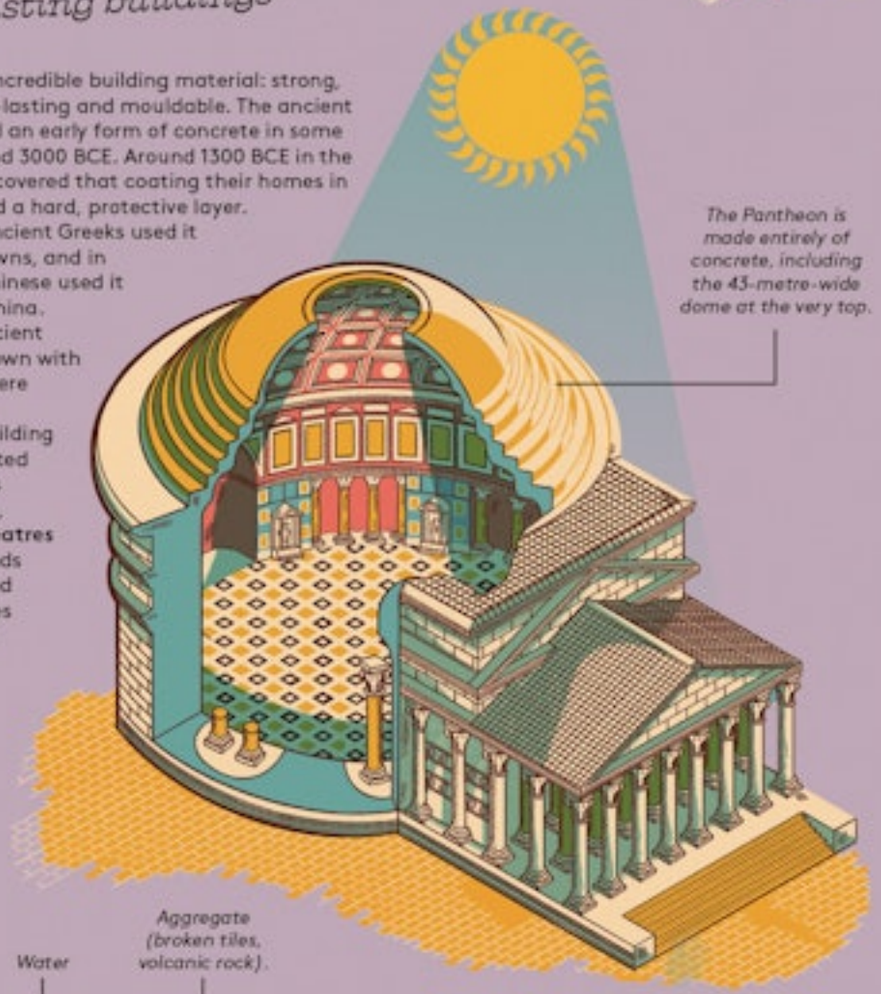
Before the compass, land travellers used maps and landmarks such as rivers, hills and towns to work out where they were and in what direction they were travelling. Sailors stayed close to coastlines so they could navigate using cliffs, rocks, reefs and ports. People also used heavenly bodies like the Sun, the Moon and the stars to get their bearings – the Sun always rises in the east, and the Pole Star is a bright star that is only visible in the northern hemisphere and always points north. However, navigating using the sky is impossible if it's cloudy, which is why a compass is essential.

Concrete

29

"A wonder material for long-lasting buildings"

Concrete is an incredible building material: strong, fireproof, long-lasting and mouldable. The ancient Egyptians used an early form of concrete in some of their pyramids around 3000 BCE. Around 1300 BCE in the Middle East, people discovered that coating their homes in burnt limestone created a hard, protective layer. Around 600 BCE, the ancient Greeks used it in their temples and towns, and in 300 BCE the ancient Chinese used it in their Great Wall of China. However, it was the ancient Romans who went to town with concrete. First, roads were built, then before long it was used for most building projects. They constructed grand buildings such as **aqueducts** and bridges, public baths, **amphitheatres** big enough for thousands of spectators, and grand temples. Many examples of Roman architecture still exist, including the Pantheon. But what makes concrete so strong?



The Pantheon is made entirely of concrete, including the 43-metre-wide dome at the very top.

Winning Recipe

The ancient Romans made concrete by binding aggregate (broken rocks, tiles, rubble), by using mortar (a mixture that hardens) made with water, quicklime and a volcanic dust called 'pozzolana'. Concrete made with pozzolana and saltwater grew harder in seawater, making it ideal for building ports and harbour walls. The recipe for concrete was lost after the Roman Empire fell in 476 and wasn't rediscovered until the late 1700s. Modern concrete is made by mixing cement (the binding agent), water and aggregate.

Glass

30

"For windows, vessels, screens and spectacles"

Glass is everywhere! The first manufactured glass appeared around 2500 BCE and was made by melting sand or quartz. The ancient Egyptians and Mesopotamians (who lived in what is now modern-day Iraq) used it to make coloured beads for jewellery. This fashion spread to India, China, Europe and beyond. Better glassmaking techniques led to bottles, bowls, vases and drinking vessels – some were practical and plain, others were expensive and highly decorated. By the late 1600s, lead oxide was added, which made glass clearer and easier to shape. Glass bottle-making machines appeared in 1901. In 1903 a machine was invented to mass-produce clear glass windowpanes. Glass today can be transparent, opaque (not see-through), patterned and coloured. It's versatile, relatively cheap to produce, sustainable and recyclable too, so it can be used for many things, including mirrors, ornaments, lightbulbs, oven doors, televisions, smartphones, and laptop screens... to name just a few!

Clear glass is mostly made from sand, with the addition of soda ash and limestone. Adding cobalt turns glass blue, adding chromium turns it green and adding gold creates red.

Molten Magic

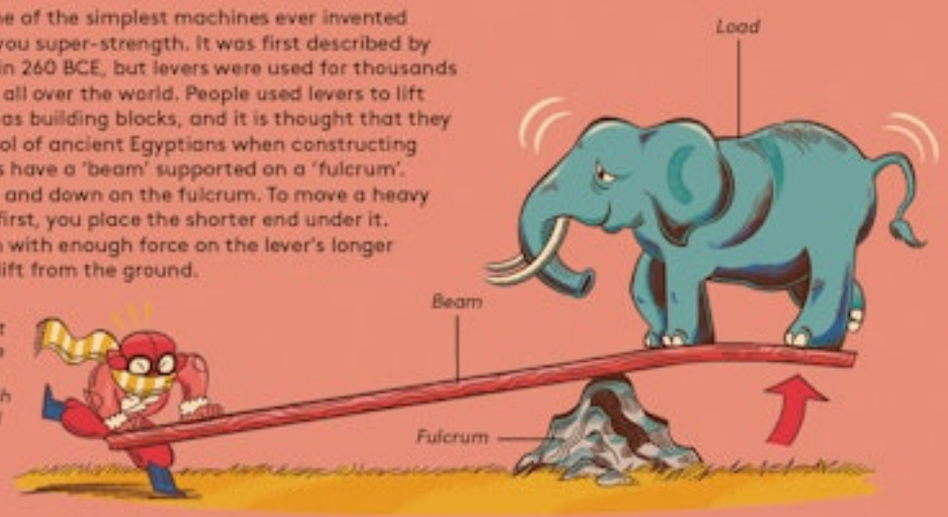
Glassblowing was invented in the Middle East in the first century BCE, and is still used today, to make bottles, vases and decorative sculptures. Glass is heated in a furnace until it melts to the consistency of treacle. A blob is gathered on the end of a hollow metal blowpipe. The glassblower blows through it to create an air bubble inside the glass blob. The heat of the glass makes the air expand, and the glass bubble grows. The glassblower shapes the glass by twisting, swinging and rolling it on a smooth surface. Finally, the finished glassware is allowed to cool until it's hard.

Lever

31

"A simple tool that gives you superhero strength"

The lever is one of the simplest machines ever invented and it gives you super-strength. It was first described by Archimedes in 260 BCE, but levers were used for thousands of years before that all over the world. People used levers to lift heavy objects, such as building blocks, and it is thought that they were an essential tool of ancient Egyptians when constructing the pyramids. Levers have a 'beam' supported on a 'fulcrum'. The beam moves up and down on the fulcrum. To move a heavy object with a lever, first, you place the shorter end under it. Then, pressing down with enough force on the lever's longer end, the object will lift from the ground.



Archimedes is thought to have said, "Give me a long enough lever and a fulcrum on which to place it, and I shall move the world".

Electric Drill

32

"Making DIY easy peasy"

The first drills were simple, hand-operated devices made of flint, and were used by hunter-gatherer humans who lived between 25,000–12,000 BCE to make bone amulets. From around 6000 BCE prehistoric humans began drilling holes into people's skulls. Called 'trepanning', it's thought this procedure was used to cure pain or seizures and to let evil spirits out. But whatever was being drilled – stone, wood, leather or bone – doing so by hand was hard work.

Things got easier in 1889 with the first electric drill, designed by Scottish-born Australian engineer Arthur James Arnot. This huge machine was used to bore foundation holes for buildings.

A **portable** drill for smaller jobs followed soon afterwards in 1895, and in 1917 the company Black & Decker **patented** a drill with a vertical grip and an on-off trigger just like those used by builders and DIYers today.

Piano

33

"A marvellous musical wonder"

The piano was inspired by several older musical instruments. The Middle Eastern hammered dulcimer has strings stretched across a wooden sound box; it's played by striking the strings with a pair of hammers. Invented around 2,000 years ago in ancient Greece, the organ is a keyboard instrument; when the player presses a key it sends a blast of air through pipes to create musical notes. Fourteenth-century European instrument-makers combined elements of the dulcimer and the organ – including the sound box, strings and keyboard – to create the clavichord, then the harpsichord a century later. The problem was the clavichord couldn't be heard properly over other instruments, and harpsichord players couldn't regulate how softly or loudly they played the notes. Italian harpsichord-maker Bartolomeo Cristofori came up with the solution sometime in the early eighteenth century. His 'piano' (although that name came later) used leather-covered hammers to strike strings inside a sound box. Louder than a clavichord and capable of playing soft and loud notes, the piano allowed composers to write powerful and emotional music.

The piano's full name is 'clavicembalo col piano e forte', which roughly translates from Italian to 'a harpsichord that can play soft and loud noises'.

The hammers strike the strings only briefly, creating a crisp, clean sound. The hammers also return to their 'resting' position without bouncing so they can be quickly restruck.

More Keys Please!

Composers were getting more ambitious and found Cristofori's original design of 54 keys limiting, so a broader range of notes were added. Most modern pianos have 88 keys – 52 white and 36 black – providing composers with a wide variety of notes to make music. Because of this, the piano is still a popular instrument and is used in many musical styles, including classical, blues, jazz, folk, rock and pop.

The piano is both a percussion and string instrument. The sound comes from stretched strings but the string vibrations are caused by striking hammers.

Wind Turbine

34

"Harnessing the power of wind"

You might have seen a wind turbine up on a hill or in the distance out at sea, towering above the ground or ocean and turning around. Even though this electricity-generating invention seems modern, we have been harnessing the power of the wind for a very long time. The first-known record of a 'wind wheel' was in ancient Greece. By the ninth century, they were being used in places such as Iran to drive mills to grind grain and pump water, and later, in China and across Europe, too. It wasn't until 1887 that 'wind wheel' technology had a revolution. A strange contraption appeared in a garden in Scotland. It was 10 metres tall, had four 4-metre-long arms that turned in the wind, and was attached to an electricity-generating machine called a dynamo. Built by engineer James Blyth, it was the first wind turbine. The electricity it created was used to power all the lights in Blyth's home.

Not long afterwards, American inventor Charles Brush built an even larger one at his mansion in Ohio. Standing 18 metres tall and 17 metres across, it was made up of 144 blades, and powered 100 light bulbs and all the machines in Brush's laboratory. By the early 1930s, thousands of wind turbines had sprung up on farms all over the United States to power lights and water pumps.

Green Energy

Today wind turbines are all over the place – sometimes standing alone, sometimes in huge windfarms on land and sea. The biggest windfarm in the world is in China and has more than 7,000 turbines. Some are over 100 metres tall and have motors that turn the whole turbine, so they always face directly into the wind for maximum efficiency. Modern powerful wind turbines can produce 10,000 kilowatts of electricity per hour – that's enough to supply 20,000 homes with all the power they need.

Helicopter

35

"A whirling way to fly"

Would you believe that the helicopter was conceived way back in the fifteenth century? Genius inventor Leonardo da Vinci's flying contraption idea, the Aerial Screw, had a 4.6-metre-wide rotor turned by a crew of four. Although it was never built (and wouldn't have flown even if it had been), da Vinci's idea was centuries ahead of its time. The first functioning helicopters didn't appear until the late 1930s. They were unstable and dangerous, and accidents were common. The first reliable helicopter to whirl into the air was the single-seater, twin-rotor FW-61, invented in 1936 by German engineer Henrich Focke. The first mass-produced helicopter was invented by Russian-born Igor Sikorsky. His R4 *Hoverfly* seated two and had a top speed of 120 kilometres per hour. Today there are many types of helicopters, from small twin-seaters to enormous **cargo**-carrying monsters with multiple engines.


Aerial Screw


Cornu's 1907 'flying bicycle'

Versatile VTOLs

The air is too thin at high **altitudes** for helicopters to be able to fly as high as aeroplanes. (The highest a helicopter has ever flown is 13,000 metres). However, they make up for that with their unique flying abilities: they can vertically take-off and land (VTOL), hover in one spot and move in any direction. They can also carry passengers and equipment such as winches, searchlights and fire-fighting kit, making the helicopter an ideal vehicle for emergencies. Rescuers have a perfect vantage point to search for people lost at sea or on land from a helicopter, and lower winches to hard-to-reach spots.

Chocolate

"The world's favourite sweet treat"

Is there anything better than the taste of chocolate as it melts on your tongue? It's no surprise that chocolate is the world's favourite sweet treat. However, for most of its 3,500-year history, chocolate was consumed only as a drink – and it wasn't even sweet! Chocolate comes from the cacao tree, and it first appeared in ancient Mesoamerica, a region that extends from modern Mexico down into Central America, where these trees grow. Some experts believe the Olmec people were the first to use cacao beans to make a chocolate drink from around 1500 BCE. The ancient Mayans (people who lived in what is now modern-day Guatemala) believed cacao beans were a magical gift from their gods. They roasted and ground up the beans, then mixed the powder with water, chillis and cornmeal to make a thick, bitter, frothy drink called *xocolatl*.

Chocolate Spreads

Explorers brought the cacao bean to Spain sometime in the sixteenth century. At first, the chocolate drink was rudely described by the Spanish as a 'bitter drink for pigs'. However, it caught on in a big way when sweetened with honey or sugar, and became fashionable with royalty and the rich. The rest of Europe also developed a taste for chocolate and began importing cacao beans from Central American plantations. 'Chocolate houses' soon became as popular as taverns and served hot chocolate blends made with jasmine, citrus peel, cinnamon, cloves, chilli and **ambergris**.

The Aztecs (people who lived in what is now modern-day Mexico) poured xocolatl from one pot to another to make it thick and frothy. Xocolatl contained caffeine, had a real 'kick' and was quite addictive.

How xocolatl was made:

1. Cacao trees can grow up to 12 metres tall. They produce large pods filled with about 20–60 cacao seeds, or beans, covered in a sweet, soft pulp.

2. The pods are harvested and the beans and pulp are removed.

3. The pulp and beans are spread out to ferment.

From Drink to Bar

In 1828, a Dutch chemist invented a machine to squeeze the fat, known as cocoa butter, from the cacao bean, which left behind a fine powder called cocoa. When this was mixed with milk, it created a delicious drink similar to the hot chocolate we enjoy today. Then, in 1847, English chocolatier J. S. Fry created the first chocolate bar by hardening a mixture of cocoa butter, sugar and chocolate liquor in a mould. Milk chocolate appeared in 1876 in Switzerland when dried milk powder was added to the recipe. Nowadays there's a vast number of chocolate manufacturers making a mouth-watering array of chocolate types: milk, dark, aerated and flaky chocolate, and chocolate filled with caramel, nougat, honeycomb, fruit and nuts.

We consume over three million tonnes of cocoa beans a year and in 2021 the global chocolate market was worth about $113 billion. That's how much we love chocolate!

It's thought that the word 'chocolate' comes from the Aztec xocolatl, which means 'bitter drink'. The scientific name for the cacao tree, Theobroma cacao, translates to 'food of the gods'.

The Aztecs used cacao beans, as money: one bean bought an avocado; four bought a pumpkin; 10 a rabbit; 100 a turkey.

High Human Cost

When Europe fell in love with chocolate, cacao farming in the Caribbean and Central and South America became big business. Cacao plantation owners made huge profits. Between the seventeenth and nineteenth centuries, thousands of enslaved people from Mesoamerica and Africa were forced to look after the cacao trees, harvest the pods, then process the beans. It was incredibly hard work. As well as having their freedom stolen from them, the workers had to endure horrendous living conditions, disease and constant physical abuse.

4. The brown beans remaining are dried.

5. Then they are roasted.

6. They are shelled, then ground, which releases the cocoa butter. This mixes with the cocoa solids to make 'chocolate liquor'.

7. Water, chillis and cornmeal are added to flavour the drink.

Waterwheel

37

"Mechanical muscle"

Around 3,000 years ago all the energy needed for getting any task done, from the menial to the backbreaking, came from one thing: muscle. And then, around the fifth century BCE, the ancient Chinese invented the waterwheel, which was the first device to drive machines. Waterwheels convert the energy created by flowing water into power. This power can be used to turn heavy machinery for longer and with more efficiency than people or animals could ever manage. Although a truly ancient invention, waterwheels are so effective and useful, they were still being used well into the twentieth century. Waterwheels drove mechanisms that lifted water to irrigate fields, moved saws to cut wood, and turned millstones to grind grain into flour and wood into pulp for paper manufacturing. They were also used to power machinery that beat cloth with hammers in a **fulling mill**, and crushed a special kind of mined rock called 'ore' so that the valuable metals inside could be extracted.

Industrial Revolution

Along with the steam engine (see page 81), the waterwheel helped kickstart the Industrial Revolution in the United Kingdom. They powered enormous bellows used to heat blast furnaces in ironworks, hammers to shape molten metal into useful shapes, and spinning machines to produce cotton. The biggest waterwheel that still works is the Laxey Wheel on the Isle of Man. It's bright red, 22 metres in diameter and was built to pump water in 1854.

Laxey Wheel

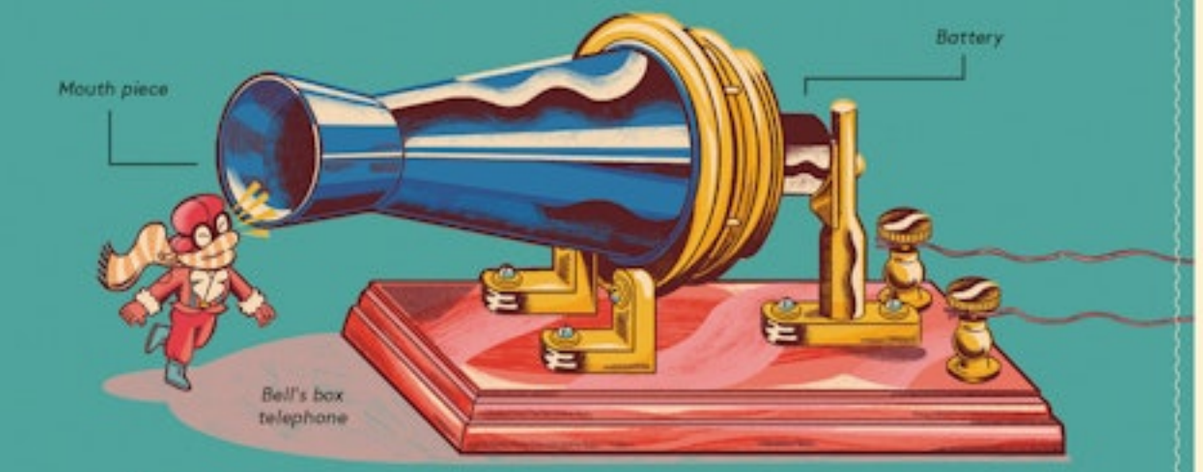
Telephone

38

"Long range communication"

The telephone changed the world because, unlike the mail and the telegraph, it gave people the ability to have an audible and instant conversation. The technology has not stopped developing since the first devices appeared. Before the telephone, in the 1840s, came the telegraph, an early text-messaging service. Messages could be sent from one telegraph to another through cables. A few decades later, in the 1870s, the telephone appeared. Assisted by African-American inventor Lewis Latimer (who also created an early air-conditioner), Scotsman Alexander Graham Bell first **patented** the idea with his own design in 1876. It worked by converting sound into an electrical signal that could travel along wires to a receiver. Early mobile phones were not very mobile! They were clunky, heavy and couldn't transmit signals very far. The first was the Motorola 8000X, which went on sale in 1983. It cost £3,000 (that's about £11,000 today) and had a battery life of 30 minutes! Mobile phone designs improved until they were small enough to fit in a pocket, had longer-lasting batteries, and could also send text messages.

Motorola 8000X



As well as creating his own telegraph design, American inventor Samuel Morse came up with morse code, a language used by telegraph operators, which uses combinations of short 'dot' and long 'dash' signals to represent letters.

Smart Phones

Smartphones are pocket-sized computers that do far more than make calls and send text messages. They first appeared in 1992. Developed by American tech company IBM, the Simon Personal Communicator was a mobile phone that could send emails and faxes. Smartphones really took off in 2007 when Apple released their first touchscreen iPhone. On a modern smartphone we can play games, browse the Internet, watch films, listen to music, navigate using GPS (see page 65), take photographs and videos, make payments and store data.

Money

39

"Making trading easy all over the world"

Money is used everywhere, all the time. Money can be exchanged in return for goods such as a bicycle, and services such as paying someone to work. Before money, people bartered with each other – swapping goods they had for goods they needed. For example, a crop grower might have swapped 10 bags of grain for a cow from a cattle farmer. Money was invented to make trade easier. It has an agreed value between buyer and seller, it can be exchanged anywhere, it can be carried easily and it's durable. The first metal coins, called staters, appeared in the Lydian Empire (located in what is now Türkiye) during the seventh century BCE. They were made from silver, a metal that is valuable because of its rarity. Paper money was first used in China around 1,000 years ago, because merchants were tired of carrying heavy coins. These days most financial transactions are done electronically using credit or debit cards, with no physical money changing hands at all.

People have made fake money (a crime called counterfeiting) since it was first invented. A common trick was to melt coins, add worthless metal to bulk out the mixture, then remake a larger number of coins.

The heads of kings, queens and rulers were often stamped onto coins to prove they were genuine. Archaeologists are able date the coins depending on whose image appears on them.

Peculiar Payments

There have been many weird and wonderful forms of money in the past. Knives, spades and seashells were used as forms of payment. Salt was once so valuable as a food preservative it was called 'white gold'. One of the most unusual currencies was used on the Solomon Island of Yap in the Pacific. The islanders' coins – called rai stones – were large limestone discs with a hole in their centres, and some were over three metres in diameter! Rai stones were valued not just on their size, but on how hard the stone was to obtain.

Soap

40

"Lather up to stay clean and healthy"

Before soap, people washed with water. The earliest soap was made in the ancient city of Babylon (located in modern-day Iraq) and dates to around 2800 BCE. It was made from animal fat mixed with wood ash, and was stored in pots. The grey, greasy, gritty mixture was used to clean clothes (not bodies!) and was very different to the soaps we use today. The ancient Egyptians used soap for medicinal purposes. In around 1550 BCE they wrote the *Ebers Papyrus*, one of the oldest medical books, which includes this soap recipe: 'Animal and vegetable oils mixed with alkaline salt'. Centuries ago in the West African nations of Nigeria, Togo and Benin, the Yoruba people made 'black soap' (known as *ose-dudu*), from shea tree bark and plantain skins. From around the second century CE more people began to use soap to wash themselves. However, it wasn't until the mid-nineteenth century CE that scientists discovered that germs caused diseases, and washing with soap lowered our chances of getting sick.

Soap is an excellent cleanser because it removes oil – something water cannot do on its own. Soap molecules 'grab' the oily substances and lift them off, so they can be rinsed away.

A soap factory, complete with preserved soap bars dating back to 79 CE, was found in the ruined ancient Roman town of Pompeii. At first, the ancient Romans used soap to treat skin disorders rather than clean themselves.

Smooth and Aromatic

The first scented soaps emerged from the Middle East around the ninth century. One of the earliest came from Syria. It was a green, olive-oil based bar infused with laurel oil. Other ingredients included flower petals, thyme and lavender. Soap recipes didn't change much until the nineteenth century, when ingredients and production methods improved to create smooth, colourful, pleasant-smelling bars. Soap got cheaper too, meaning anyone could afford to buy it.

Internal Combustion Engine

41

"The dawn of the automobile age"

From the late 1700s to the mid-1800s many engineers experimented with trying to create an engine that was smaller and more efficient than those driven by steam (see page 24). The earliest of these 'internal combustion engines' (which unlike steam engines burn fuel inside the engine) were powered with gas, but later by liquid fuels. Building on decades of research and advancement by other inventors, it was German engineer Nicolaus Otto who made the major breakthrough with his quiet and efficient 'four-stroke' petrol engine. Invented in 1876, it provided the basis for all the internal combustion engine designs that followed (although Otto never intended his to be used for transportation). The first automobile to use an internal combustion engine was invented by another German, Karl Benz, in 1885. His Motorwagen had three wheels, a 3hp (horsepower) petrol engine of his own design, and could travel up to 16 kilometres per hour. Faster and more powerful automobiles powered by internal combustion engines followed, but it wasn't until they were **mass produced** on assembly lines (see page 83) that ordinary people could afford them.

Benz's Motorwagen

Ford model T-1

DMC DeLorean

2021 F1

As well as millions of trucks, vans, buses, coaches and motorbikes, there are also about 1.4 billion cars on the road, with around 60 million more being manufactured every year.

How a four-stroke engine works:

1. INTAKE
The piston lowers and the intake valve opens, drawing in the air-fuel mixture.

2. COMPRESSION
The piston moves upwards and the air-fuel mixture is compressed.

3. POWER
When the piston reaches the top, the spark plug creates a spark, igniting the mixture.

4. EXHAUST
The piston moves downwards and the exhaust valves opens, drawing out the fumes.

Fuelling Up

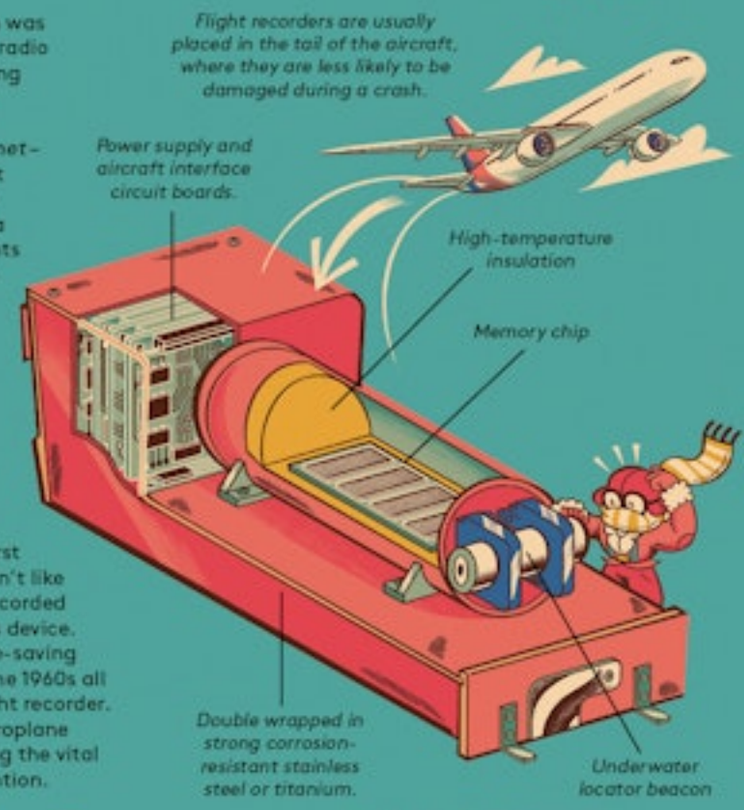
Most combustion engines run on petrol (also called gasoline) or diesel, and some use biofuels (made from organic matter such as plants) and ethanol (a type of alcohol). In a four-stroke engine, a mixture of air and fuel is drawn into the cylinders and their movement creates the power that makes an engine run. The internal combustion engine has given people the freedom to travel far and wide, but the emissions they produce are a major contributor to global warming.

Flight Recorder

42

"Safety record in a box"

When Australian David Warren was a boy, his father gave him a radio set. This gift sparked a lifelong love of electronics. As a young man in the 1950s, Warren was part of a team investigating why the *de Havilland Comet* – the first jet aircraft (see page 84) – kept crashing. Warren realised the mystery could be solved quicker if they had data from the aircraft during its last moments before the crash. So, taking inspiration from a miniature tape recorder, Warren set to work. In a few years he'd created a reusable device that recorded flight information (the 'flight data recorder' part, or FDR) including **altitude**, direction, speed and cabin pressure, as well as the pilots' voices from the cockpit (the 'cockpit voice recorder' part or CVR). Earlier inventors had tried to invent similar devices, but Warren's was the first that worked really well. Some pilots didn't like the idea of their conversations being recorded which led to some early suspicion of his device. However, airline companies saw the life-saving benefits of Warren's invention and by the 1960s all commercial airliners had to carry a flight recorder. Over the years, air travel safety and aeroplane designs have been vastly improved using the vital information gathered by Warren's invention.



Flight recorders are usually placed in the tail of the aircraft, where they are less likely to be damaged during a crash.

Power supply and aircraft interface circuit boards.

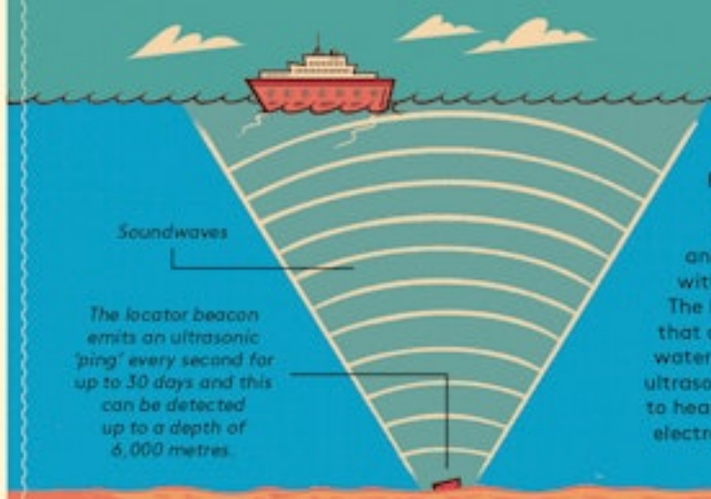
High-temperature insulation

Memory chip

Double wrapped in strong corrosion-resistant stainless steel or titanium.

Underwater locator beacon

The first thing investigators look for after a plane crash is the flight recorder.



Soundwaves

The locator beacon emits an ultrasonic 'ping' every second for up to 30 days and this can be detected up to a depth of 6,000 metres.

Built to Last

Flight recorders are known as 'black boxes', but they are painted bright orange so they can be found more easily. As well as being waterproof and fireproof, modern flight recorders are built to withstand the huge forces of high-speed impacts. The locator beacon helps investigators find aircraft that crash into the sea. Triggered when immersed in water, these small, battery-powered devices give off ultrasonic signals (which are too high for human ears to hear, but can be detected over long distance using electronic tracking devices) that guide search teams to the aircraft's exact location.

Transistor

43

"Behind every electronic device"

The transistor may be the smallest invention in this book, but this micro electronic component is one of the most world-changing. A transistor's job is to amplify, control and generate electrical signals. It is a vital part in every electronic device from satellites to submarines, telephones to toys, calculators to computers. (Although the transistor was invented in 1947 by American scientists John Bardeen, William Shockley and Walter Brattain, many other people supported their work and had already set the foundations in place to build on.) Wearable electric hearing aids were one of the first devices transistors were used for. They have a battery-powered sound amplifier attached to a small speaker that fits inside the ear. This life-improving piece of tech was only made possible by the tiny yet tremendous transistor. Appearing in shops in the mid-1950s, pocket-sized transistor radios were the first mass-produced devices that used transistors. They allowed people to listen to their favourite radio station wherever they were. Transistors allowed new technology to become smaller and paved the way for many later inventions in the field of electronics, most notably the computer.

Before transistors, electronic devices such as televisions and radios used glass vacuum tubes (also called 'valves') to control electrical currents, but they were large, consumed a lot of power and could overheat.

Super Micro Transistors

Of the billions of transistors manufactured every year nowadays, most are used in microchips, along with all the other electronic components that make our technology function. Over the years transistors have got smaller and smaller too. This means they can be used in large numbers. Some microchips contain trillions of microscopic transistors, which are used to create microprocessors – the tiny computers that power modern computers and smartphones.

Tea

44

"One of the most popular drinks in the world"

More than a quarter of the world's population drinks more than three billion cups of tea every day. But have you ever wondered who invented the teabag in your cup? Around 5,000 years ago, a Chinese emperor drank the first cup of tea, and he loved it. People began pouring boiling water over loose tea leaves to brew this relaxing beverage. However, getting rid of the used, wet tea leaves was a messy job. In 1901, Americans Roberta Lawson and Mary Molaren solved this problem with the 'tea leaf holder' – a fabric bag containing just the right amount of tea for a single cup. This idea caught on in a big way. In 1944 the first sealed square teabags made from paper fibre appeared, which are just like the ones we use today. In any supermarket you'll find shelves stacked with lots of different types – square, round, pyramid-shaped, and teabags with string tabs so that you can fish it out of the cup easily. Ah! Lovely! Time to put the kettle on.

Legend says that one day in ancient China, Emperor Shennong was boiling water to drink when a leaf from a tea plant landed in his pot. When Shennong sipped the tea-infused water, he found it refreshing.

Truths About Tea

To start with, the Chinese took tea as a medicine. Then they drank it as a relaxing beverage. All tea – including black, green, yellow, white and oolong – comes from an evergreen shrub called *Camellia sinensis*, commonly known as the tea plant. Only the youngest leaves – called 'flushes' – are picked from the tea plant because they have the best flavour. After water, tea is the second most popular drink in the world. In the United Kingdom, tea was very expensive in the sixteenth and seventeenth centuries. This meant smugglers could make a lot of money by importing it illegally.

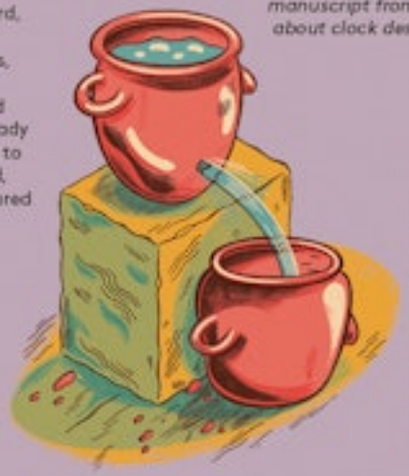
Timekeeping

"So you'll never need to be late"

Keeping track of time helps us plan our days, keep appointments and be more efficient. But the earliest timekeeping methods did not need objects, machines or numbers. It's likely that prehistoric people all over the world used observations of the changes in the natural environment to split daily time into 'daybreak', 'sunrise', 'morning', 'afternoon', 'late afternoon', 'sunset', 'evening' and 'night'.

Water Clock

Water clocks (also called *clepsydra*, from the Greek word, meaning 'water thief') were used by many ancient peoples, including in Mesopotamia (modern-day Iraq), Egypt and India. These clocks used a steady flow of water from one vessel to another. As the water drained, it revealed lines, which measured time intervals. Some of the indigenous American tribes of North America had a different method – they placed a floating vessel pierced with a hole into a bucket of water. Time was measured by how long the vessel took to sink.



Early clocks only had an hour hand. The first record of a minute hand appeared in a manuscript from 1475 about clock designs.

Sundials

Sundials were first used by the ancient Egyptians and Mesopotamians (people who lived in what is now modern-day Iraq) from at least as early as 1500 BCE and they are still used today. A sundial can be a stick stuck in the ground or a towering stone obelisk in a public square. As the Sun moves across the sky, the upright part casts a shadow, and the position of the shadow on the ground tells you roughly what time of day it is.

Candle, Oil and Incense Clocks

Candle clocks were used in China from around 520 CE. Marks representing intervals of time were made in the wax and as the candle burned down the marks could be counted off. Oil lamp clocks had timings marked on the lamp's fuel container. Incense clocks, used in China and possibly India, gave off different smells as each hour passed.

Mechanical Clocks

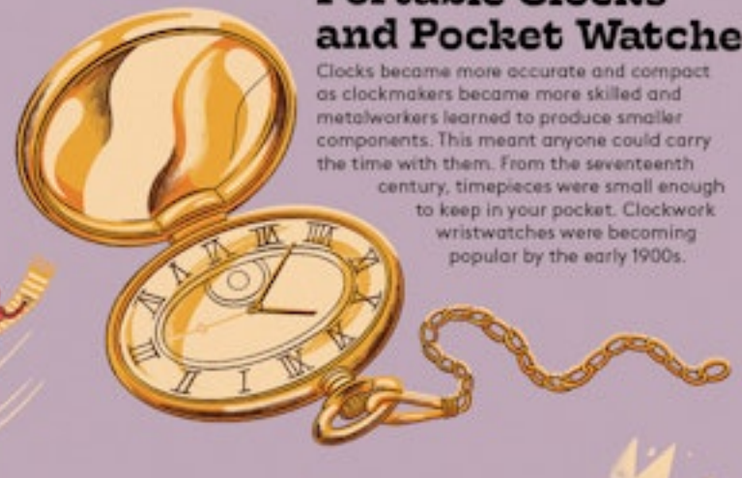
Mechanical clocks were invented in the Medieval period. They work by using weights attached to interlocking cogs, gears and springs. The weight gradually drops, causing this mechanism to move, which in turn rotates the hands around the dial at a constant speed. Clocks with loud bells inside church towers and town buildings let everyone know what time it is.

Pendulum Clocks

Italian astronomer, scientist and engineer Galileo Galilei realised that a swinging pendulum suspended beneath a clock kept accurate time. However, it was Dutch inventor Christiaan Huygens who first built a working pendulum clock in 1657. Far more accurate than all previous timekeeping methods, pendulum clocks, such as the tall grandfather clock, also created the tick-tock sound we associate with the passing of time.

Portable Clocks and Pocket Watches

Clocks became more accurate and compact as clockmakers became more skilled and metalworkers learned to produce smaller components. This meant anyone could carry the time with them. From the seventeenth century, timepieces were small enough to keep in your pocket. Clockwork wristwatches were becoming popular by the early 1900s.



Quartz Watch

The first quartz clock was invented in 1927 and the first quartz wristwatch in 1969. Quartz crystals vibrate when charged with electricity from a battery, and these vibrations measure time so accurately, quartz timepieces lose only one-third of a second per year. Most modern clocks and watches are powered by batteries.

Early atomic clocks like this Caesium-133 type were huge in size.

Atomic Clock

Atomic clocks are the most accurate timekeeping devices ever invented. In the late 1940s scientists in the United States showed that time can be measured using atoms. Atoms are the smallest unit of matter, and they vibrate with incredible reliability. By measuring this resonance, atomic clocks maintain near perfect time, losing only one second every 140 billion years!

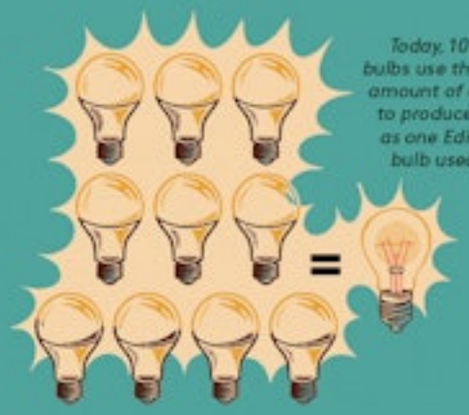
Electric Lightbulb

46

"Lighting up the world"

For centuries we lit our homes with candles, flaming torches and oil lamps, but now all we have to do is flick a switch. As simple as it seems, it took many years of painstaking experimentation before the first successful lightbulb was invented. In 1802, English chemist Humphry Davy created the first electric light by passing an electric current through a strip of platinum. However, his 'electric arc lamps' produced a lot of heat and didn't last long. But other inventors learned from his discovery. In 1840, British scientist Warren De la Rue made a longer-lasting lightbulb by using a vacuum-sealed glass tube. This tube protected a platinum filament – the thin piece of metal that creates a lightbulb's glow, but the platinum proved too costly to be practical. Slowly but surely, scientists were getting closer to their world-changing goal of inventing a long-lasting, practical and affordable lightbulb. In 1878, after many experiments, English chemist Joseph Swan used the vacuum design with a filament made from carbon – it lasted for more than 10 hours but then burned out. American inventor Thomas Edison built on Swan's work and discovered that a plant-based filament in a perfect vacuum tube cast a pleasant light for an astonishing 1,200 hours. Swan and Edison joined forces to sell 'Ediswan's Incandescent Lamps' and the age of instant light began.

Electric streetlamps are easier to operate than the gas lamps they replaced, and by casting a brighter light they make streets safer.



Today, 10 LED bulbs use the same amount of energy to produce light as one Ediswan bulb used to.

The Ediswan Bulb

The problem with incandescent bulbs is that they waste a lot of energy creating useless heat instead of useful light. The more efficient, low-energy Ediswan bulb was invented around a century ago. It used up to 80 per cent less energy, and lit up when an electric current was passed through a tube containing a gas called argon and a tiny amount of mercury vapour. This process generates invisible ultraviolet radiation, which excites the molecules inside the tube in a fluorescent coating called phosphor. This creates useful visible light.

Gunpowder

47

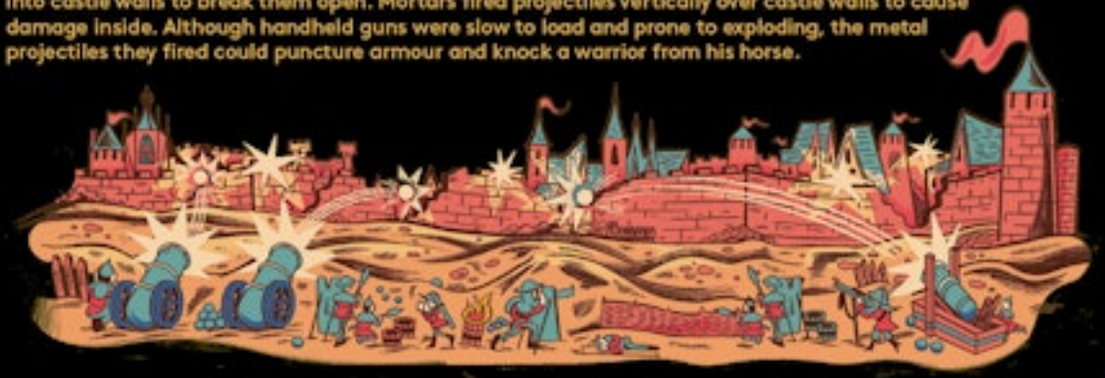
"Exploding powder for fireworks and war"

It's believed that gunpowder was invented in the ninth century CE by Chinese alchemists who were trying to concoct a medicinal potion to give them everlasting life. Indeed, the Chinese word for gunpowder – *huoyao* – actually means 'fire medicine'. It's strange to think that their experiments mixing sulphur, saltpetre (a naturally occurring mineral) and charcoal created an explosive material with the power to take life rather than extend it. Because gunpowder is noisy and creates bright, dramatic explosions, the ancient Chinese used it to create awe-inspiring firework displays – just like we do today. They used bamboo sticks filled with gunpowder and tossed them on a fire. When the gunpowder ignited, it blasted the sparking, fizzing, popping tube into the air. But these displays were not just about entertainment, they were also used to scare evil spirits away, and celebrate births and weddings.

These days fireworks contain chemicals to create beautiful multicoloured displays including copper salts for blue, strontium salts for red and barium salts for green.

Fire, Shot and Smoke

Gunpowder changed warfare by making weapons deadlier than ever before. By the tenth century, the ancient Chinese were attaching fireworks to arrows, creating the first explosive projectiles. In the eleventh and twelfth centuries the ancient Chinese and Mongols were using early forms of hand-thrown bombs and wall-breaking cannons. Cannons used the explosive power of gunpowder to propel solid iron balls horizontally into castle walls to break them open. Mortars fired projectiles vertically over castle walls to cause damage inside. Although handheld guns were slow to load and prone to exploding, the metal projectiles they fired could puncture armour and knock a warrior from his horse.



Textiles

48

"Wonderful weaves"

The discovery of specialised bone tools in Morrocco suggest humans were wearing animal-skin clothes around 120,000 years ago. The oldest needle, from 50,000 years ago, was found in South Africa, and others have been uncovered in China, Russia and Spain. Textiles – manufactured fabrics or cloths, which can be used for making clothes and other goods – came much later. Some of the oldest textile fragments come from Peru. Made with plant materials and probably used for clothing, baskets, floor coverings and bedding, they were woven around 12,000 years ago. One of the earliest dyed cotton textiles, found to be over 6,000 years old, was also found in Peru. Coloured blue using indigo (a dye from a plant), this beautifully woven piece of fabric shows the skill and technological know-how of the ancient South Americans. Textiles were created independently by civilisations all over the ancient world, including India, Africa, China, the Americas and Europe. Throughout history, people have worn clothes to cover themselves, keep warm and stand out from the crowd, so the art of textile-making is constantly evolving and improving.

Peruvian woven cloth

Sleeved tunic

Chinese silk purse

Wool socks

The process of producing silk textiles from silkworms began in China around 3000 BCE and was a closely guarded secret.

South American Nasca mantle cloth

The Art of Spin

Textiles can come from plants, such as cotton and flax; animals, such as wool and silk; or human-made materials, such as acrylic and nylon. First, these materials are processed, usually 'spun' on a spinning wheel, into strong lengths of yarn. Next, the yarn is woven to form the textile. This process is done on a machine called a loom, which can be mechanised or operated by hand. After the fabric's been woven, it's cleaned, then dyed, printed or patterned, and finally stretched out on frames. Then it's ready to be turned into clothes, rugs and a myriad of other products.

Television

49

"Home entertainment box"

If we can send sound through wires, can we send images too? That's the question scientists began asking themselves following the invention of the telegraph and the telephone (see page 47). In 1883, German inventor Paul Nipkow invented the electric telescope, which was a spinning disc that projected black and white images transmitted through wires. Nipkow's device played a vital role in television's development, although the first television set didn't appear until years later. In the early 1900s many more scientists improved on each other's ideas to create television. Then in 1925, Scottish inventor John Logie Baird built a working television using items including an old tea chest, a hatbox, a pair of scissors, darning needles and Nipkow's electric telescope. Baird demonstrated his device by transmitting moving images of human faces, and in 1928 founded his own television company. Televisions slowly improved, pictures got sharper, sound was included and TV stations transmitted plays and dramas. People built televisions from kits and sat entranced in front of flickering black-and-white screens.

Many people in the early 1900s dismissed the idea of the television as a waste of time and money because they couldn't think of a way to profit from it. How wrong they were!

Dawn of the Television Age

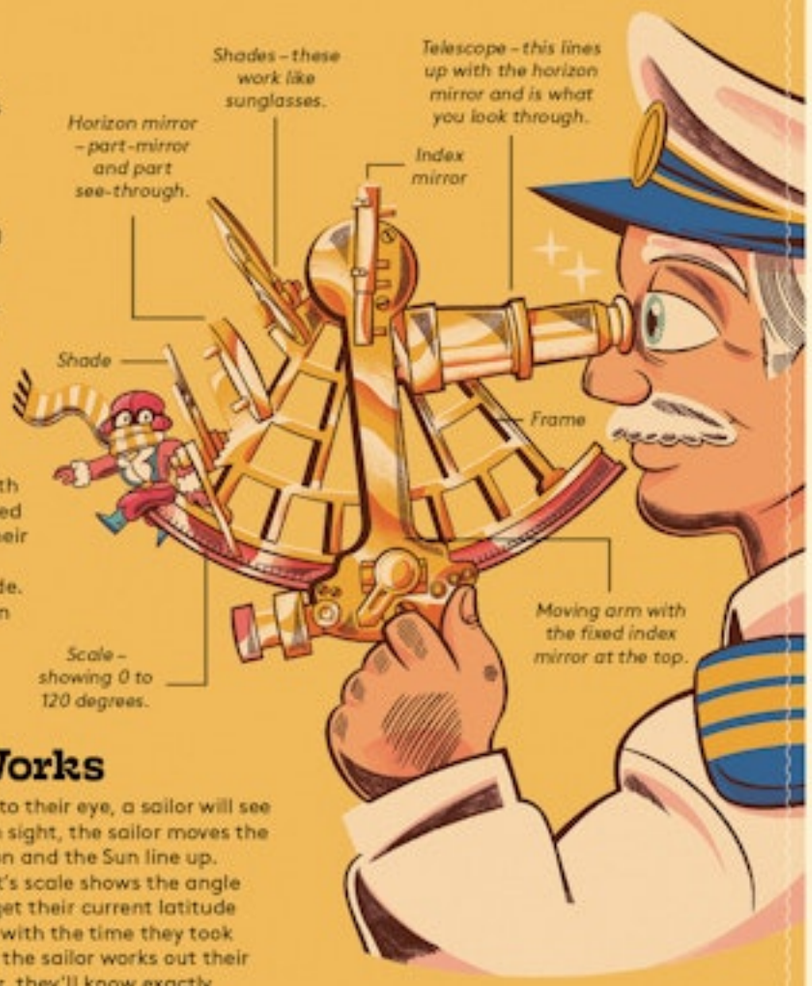
By the 1930s, Nipkow's mechanical disc had been replaced by all-electric cathode ray tube technology, which created a much sharper image. The television really took off (especially in the United States) in the 1950s as sets got cheaper. (Baird had demonstrated the first colour television in 1928 by transmitting images of a young girl wearing different-coloured hats, but in 1928 colour TV took over from black and white.) Nowadays, nearly every house in the world has a colour television capable of showing hundreds of channels dedicated to all manner of shows from cartoons and comedies to documentaries and dramas. But don't watch too much or you'll get square eyes!

Sextant

50

"Helping you find your way at sea"

When sailing on the high seas, how can you tell your position if all you can see is sea? Well, for thousands of years after the ship's invention (see page 68), most sailors stayed within sight of the shore. This helped vessels to travel from port to port without losing their way. To navigate on the open sea, you need to know two things: your latitude and your longitude. Your latitude is how far north or south you are from the equator, which is the imaginary circle around the Earth halfway between the North and South poles. Your longitude is how far east or west you are from the meridian, a line which runs north-south through Greenwich in England. Invented in the 1750s, the sextant told sailors their latitude. Invented in 1761, the marine chronometer told sailors their longitude. By providing exact positions even when thousands of kilometres out to sea, these two instruments made a new age of exploration possible.



How a Sextant Works

When holding the sextant's telescope to their eye, a sailor will see the horizon mirror. With the horizon in sight, the sailor moves the arm to adjust the view until the horizon and the Sun line up. The position of the arm on the sextant's scale shows the angle between the horizon and the Sun. To get their current latitude the sailor references this angle, along with the time they took the reading, against sea charts. Once the sailor works out their longitude using a marine chronometer, they'll know exactly where they are in the world to within a few hundred metres.

1. Hold the sextant and look through the telescope at the horizon.

2. Move the arm to line up the bottom edge of the Sun with the horizon.

3. Rotate the sextant to check the two are lined up, then read the angle from the scale.

English genius Sir Isaac Newton designed a type of sextant but never published his idea. In 1730 Englishman John Hadley and American Thomas Godfrey both developed the sextant at the same time (independently of each other).

Games Console

51

"Endless hours of fun"

The first computer games had no graphics and no sound. They were developed in the 1950s and 60s, were usually text or number-based, and needed huge computers to run. It was German-born American engineer Ralph Baer who came up with the idea of a games console that could be hooked up to a television. Just like the consoles of today, his 'Brown Box' had two controllers, and it could play several games. By 1972 Baer had developed his concept into the Magnavox Odyssey, the very first games console available to buy. Most of the Odyssey's games were based on sports like tennis, hockey or ping pong. Two players controlled a racquet or bat (represented by a movable white line, one on each side of a black screen) to hit a ball (a moving white square) back and forth. Although it didn't sell well, the Magnavox Odyssey kick-started the console age.

Home Entertainment

Since the Odyssey, games console development has never stopped. Companies compete fiercely to create the biggest-selling devices and the most exciting games. Consoles capable of running games with sound and colour appeared in the late 1970s, along with joysticks and games on cartridges rather than built into the console. The first hand-held consoles appeared in 1979, as well as classic games such as Tetris and Pac-Man. Modern games consoles like the Microsoft Xbox and Sony PlayStation are as powerful as desktop computers and capable of running games with hundreds of levels and photorealistic graphics.

Plastic

52

"A wonder material"

Human-made plastic is all around us. We package parcels with plastic tape, we wear clothes made from plastic fibres, we drink from plastic bottles and we brush our hair with plastic brushes and combs. But did you know natural plastics occur in plants, animal horns and even inside our bodies? What makes plastics so special are the long, flexible chains of molecules, called polymers, that make them **malleable**. The first manufactured plastic was created in 1869 by American John Wesley Hyatt. He used the plastic found in plants called cellulose to make a soft substance that could be shaped then hardened into a waterproof material he called celluloid.
The first manufactured plastic using non-natural (synthetic) material was invented in 1907 by Belgian-born American Leo Baekeland. He mixed waste from coal tar with formaldehyde and called it 'Bakelite'. Many more plastics followed, including transparent, shatterproof acrylic in 1928, used for windows; soft, lightweight polystyrene in 1839, used for packaging; flexible, durable vinyl in 1872 used for shower curtains, and the most-produced plastic in the world, polyethylene, in 1898, used for wrapping.

The Olmec people of Mexico were the first to use natural plastic by making rubber balls from gumtree sap 3,500 years ago.

The Problem with Plastic

As plastic became so economical to produce, many products such as shopping bags, bottles and straws were designed to be used once then thrown away. It has become a big problem for the environment. We create over 390 million tonnes of plastic every year, and a huge amount ends up in the oceans where it entangles, chokes and poisons sea creatures. Modern plastics can take centuries to break down and when they do, they can form tiny plastic particles called 'microplastics'. If these get inside us or other animals, they might cause illness. There are things we can do to help, including recycling more and avoiding single-use items. Plastic manufacturers can make more biodegradable plastic alternatives. Scientists have even discovered that some organisms love eating plastic, which could be a way to help tackle plastic waste in the future.

Refrigerator

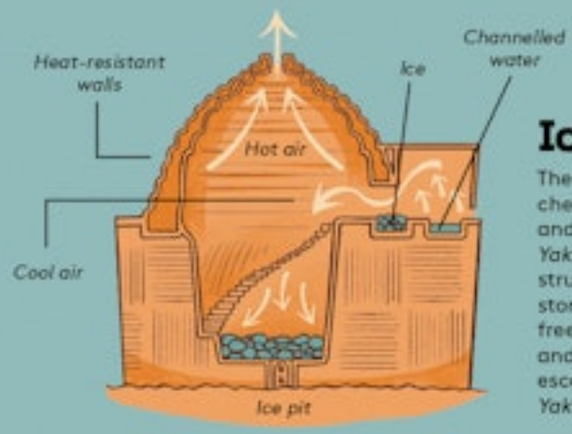
53

"A new ice age"

For a long time, humans have known that storing food in cool streams, caves, cellars or pantries helps keep it fresh. In 1756 Scottish scientist William Cullen demonstrated artificial refrigeration by boiling a liquid chemical called diethyl ether inside an airtight container. When the diethyl ether evaporated, it absorbed the warmth inside the container. This lowered the temperature so much that ice formed!
Inspired by Cullen's work, other scientists did their own refrigeration experiments. In 1805, it was American inventor Oliver Evans who came up with the idea for a food-and-drink preserving fridge, which could work continuously by keeping the chemicals needed to chill the air contained inside a closed pipe system. Evans never actually built one, but in 1835, American inventor Jacob Perkins did, and his design is the basis of all modern fridges. The first electric-powered fridges for home use appeared in the early 1900s. Early models used dangerous chemicals and cost nearly twice as much as a car at the time. Fridges were constantly improved by many clever people, leaving us with the energy-efficient, ice-making, internally-lit units we have in our kitchens today.

*Refrigerators keep food fresh because the cool temperature slows down the growth of rot-causing **bacteria**.*

*In the 1930s, African-American inventor Frederick Jones developed a **portable** refrigeration unit for trucks, which was used to make sure food and blood for transfusions didn't spoil on long journeys.*



Ice Houses

The Persian Empire (modern-day Iran) didn't need chemicals or electricity to refrigerate their food, or make and store ice. By 400 BCE this civilisation were building *Yakhchāl* – which means 'ice pit'. *Yakhchāl* are large, domed structures of heat-resistant mortar built over underground storage pits. Water is channelled to the *Yakhchāl*, where it freezes overnight. Cool air enters through holes in the walls and sinks to the bottom of the pit. Hot air rises and escapes from a hole in the roof. These processes keep the *Yakhchāl* cold, even in the burning heat of the Middle East.

Maps

"Helping us find our way"

54

For millennia, humans have recorded their surroundings by drawing two-dimensional maps: stars in the sky, settlements, villages and towns. Then, as people explored further afield, maps expanded to include countries, continents, and finally the whole world. One of the oldest-known maps is painted on a cave wall in France. Created around 16,500 years ago, it's thought to show a star cluster called Pleiades. One of the earliest examples of a **portable** map dates from between 10,000–12,000 BCE. It's inscribed onto a woolly mammoth tusk and is thought to show a series of dwellings by a river. A brilliant map from the ancient Mesopotamian empire of Sumer (modern-day Iraq) was etched onto a clay tablet in around 1500 BCE. It includes notations in cuneiform (see page 70), and shows a city called Nippur surrounded by royal estates. The Turin Papyrus Map from ancient Egypt was drawn around 1150 BCE showing the exact location of rock formations, it was used to help decide the location of a quarry. Around 500 BCE, the first world map is believed to have been created by an ancient Greek **cartographer** called Anaximander. It shows what the Greeks believed the world to be, and includes only the continents of Africa, Europe and Asia surrounded by ocean. Today, photographs and images taken from aeroplanes and satellites have allowed us to accurately map the Earth's surface.

Archaeologists believe the art at the Lascaux Cave includes a group of stars called the Summer Triangle, and the star cluster Pleiades.

The Turin Papyrus Map, marks different rock types and the rises and dips in the land. It also shows the location of an ancient gold mine!

On the mammoth bone map, the lines represent the rivers that existed in the area.

Anaximander reportedly believed that Earth was shaped like a cylinder, and that humans lived on the flat top surface. By the third century BCE the ancient Greeks knew the world was a sphere, unlike the Mesopotamians who thought it was flat.

Map of the World

The oldest-surviving globe was made in 1492. It was called *Erdapfel*, which means Earth Apple in German. *Erdapfel* is very different to modern globes, as mapmakers at the time didn't know other areas, such as the Americas, Australasia or Antarctica, even existed as large parts of the Earth hadn't yet been explored.

GPS

"You are here"

55

The Global Positioning System (GPS) has put the whole world in our pocket. This navigation system uses a network of satellites orbiting in space and receivers on the ground to pinpoint where you are anywhere on Earth down to a matter of centimetres. It can also guide you wherever you want to go, whether to the nearest cinema or the other side of the world. Development of GPS began in the 1960s by the American military to help submarines keep track of their locations. Many people worked on the project and, in the 1980s, it was opened up for free use by anyone in the world. Ivan Getting, one of the minds behind the system, called satellites 'lighthouses in the sky' when he proposed how the system could work. You can use GPS on smartphones, tablets, computers and vehicle satnavs. Easier to read than paper maps, GPS works to show your location and movements as they actually happen in real time, tell you the quickest route to your destination, and provide up-to-the-minute information on traffic jams and route diversions.

The ground stations use radar to monitor and control the satellites.

A GPS receiver, like the one inside your phone, is always listening for a signal from these satellites. Once the receiver calculates its distance from four or more satellites, it knows exactly where you are.

Hidden Figure

An important contributor to the creation of GPS was African-American mathematician Dr Gladys West. She began work as a computer programmer and satellite data analyser for the US Navy in 1956. She used the data to work out an accurate measurement of Earth's shape, an extremely complex task and one that has made the Global Positioning System highly accurate.

Sandwich

56

"Simple but scrumptious"

You've probably eaten a sandwich before. It might even have been today! We know that people have enjoyed tasty fillings contained inside different types of bread all over the world for centuries – probably for as long as bread has existed. Today the sandwich is one of the most popular foods in the world, and hundreds of millions of them are eaten every day. But why are they so popular for satisfying a rumbling stomach? They are easy to make, easy to carry, and you can put anything you fancy inside, savoury or sweet. One of the earliest-known sandwiches was invented by a Jewish religious leader called Hillel the Elder in the first century BCE. He suggested placing lamb meat and herbs inside two **matzo flatbreads**. Today, popular fillings include meats, cheeses, fish, salad, pickles, sauces and peanut butter and jelly. I bet you're hungry after reading this. Go on... make your favourite sarnie!

The invention of packaged pre-sliced bread in the 1920s made making sandwiches easier, quicker and – by removing the need for a sharp bread knife – safer.

Sandwich Spread

But when did they start being called 'sandwiches'? Well, the story goes that an English **aristocrat**, John Montagu, the fourth Earl of Sandwich, was playing cards with friends in the late 1700s. He didn't want to leave the gaming table to eat, so he asked the cook to put some meat inside two slices of bread. This meant he could eat with one hand, hold his cards in the other and carry on playing. The idea caught on among the English nobility, spread throughout Europe and beyond, and it became known as the 'sandwich' after the Earl.

Martial Arts

57

"Human combat in action"

For early people, the need to fight off animals – and other humans – using their bodies and brute strength was a matter of survival. Cave paintings in Spain depicting scenes of human warfare are thought to date back to 10,000 BCE. Over time, methods of human combat began to develop into thought-out practices that could be taught. Wrestling and boxing are thought to be the oldest-known combat sports. *Malla-yuddha*, an early form of wrestling-boxing, dates from around 3000 BCE in India. Though martial arts are commonly associated with East Asian cultures, they are not unique to Asia, but during the Warring States Period in China (480–221 BCE), a time of intense fighting between seven states, combat strategy developed extensively in the region. Combinations of kicks, punches, wrestling and weapon use were honed into what we recognise as martial arts today. Kung-fu, Karate, Judo and Jiu-jitsu are prominent martial arts practised around the world today, but they are relatively new in the history of martial arts. Other types of martial arts include *Pentjak silat* (Indonesia), *Iua* (Hawaii), *Savate* (French), *Capoeira* (Brazil) and *Kalaripayattu* (India).

The word 'martial' derives from the name of Mars, the Roman god of war.

All martial arts share the same objective: to defeat a person physically or to defend oneself from physical threat.

At the Olympics

In the sport of *pankration*, a combination of boxing and wrestling, almost anything went! This human combat sport originated in Ancient Greece around 2000 BCE and became an Olympic sport in 648 BCE. It is said to have its roots in mythology, used by the hero Heracles to defeat the **Nemean Lion** and Theseus to kill the **minotaur**. The only moves not allowed were biting, gouging of eyes and other body parts or attacking your opponent's private parts! Outside of the Olympics, *pankration* was used by the Greek army in warfare.

Ships

"Vessels to sail the open sea"

58

It's much quicker and easier to travel and transport **cargo** over water than land, so it's no surprise that humans have been inventing new types of ocean-going vessels for thousands of years. Here are a some notable designs.

Ancient Sailing Ships

The ancient Phoenician (modern-day Lebanon) and Egyptian civilisations ventured into the Mediterranean to trade with their neighbours from around 3000 BCE. Their vessels had rounded wooden hulls to store **cargo**, square sails, a row of oarsmen, and were steered with a long paddle at the stern. These ships were often brightly painted and had carved wooden figureheads at the front.

Polynesian Voyaging Canoes

Around 3,000 years ago brave explorers from Southeast Asia undertook epic journeys of discovery into the Pacific. Their remarkably stable wind-powered voyaging canoes were made with two narrow hulls lashed together with rope and boards. Each hull was crafted from a carefully hollowed-out tree trunk and had a sharp prow for slicing through the waves.

Junk

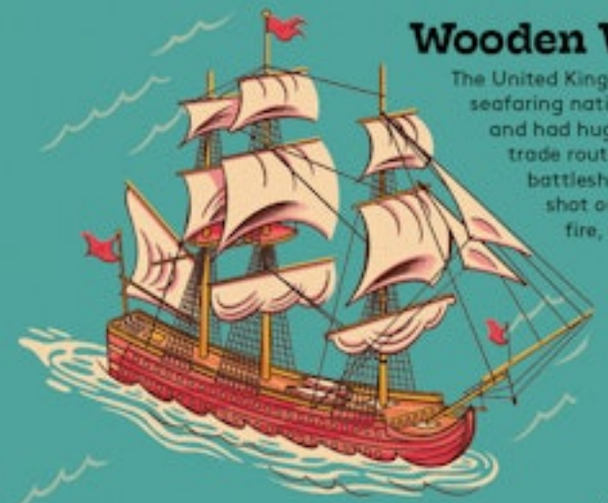
Chinese and Japanese sailing junks first appeared around 200 BCE, and motorised versions are still used today. The junk's sails, wide hulls and wedge-shaped prows made them durable and capable of carrying lots of **cargo** over even rough seas, and their flat bottoms allowed them to dock in shallow waters. Provisions and **cargo** were stowed in watertight compartments.

Norse Longboat

From around 800–c.1200 the ferocious **Norsemen** known as Vikings built state-of-the-art longships. These sleek, swift vessels were perfect for raiding, trading and exploration over sea or up rivers. Their strong hulls were shaped so they could travel backwards as well as forwards, and were light enough to be hauled across land.

Wooden Warships

The United Kingdom, France and Spain were the most powerful seafaring nations of the eighteenth and nineteenth centuries and had huge fleets of warships to protect their shores, trade routes and overseas empires. Some of the biggest battleships had over 100 cannons in long lines, which shot out deadly balls of solid metal when they opened fire, filling the air with noise, fire and smoke.



Clippers

In the mid-1800s the race was on to transport luxury goods, such as tea, from China to Europe. Clippers were built for speed, with narrow hulls of **wrought iron** and wood, and sharp prows. The fastest clipper, *Cutty Sark*, raced along at 32 kilometres per hour.

Ocean Liners

From the nineteenth century, ocean liners driven by powerful and reliable steam engines allowed people to travel all over the world in comfort and luxury. One of the most-famous ocean liners was the RMS *Titanic*. Launched in 1912, she carried 2,240 passengers, was 269 metres long and 62 metres high. She sank on her first voyage after scraping against an iceberg.

Container Ships

Before the 1950s, **cargo** was loaded onto ships in whatever odd-sized crates, boxes and sacks it arrived in. This was inefficient and time consuming. The problem was solved with the invention of containers, which are all the same size and can fit together like building blocks.

Numbers

59

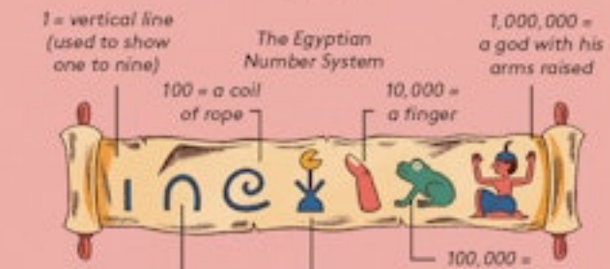
"Numerals, digits and decimal points"

A number is a value that represents quantity, often shown as a symbol (for example, 1) or a word (one). First, numbers were used for simple things like counting animals in a herd. But as life became more complicated, bigger numbers were needed. The earliest-known evidence of counting is the Lebombo bone – a 40,000-year-old baboon leg bone discovered in Southern Africa with notches carved into it. They are thought to be tally marks, with each notch representing a '1'. From at least 3000 BCE, people in Mesopotamia (modern-day Iraq) recorded numerical information by imprinting marks on clay tablets. The tablets included details of volumes and weights of goods like grain, milk and beer, as well as areas of land. From around the same time, the ancient Egyptians began using a set of hieroglyphs (picture symbols) to represent different values, based on the number 10. To write large numbers, symbols were repeated as many times as needed. Developed between the eighth and ninth centuries BCE, the ancient Romans used a numerical system of seven letters. Like the Egyptian system, it was also based on 10 and letters were repeated to show larger numbers, but big numbers were cumbersome to write (for example, 1984 = MCMLXXXIV).

The notches on the Lebombo bone were possibly used to track the passing of days or lunar cycles.

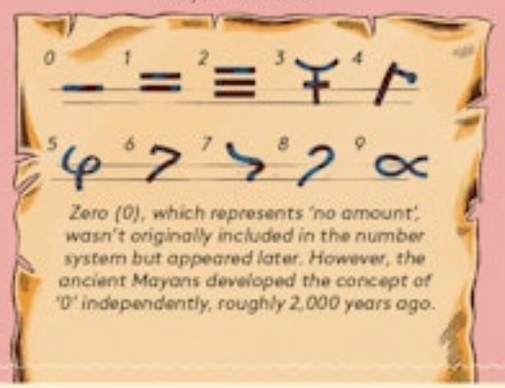
The Mesopotamian technique called 'cuneiform' was based on 60, which can be divided by lots of other numbers (1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30 and 60). Today it can still be seen in how we measure time (60 minutes in an hour).

The Egyptian Number System



With Roman numerals, larger values come first and lower values follow. Repeating a symbol doubles the value (XX = 20). If a numeral appears in front of one with a larger value, you subtract instead of add (IV = 4).

Mayan Numerals



Zero (0), which represents 'no amount', wasn't originally included in the number system but appeared later. However, the ancient Mayans developed the concept of '0' independently, roughly 2,000 years ago.

Hindu-Arabic Numerals

Perfected in India in the eighth century, the 'positional system' gives a number a value depending on where it appears. For example, '1' on its own represents 'one', but the '1' in '10' represents ten, and the '1' in '100' represents a hundred. This system can show any number using a combination of only 10 symbols, and the addition of the 'decimal point' allows us to show fractions (a number value less than '1'). The digits used worldwide today (0–9) were developed in the Maghreb region of North Africa.

Wheelchair

60

"Transportation for disabled people"

A wheelchair designed for disability was created in 1595 for King Philip II of Spain, who suffered from a painful joint disease called gout. Sometime in the seventeenth century a self-propelled wheelchair was invented by German watchmaker Stephen Farfler. He had lost the use of his legs but still wanted to get around under his own steam. Using his clock-making skills, he built a wooden three-wheeled chair he could drive by turning handles fixed to the front wheel. In the 1750s, inventor James Heath, of Bath, England, saw the need for a chair that was lighter, more practical and more comfortable, so he created the 'bath chair'. There was a handle on the front wheel that allowed the rider to steer when being pushed. More than a century later, around 1890, a wheelchair that could be moved by the rider by pushing the wheels was invented by Frenchman Eugene Vincent. In the 1930s, American mechanical engineers Harry Jennings and Herbert Everest invented the first lightweight, foldable wheelchair. Most modern non-motorised wheelchairs are still based on their design.

Farfler's chair

A slate in China, from around 1500 BCE, shows an image of a wheeled chair.

Folding wheelchair

Modern Wheelchairs

These days there are many wheelchair types made for people living with a disability, including motorised wheelchairs, and wheelchairs with headrests, backrests, armrests and leg-rests that can be raised or lowered. Wheelchairs used by disabled athletes for adapted sports such as basketball, tennis and racing are specially designed and built to be sturdy, strong and speedy.

Submarine

61

"The under-the-water sailing vessel"

Designing a safe submarine involves solving a lot of difficult problems, and failure means almost certain disaster for the crew. Submarines must be watertight, strong enough to withstand huge amounts of pressure, and be capable of travelling in all directions including up and down. They must also provide the crew with all the oxygen, food, water and living facilities they need for their whole journey. These are the reasons why the development of a truly successful submarine took centuries to achieve. Back in 1620, Dutch inventor Cornelis Drebbel launched his oar-powered submarine into the River Thames, although we don't know if it could actually submerge. Much later, in 1775, American David Bushnell designed the single-seater *Turtle* to sneak up on enemy warships and plant explosives. *Turtle* was hand-operated, hard to steer and demanded nerves of steel to pilot. The advancements of technologies such as batteries, motors and engines in the nineteenth century brought new models of submarine that could stay submerged longer and travel further. However, submarines didn't become truly safe and successful until the twentieth century.

To submerge the Turtle, its pilot had to increase the vehicle's weight by letting water inside the bilge tank.

Stealthy Subs

Modern military submarines are designed to travel anywhere in the world without being detected by aeroplanes, ships or other submarines. Propellers are shaped to make hardly any sound as they cut through the water, and hulls are covered in sound-insulating material so that noise inside the vessel doesn't get out. Although stealthy, some of these monstrous machines are 150 metres long – that's the size of one-and-a-half football pitches. Powered by nuclear energy, these submarines can stay submerged for months at a time. The first nuclear-powered submarine, the USS *Nautilus*, travelled submerged all the way to the North Pole in 1958.

Toothpaste

62

"White, bright and fresh"

Would you rub your teeth with powder made from crushed bone, ash from burnt ox hooves, or salt to clean them? It might sound disgusting but that's how people in the ancient world did it! They also used oyster shells, mint leaves, honey and a scent called myrrh. Surprisingly, some of these mixtures were pretty effective. Things improved in the 1800s with the invention of tooth powders, which contained baking soda, ground chalk and brick dust. Water was added to turn the powder into paste. When the first minty-fresh toothpaste was mass-produced from 1873, it came in glass jars and soon became very popular. The first tubes of toothpaste appeared in the late 1880s. Most modern toothpastes contain ingredients that clean and whiten teeth, prevent cavities and gum disease, and freshen breath. Better than burnt ox hoof, that's for sure!

American inventor Leo Marraffino created stripy toothpaste because he thought children would brush their teeth more frequently if their toothpaste looked like a candy stick.

Up until the 1700s, people wrongly believed that tooth cavities were caused by tiny creatures called 'tooth worms'.

Go and Brush your Teeth!

Toothpaste came before the toothbrush! People in ancient Egypt and Babylon (modern-day Iraq) used twigs frayed at the end and the Chinese used similar 'chewing sticks' made from aromatic wood. In 1770, Englishman William Addis invented the first mass-produced toothbrush – while he was imprisoned in London for rioting. He hated cleaning his teeth by using a rag to rub soot or crushed eggshells onto them. So he carved an animal bone saved from his supper into a handle, then drilled small holes at one end, inserted stiff boar bristles into the holes, and glued them in place. After his release, Addis set up a company to manufacture his toothbrush.

Nuclear Power

"The power of splitting the atom"

63

In 1938, scientists discovered that power could be released by, literally, splitting atoms apart. This discovery was ground-breaking and scientific research into how this new source of energy could be used got underway. The age of nuclear power had begun.

Nuclear Science

Most nuclear energy is generated using the element uranium through a process called nuclear fission – the splitting of an atom's nucleus in two. This process can be started by firing subatomic (smaller than an atom) particles at uranium atoms. When an atom splits, it releases more subatomic particles, setting off a chain that splits more and more atoms. This process can be controlled in a nuclear reactor, to generate a supply of energy. However, when it is uncontrolled, the energy is explosive. This is what is seen in atomic bombs.

Energy Generation

During the 1940s and 50s, despite its complexity and risks, the development of nuclear power became the focus of nuclear research, with the aim of providing a supply of affordable energy for the world that didn't rely on fossil fuels. Electricity was generated by nuclear power for the first time in 1951, in Idaho, USA, but it really took off in the 1960s when, over the next two decades, many reactors were built around the world. Inside a nuclear power plant are a series of nuclear reactors containing uranium surrounded by a cooling liquid. Inside the reactors is where the process of nuclear fission happens. This releases heat, which is used to generate steam, which turns turbines to create electricity. Compared to the burning of coal or gas, nuclear fission releases much more energy from a relatively small amount of fuel. It doesn't release pollution into the atmosphere, but it does create dangerous radioactive waste, which must be stored safely.

Destructive Power

Atomic bombs are the most destructive weapons ever invented. They have only ever been used twice during warfare. Their development began immediately after the discovery of nuclear fission in 1938 and sped up during the **Second World War**, as each side – the German-led **Axis** Powers and the Allied Powers including the United Kingdom, France and the United States – raced to reach a breakthrough first. By 1945, the **Allies** had successfully built and tested two atomic bomb designs. On 6 August, 1945, an American bomber dropped a uranium-fuelled atomic bomb on the Japanese city of Hiroshima. Three days later, a more powerful plutonium-fuelled bomb was dropped on the city of Nagasaki. The bombs destroyed the cities and killed at least 100,000 Japanese people and many more died later from the effects of the fallout.

Disarmament

In 1968, the United States and USSR – the two states with the largest arsenal of nuclear weapons at their command – signed the Treaty on the Non-Proliferation of Nuclear Weapons. This treaty is designed to promote the peaceful use of nuclear power (such as for energy generation) and prevent the spread of nuclear weapons, with the ultimate goal of removing them from the world altogether. Since 1968, 191 countries have signed this treaty.

Other Uses

Nuclear energy powers vehicles and machines, too. Some sea vessels, such as aircraft carriers, and submarines are powered by nuclear reactors instead of combustion engines. This allows them to travel at high speeds for long periods of time. Spacecraft, such as *Cassini*, which travelled more than 1.5 billion kilometres to explore Saturn, and the *Perseverance* rover on Mars, were powered by nuclear batteries containing plutonium. The future of space travel may see nuclear-powered rocket engines that use the process of fission to travel much longer distances at faster speeds.

Snowmobile

64

"A smooth way to travel across ice and snow"

If there's snow on the ground a modern snowmobile can take you anywhere. They can tear across icy lakes, swerve through forests, scale alpine slopes, leap over snowdrifts and reach speeds of up to 150 kilometres per hour. The first successful snowmobile was designed by a Canadian inventor called Joseph-Armand Bombardier in 1960. His K60 Ski-Doo had a motor-driven caterpillar track at the rear and two steerable skis at the front. To this day snowmobiles still follow his design. Apart from being awesome fun to ride, snowmobiles allow people who live in remote, snowbound places, such as areas of Scandinavia, Canada and North America, to travel and pick up supplies.

Originally called the 'Ski-Dog', a printing error in the first advertising brochure misspelled it as 'Ski-Doo', but people liked it, so the name stuck!

Kevlar

65

"A wonder material that's stronger than steel"

What material is strong enough to stop a speeding bullet? In 1965, American chemist Stephanie Kwolek accidentally invented Kevlar while working on creating a new material to improve vehicle tyres. Kevlar, as the invention was later named, is a type of plastic that's been spun into fibres and woven together. Not only is it flexible and heat-resistant, it's also a staggering five-times stronger than steel. In just a few years, Kwolek's 'wonder material' was being used in a range of life-saving applications, including body armour, helmets and face masks for soldiers and police officers, protective clothing for motorcyclists and miners, and fire-resistant outfits for firefighters. This tough material has saved the lives of thousands of people.

The pouches in bulletproof body armour are filled with layers of Kevlar. Each layer is flexible and lightweight, allowing the wearer to move quickly and freely.

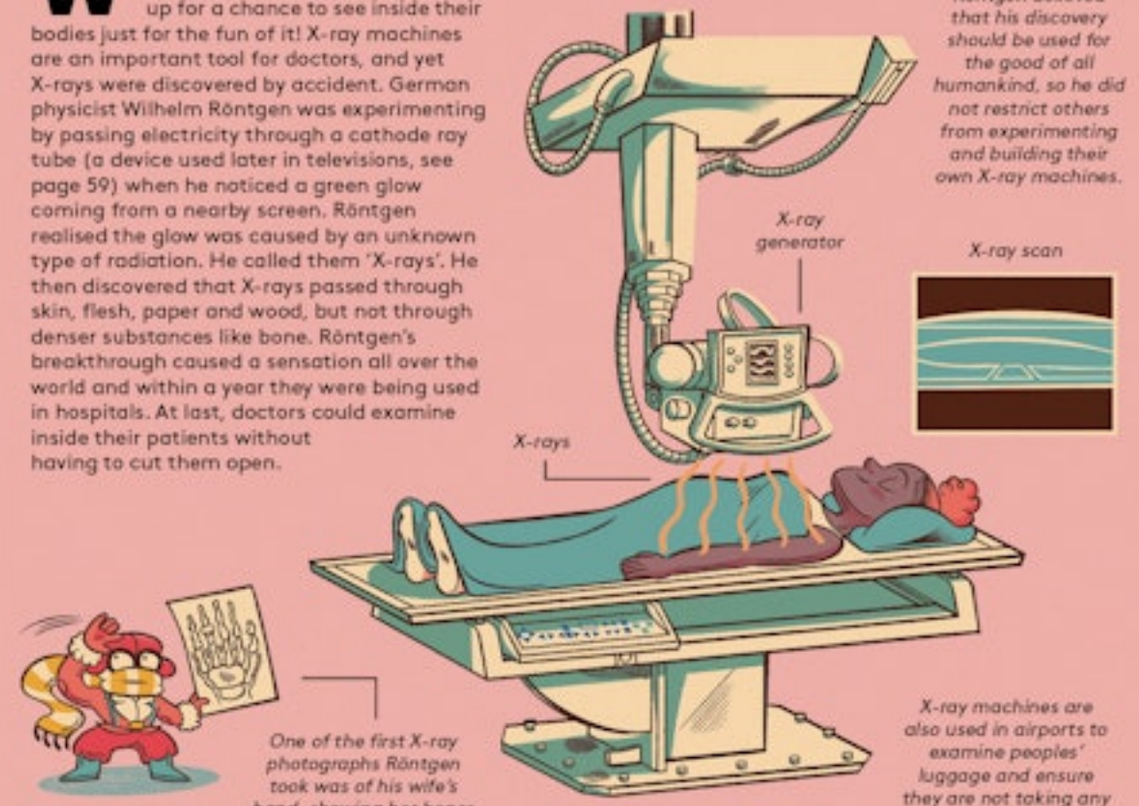
X-Ray Machine

66

"Looking inside the body"

When the X-ray machine was invented in 1896 people queued up for a chance to see inside their bodies just for the fun of it! X-ray machines are an important tool for doctors, and yet X-rays were discovered by accident. German physicist Wilhelm Röntgen was experimenting by passing electricity through a cathode ray tube (a device used later in televisions, see page 59) when he noticed a green glow coming from a nearby screen. Röntgen realised the glow was caused by an unknown type of radiation. He called them 'X-rays'. He then discovered that X-rays passed through skin, flesh, paper and wood, but not through denser substances like bone. Röntgen's breakthrough caused a sensation all over the world and within a year they were being used in hospitals. At last, doctors could examine inside their patients without having to cut them open.

Röntgen believed that his discovery should be used for the good of all humankind, so he did not restrict others from experimenting and building their own X-ray machines.



One of the first X-ray photographs Röntgen took was of his wife's hand, showing her bones and wedding ring.

X-ray machines are also used in airports to examine peoples' luggage and ensure they are not taking any weapons or explosives onto the plane.

Little Curies

Polish-born Marie Curie was a brilliant chemist and physicist who specialised in radiation. Among her many amazing achievements was her life-saving work with X-ray machines during the First World War (1914–18). Curie knew that wounded soldiers were more likely to survive if they were X-rayed and diagnosed quickly. To enable this she converted trucks into mobile X-ray machines and trained nurses to use them. Then Curie and her courageous team drove to the battlefields to tend to the wounded on the spot. It's estimated that Curie's 'Little Curie' X-ray vans treated over one million soldiers during the war.

Stirrups

67

"Staying in the saddle"

One of the simplest inventions in this book, the stirrup completely changed the way battles were fought. Humans **domesticated** horses around 6,000 years ago. Since then, horses have ploughed our fields, hauled our loads, and carried us on our travels and into battle. From around 500 BCE the **nomadic** Scythians people of Asia were using saddles made from cushioned leather. Riders stayed on by gripping the horse's sides with their legs. When riding quickly or during battle, this was difficult, and accidents would have been common. However, the invention of the stirrup changed this. It's not known exactly where or when the stirrup first appeared, but some evidence suggests it was in China around the second century. These simple metal devices hung down on either side of the saddle from leather straps, and made it easier for riders to mount, stay on, and dismount, which meant that mounted warriors could stay firmly in the saddle even when wearing armour and riding at top speed. By the middle of the eleventh century, European and Middle Eastern battlefields were dominated by heavy cavalry – armour encased, lance-wielding knights capable of charging into foot soldiers and smashing them aside like scarecrows.

Small leather toe-stirrups were being used in India in the second century BCE. They increased stability and were perfect for riders who rode barefoot in the hot sun!

Along with the lance, sword and ***mace****, fear was one of the Medieval knight's most effective weapons. It took a brave foot soldier to stand their ground as a thundering line of cavalry bore down on them.*

Ancient Chinese Stirrups

Evidence for stirrups in China has been found in ancient art and inside sealed tombs. A figurine showing a rider using a mounting stirrup (only used to help the rider into the saddle) was discovered in a tomb in 1974, and dates to around 302 BCE. A figurine showing a pair of riding stirrups dates to around 322 BCE. The earliest real stirrups found (also in a tomb in China) date to 415 BCE.

Radio

68

"Long-distance wireless communication"

The invention of radio communication came about in the 1890s, thanks to technology developed for the telegraph and the telephone. A radio detects radio waves and transmits them from a speaker as sound without the need for wires. Like visible light, radio waves are a type of electromagnetic wave – waves of travelling energy that have an electric and magnetic field. Their existence had been predicted before being proven by German physicist Heinrich Hertz in 1887, and inventors and scientists immediately began to work out how they could be used. In 1894, English physicist Oliver Lodge demonstrated a radio receiver that rang a bell when it picked up radio waves from the next room. In 1895, Russian physicist Alexander Popov created a radio receiver that could detect lightning 30 kilometres away and Indian physicist Jagadish Chandra Bose conducted experiments into the way that electromagnetic waves worked. Italian inventor Guglielmo Marconi created a radio device for long-distance communication that would prove that radio communication was possible.

On 24 December 1906 the first human voice was heard over the radio waves. Canadian American inventor Reginald A. Fessenden made the first broadcast of entertainment and music to a general audience, from the coast of North America.

Radio Revolution

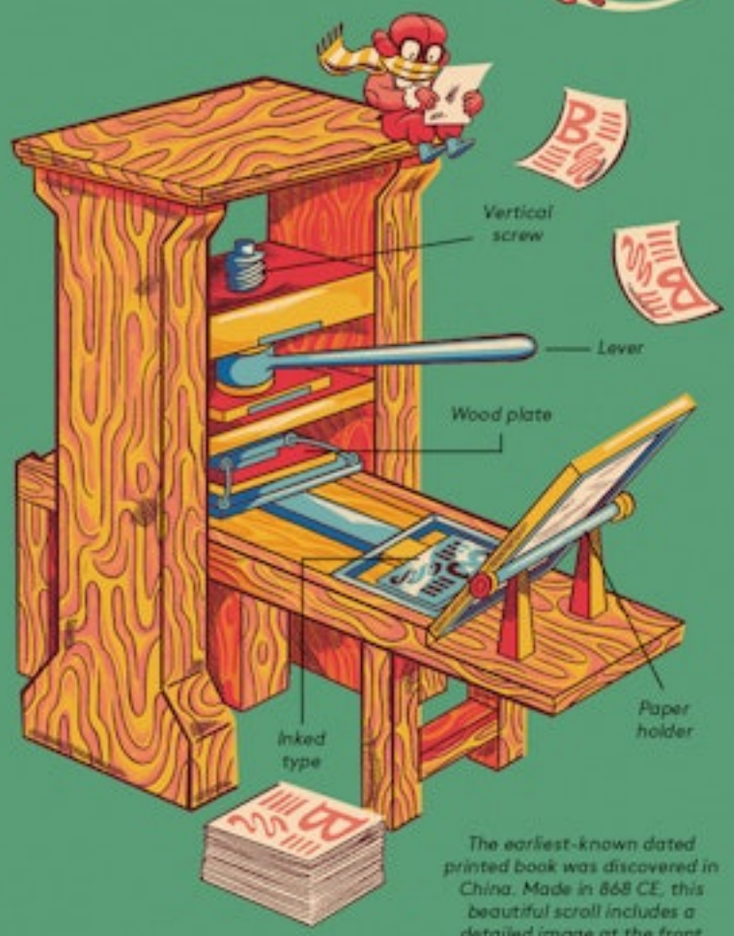
Shipping companies quickly realised how useful radios could be, and they were soon being used for ship-to-shore and ship-to-ship communication – including distress signals. Radios also played an important role in communication during the **First World War** and later the **Second World War**. But it wasn't until the 1920s when 'the Golden Age of Radio' began. This was when AM (amplitude modulation) became established, a method of transmission that allows complex sounds – from speech to music – to be broadcast and received. Governments set up their own radio companies to broadcast news, music, plays and documentaries directly into people's homes.

Printing Press

69

"Spread the word"

The fastest modern printing presses can produce 70,000 full-colour newspapers every hour – that's 19 per second! These massive, automated machines work around the clock churning out all the books, magazines, newspapers and comics we read. The first really fast printing press was invented in the 1450s by a German goldsmith called Johannes Gutenberg. He based his revolutionary design on machines used for squeezing grapes and olives. Gutenberg made a page of writing by pressing a sheet of paper down onto ink-covered metal blocks. These blocks had raised letters and punctuation points on them and were arranged to make words and sentences. Using this 'movable type' printing method, Gutenberg's press could produce 3,600 pages every day, which was much faster than ever before! With more people reading than ever before, Gutenberg's cheap pamphlets and books, helped revolutionary ideas about politics and religion to spread like wildfire across borders and seas.



The earliest-known dated printed book was discovered in China. Made in 868 CE, this beautiful scroll includes a detailed image at the front called a 'frontispiece'.

The First Printers

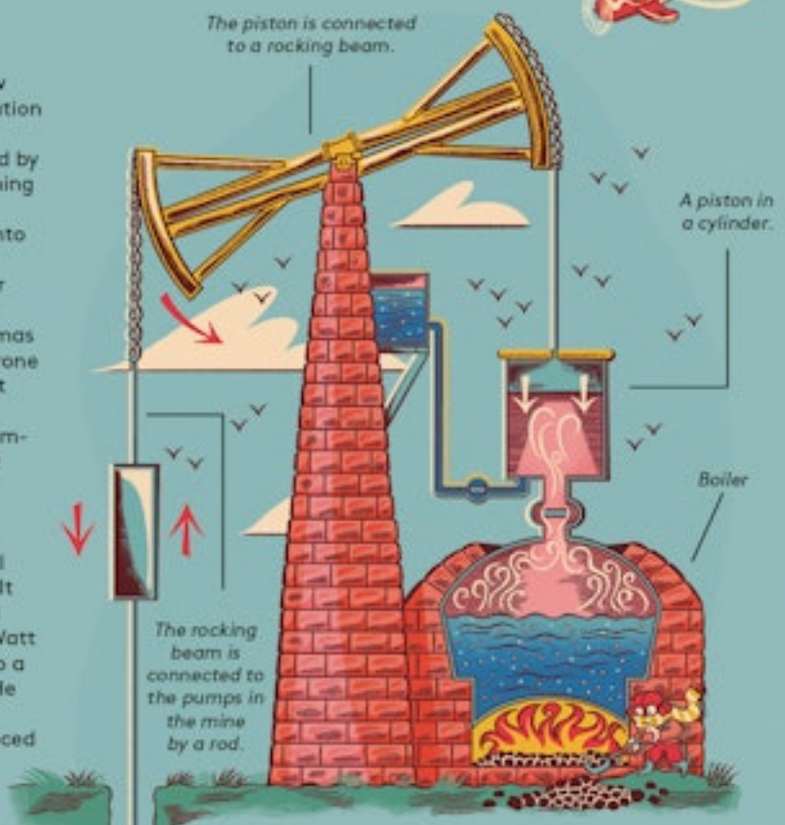
Important printing techniques had been mastered in East Asia long before Johannes Gutenberg was even born. Woodblock printing, where flat pieces of wood carved with words and pictures were covered in ink and pressed by hand onto paper, was being used in China from the seventh century. The first movable type (made from baked clay) was invented around 1041 CE. Metal movable type appeared in the early thirteenth century. These crucial ideas spread to Korea and Japan, and eventually westward to Europe. Without them, Gutenberg would never have been able to create his famous printing press.

Steam Engine

70

"Turning water into power"

You probably already know that the Industrial Revolution of the eighteenth to nineteenth centuries was powered by thousands of steam engines, turning countries such as the United Kingdom and the United States into industrial giants. One of the first useful steam engines was a water pump for draining mines. It was invented by English engineer Thomas Savery in 1698. However, it was prone to exploding and needed frequent repairs. Englishman Thomas Newcomen also developed a steam-driven water pump in around 1712 and for the next 50 years, his 'atmospheric engine' provided factories with water and drained flooded mines – including the coal mines that fuelled his machines! It was a young Scottish mechanical instrument maker called James Watt who turned the steam engine into a truly world-changing invention. He saw how inefficient Newcomen's engine was and, in 1774, he produced a steam engine that was more powerful, more efficient and far easier to operate. From that point onwards, steam engines were used to power not only water pumps, but cranes, steamships, traction engines, steam locomotives, and machines in factories and mills.



The cylinder is filled with steam from the boiler, pushing the piston up and, in turn, lowering the plunger in the water pump. Then cold water is injected into the cylinder to change the steam back to water and create a vacuum. This pulls the piston down and raises the plunger in the water pump.

Ancient Steam Power

What you might not know is that the very first steam engine was invented way back in the first century! The ancient Greek *aeolipile* was a metal sphere suspended over a cauldron. Steam was fed into the sphere and when enough pressure had built up the steam blasted out from nozzles, making the sphere rotate. Although ingenious, the *aeolipile* had no practical purpose. However, in 1551, Syrian scientist Taqi al-Din described something that was really useful. His steam-machine directed a concentrated jet of steam at a series of flat blades (or 'vanes') attached to a meat-roasting spit. The steam jet moved the vanes, which in turn rotated the meat so it cooked over a fire.

Portable Music

71

"A whole album in your pocket"

The compact cassette tape was invented by the Philips company in Belgium in 1962. This small plastic device, which stored sound on magnetic tape, soon overtook vinyl records as the main way people listened to and shared music. Cassette tape players got ever smaller, and when the Sony Walkman appeared in 1979 it completely changed the way we listen to music. This battery-powered cassette tape player was small and lightweight enough to snap onto a belt or fit into a pocket. One press of the chunky 'play' button made your favourite tunes pour through stereo headphones wherever you might be: relaxing in your bedroom, walking to the shops, catching the bus to school, lounging on the beach, jogging in the park or exercising in the gym. In 1984 Sony released the D-50 Discman, the first **portable** CD player. CDs create better-quality sound than a cassette and allow the listener to instantly skip between songs whereas tapes had to be fast-forwarded and rewound, which took longer. However, the Discman was prone to skipping because of the delicate laser technology inside that read the CD. By the 1990s, **portable** CD players were more popular than **portable** cassette players.

Sony also released a double-tape Walkman version, a waterproof version, and even one that was solar powered.

*Many manufacturers released their own **portable** cassette players, but none were as popular as the Sony Walkman. Between their invention in 1979 and discontinuation in 2010, around 200 million cassette Walkmans were sold.*

Digital Audio Players

The first **portable** music players that stored music digitally in an onboard hard drive appeared in 1998. These devices, known as Digital Audio Players (DAPs), were smaller and lighter than their predecessors, and took advantage of previous electronic inventions, including the transistor and microchip (see page 52). The user loaded music onto the DAP's hard drive from a computer, choosing albums from their collection to play on the go. The Apple iPod, the first DAP that saw widespread popularity, appeared in 2001 and could hold thousands of songs. DAPs are now a standard feature on most modern smartphones.

Assembly Line

72

"The birth of mass-produced cars"

The first moving assembly line was so quick it turned piles of parts into fully painted and driveable cars in only one and a half hours. The idea came from American car manufacturer Henry Ford. He wanted to manufacture vehicles as quickly as possible and, by 1925, 10,000 gleaming Ford Model T automobiles were rolling out of his factories every day. Workers stood in lines along the long factory floor as the car's chassis (base frame) moved along a conveyor belt at about two metres per minute. Each worker did a single job, such as fit the engine, attach a wheel, screw in a seat, again and again, until the chassis had become a finished automobile. The moving assembly line, plus the mass-produced and identical parts used to make the cars, cut production costs and allowed Ford to sell his Model Ts cheaply. Even people on modest incomes could afford one. Ford's invention also led to other companies taking up the idea, transforming car manufacturing into the automated industry it is today.

Although Ford's assembly line employees were well paid, having to do the same task hundreds of times all day was so dull it caused some workers to leave for manufacturers who built cars the old-fashioned way.

Ancient Assemblers

There was one moving assembly line that came centuries before Ford's. The Venetian Arsenal, a complex of shipyards and armouries, was built in Venice in the twelfth century. By the sixteenth century it employed 16,000 workers and the whole operation ran incredibly smoothly. Rope, timber and cloth were delivered regularly. All the parts of each ship were standardised (made identical) to speed up construction. The ships moved along a canal to be built stage-by-stage by the ship builders known as shipwrights. At the end of the canal the galley was ready to sail the wide blue waters of the Mediterranean.

Jet Engine

73

"Fast flying machines"

In the late 1920s, daredevil English pilot and engineer Frank Whittle began work on inventing a new aircraft engine that would be much faster than the propeller engines already in use: the jet. Not only did he have to create the engine, he also had to design an aircraft strong enough to use it. In 1941, as the **Second World War** raged, Whittle fitted his gas-turbine jet engine into a Gloster E.28/39 test aircraft. The flight was a success and proved jet engines worked. Three years later Great Britain's first jet fighter – the *Gloster Meteor* – roared into the air powered by two of Whittle's turbojet engines. Unknown to Whittle, a German engineer called Hans von Ohain was also designing a jet engine at the same time. Although Ohain started a few years later, he progressed faster because he had government support. In 1939 Ohain successfully tested his turbojet engine in a Heinkel HE-178 test aircraft. In 1944, the Germans sent Messerschmitt ME 262 fighter jets into combat. Capable of speeds up to 870 kilometres per hour, the ME 262 proved that the future of flight was jet powered.

Most modern jet aircraft are fitted with fuel-efficient turbofan engines, which use spinning fans to pull air into the combustion chamber to greatly increase thrust.

The aircraft is pushed forwards by the force of the gases coming out of the back of the engine.

The Gloster Meteor was a successful aircraft. Around 4,000 were built and used over the world. In 1946 a Meteor F4 broke the jet aircraft speed record.

Jet engines draw in air from the front.

A jet engine burns fuel, which releases exhaust gas.

The Jet Age

Whittle and Ohain, plus the many other inventors who contributed to the technology, kickstarted a 'jet age' that is still with us today. From the late 1940s, many inventors around the world competed to design jet planes – both military and civilian. Powerful enough to propel large aeroplanes smoothly and at high speed with hundreds of passengers on board, the jet engine made commercial flight possible. Commercial jets have made global travel easier, safer and more affordable. Today, tens of millions of passengers fly every year.

Robot

74

"Harder, better, faster, stronger"

The word 'robot' comes from the Czech word robota which means 'forced labour'

Fictional robots that do the work previously carried out by people appeared 40 years before the invention of real industrial robots. They were dreamed up by Czech science-fiction writer Karel Čapek in 1920 for his play *R.U.R.* His robots are artificial humanoid slaves who rise up and destroy their human masters. Luckily, the real industrial robots we use now have not done the same thing to us ... yet! Most robots used in factories don't look anything like people. The first industrial modern robot was invented in 1951 by American engineer George Devol. Called Unimate, it was a digitally operated and programmable hydraulic arm that moved hot metal components around automobile factories. In 1978 the far more sophisticated PUMA (Programmable Universal Machine for Assembly) arrived, which could do very precise jobs like welding and painting. The vast possibilities for how robots could be used was immediately recognised, and in the decades that followed robot development took off.

Curiosity Rover

In the future, we can be sure that robots will be faster, stronger, more intelligent and self-reliant than ever, especially with the advance of artificial intelligence (AI) that allows robots to think for themselves and learn – just like we do!

World of Robots

Nowadays robots are used for all sorts of jobs. Surgeons use robots with automated arms to help them perform delicate brain operations. Four-legged robot 'dogs' are used to carry equipment and **cargo**. We've sent robot rovers to Mars to explore the surface. Programmed to perform certain tasks as well as being remotely controlled, Mars Rovers have built-in laboratories for testing the atmosphere, soil and rocks that they gather.

RADAR

75

"Early Warning System"

RADAR (which stands for radio detection and ranging) uses radio waves – a type of electromagnetic radiation used in communication devices such as radios and televisions – to detect aircraft, ships, submarines and even weather from many kilometres away. Some modern RADAR can track objects over 1,000 kilometres away. Before RADAR was invented, many scientists were laying the groundwork in research in this field. In the late 1880s, German physicist Heinrich Hertz demonstrated how radio waves reflected off metal objects like an echo. In 1904 Christian Hülsmeyer, another German physicist, went on to create the 'telemobilescope', a transmitter-receiver system that could detect ships far out at sea by bouncing radio waves from their hulls, helping to avoid collision. Many countries, including the United Kingdom, United States, Germany and the USSR realised how useful RADAR could be as an early warning system against sea or air attacks. Throughout the 1930s these countries worked hard and in complete secrecy from each other to develop the best RADAR technology.

Weather radar uses microwaves to track the speed and movement of precipitation, and estimate whether it's rain, hail, sleet or snow.

Blips on a radar screen show the position and direction of travel of ships and aircraft.

Plan position indicator radar display

Wartime RADAR

In the build-up to the **Second World War**, the United Kingdom was desperate to protect its cities, factories and airbases against future bombing raids. By 1938, Scottish scientist Robert Watson-Watt had built a series of RADAR stations along Britain's south and east coasts. These stations could detect enemy aircraft from about 130 kilometres away and told the operators how high and from which direction they were flying. Without the crucial information RADAR provided to the Royal Air Force, it's possible the United Kingdom and her allies would have lost the crucial Battle of Britain (July–October 1940) against Nazi Germany, which might well have changed the outcome of the **Second World War**.

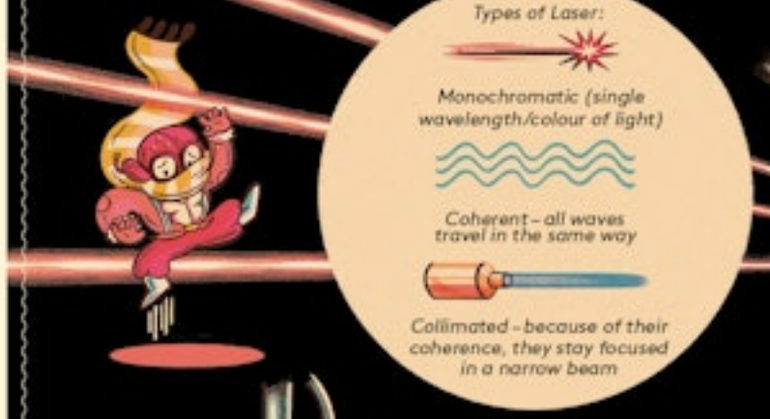
Lasers

76

"Concentrated light"

Lasers emit light that is made from only one wavelength, or colour (unlike visible light, which is made of many). This means it can be focused onto tiny spots and travel long distances without losing strength. Today lasers are common and used for many things including scanning barcodes, reading DVDs and information stored on computer hard drives to cutting, engraving, melting and welding materials, measuring distances and speed, and creating light shows. They are even used in medicine, especially cancer treatments, and eye and cosmetic surgery. However, when lasers were first developed scientists weren't quite sure what to use them for. One scientist said lasers were 'a solution looking for a problem'. Development began in the 1950s, with physicists basing their research on the ideas of earlier scientists' work on light, microwaves and electromagnetic radiation. In May 1960, American physicist Theodore H. Maiman created the first working laser by pulsing light from a photographer's flash lamp at a fingertip-sized ruby; it was used to measure distances. A few months later, scientists Ali Javan, William Bennett and Donald Herriott created a continuous infrared laser beam using helium and neon. One of the first practical uses followed in 1963, when researchers in Michigan developed lasers that could create holograms.

American physicist Gordon Gould came up with the name 'laser', which stands for Light Amplification by Stimulated Emission of Radiation.



Some lasers concentrate light so intensely they can damage eyes and skin, and cause fires.

Light that Cuts

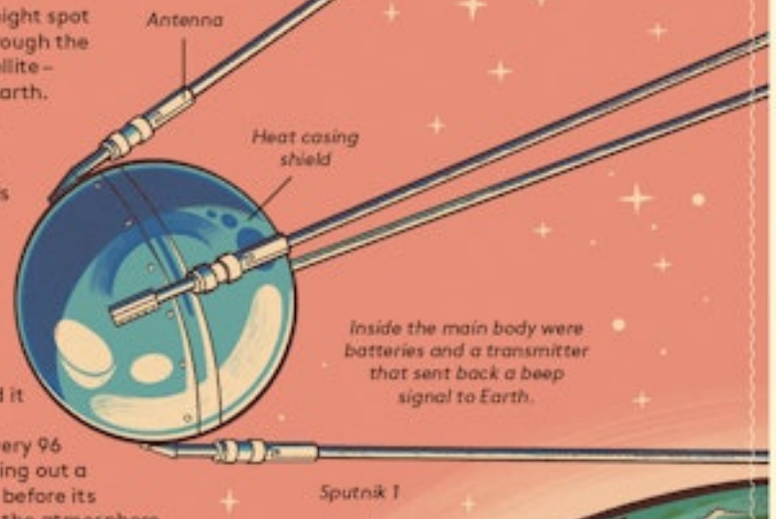
Laser cutters use laser beams to cut through, or engrave intricate patterns, pictures or words onto many different materials, such as metal, plastic, glass and stone. Laser cutters are great at these jobs because the intense heat they create (it's the heat that does the cutting and engraving) can be focused onto a tiny point, and the computers controlling the laser are super-fast and accurate.

Satellite

77

"Orbiting observers"

Gaze into the night sky and you might spot a bright, steady light moving through the darkness. Chances are it's a satellite – one of thousands of spacecraft orbiting Earth. You might not realise it, but satellites are an essential part of our everyday lives. Communication satellites transmit radio, television, Internet, GPS and phone signals all over the world. The **USSR** was the first to develop and launch a satellite into space. *Sputnik 1* blasted off on 4 October 1957, stunning the world. It was small, with a diameter of 58 centimetres and weighing 83 kilograms. It's shiny airtight sphere was made from an alloy of aluminium, magnesium and titanium and it had four long, backwards-pointing radio antennae. *Sputnik 1* orbited Earth once every 96 minutes, gathering information and sending out a steady beep-beep radio signal for 21 days before its batteries died. After 57 days it re-entered the atmosphere and burned up. *Sputnik 1* launched the Space Race, a fierce competition between rivals the USSR and the Unites States to gain superiority in spaceflight. Since *Sputnik 1*, satellites have exploded in size and number.



Inside the main body were batteries and a transmitter that sent back a beep signal to Earth.

Sputnik 1

Sentinel-2

All satellites have a power source and an antenna: the power source is either a battery or solar panels, and the antenna sends and receives information from Earth.

Super Satellites

We use satellites to watch and monitor Earth and space. Observation satellites take amazingly detailed photographs of Earth's surface, track weather patterns, and gather information about the oceans, the ice caps and natural disasters like volcanic eruptions. They help **archaeologists** find undiscovered historical sites such as ancient burial mounds and ruined cities. Satellites equipped with sophisticated cameras and telescopes look deep into space at comets, planets, stars, black holes, nebulae and galaxies that are millions of light years away.

Space Rocket

78

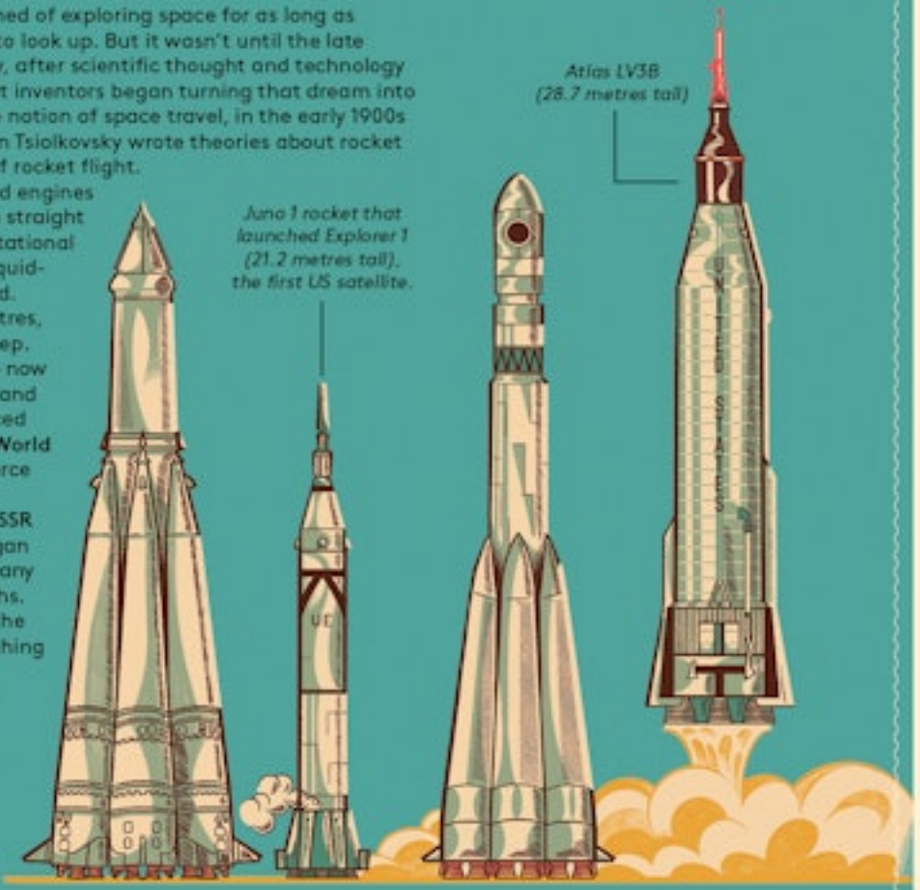
"Blasting into space"

Humans have dreamed of exploring space for as long as they've been able to look up. But it wasn't until the late nineteenth century, after scientific thought and technology had advanced enough, that inventors began turning that dream into reality. Fascinated with the notion of space travel, in the early 1900s Russian inventor Konstantin Tsiolkovsky wrote theories about rocket design and the principles of rocket flight.

Space rockets need fuel and engines powerful enough to launch straight up and out of Earth's gravitational pull, and in 1926 the first liquid-fuelled rocket was launched. Although it rose only 12 metres, it was an important first step. Rocket engine technology – now used in super-fast aircraft and uncrewed missiles – advanced hugely during the **Second World War**. The Space Race – a fierce rivalry to dominate space exploration between the USSR and the United States – began in the 1950s and spurred many technological breakthroughs. In 1957, the USSR stunned the world by successfully launching the first satellite, named *Sputnik*, into space. The United States' Juno 1 rocketed the Explorer 1 satellite into outer space a year later in 1958.

Juno 1 rocket that launched Explorer 1 (21.2 metres tall), the first US satellite.

Atlas LV3B (28.7 metres tall)



Semyorka (50 metres tall)

Vostok-K (30.84 metres tall)

Space rockets are used to launch spacecraft and satellites, which are used to study deep space and our neighbouring planets.

Saturn V (110 metres tall)

To the Moon!

America's space program is run by NASA (National Aeronautics and Space Administration). In the early 1960s, NASA's goal was to send humans to the Moon. Their Apollo program carried out countless experiments and rocket test launches until they eventually designed and built Saturn V – which is still the largest, heaviest and most-powerful space rocket ever built. Fuelled with kerosene, liquid oxygen, liquid hydrogen, and powered by five Rocketdyne J-2 engines, this rocket launched the command and service module into space on 16 July 1969. This launch carried three brave astronauts all the way to the Moon and back again.

Cultivated Meat

79

"Lab-grown meat"

Even though this burger looks just like a normal beef burger, making it did not require the death of a cow. How? It's all thanks to an amazing (and tasty) invention called '**cultivated** meat'. Developed from the late 1990s by various inventors from all over the world (including some working for NASA), **cultivated** meat is real meat that doesn't need a live animal to make it grow. The process begins by taking stem cells from a live animal such as a chicken, pig or cow. (Stem cells can create new cells of different types, such as muscle, fat or skin.) The harvested stem cells are covered in a nutrient-rich liquid containing vitamins, glucose and proteins, and are then kept inside a high-tech machine called a bioreactor. This allows the cells to grow and form muscle and fat, which makes up most of the meat we eat. Once it's finished growing, the meat can be seasoned, cooked and eaten.

*The first **cultivated** meat burger was eaten in 2013 and cost about $250,000 to produce.*

*It may become possible for scientists to **cultivate** 'fortified' meat that includes more vitamins and **minerals** for extra nutrition – like breakfast cereal.*

Clean, Safe and Cruelty-Free

To provide meat for humans to eat, livestock farming happens on a massive scale. But with this comes big problems. Animals raised for meat may be kept in poor conditions without a good quality of life. They consume huge amounts of water and feed, which uses valuable resources. Livestock farming produces around 14 per cent of all the greenhouse gases created, which contributes to global warming, and areas of rainforest are destroyed to make way for ranches. In comparison, **cultivated** meat uses far less land, water and crops. In the future, restaurants will probably provide **cultivated** meat, which might help to reduce the amount of livestock we use to feed ourselves.

3D Printing

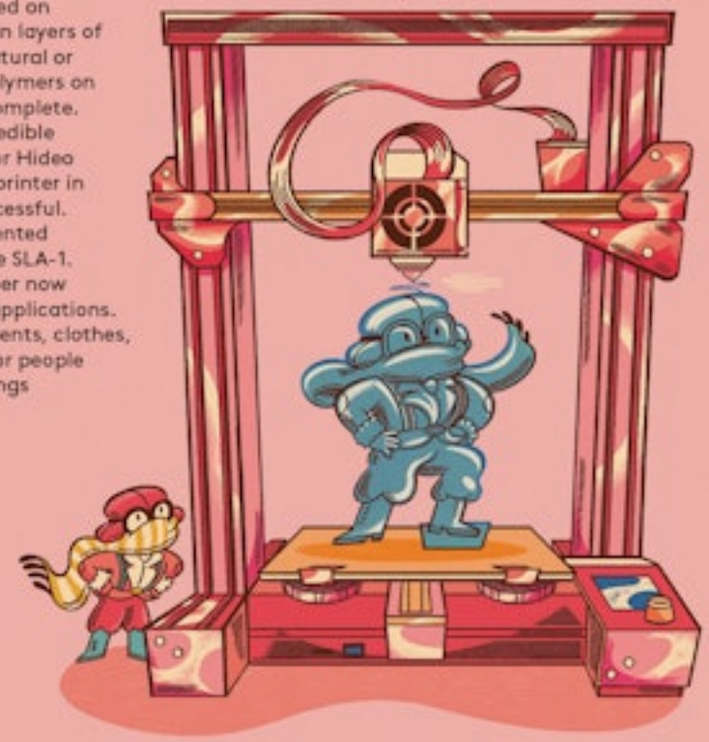
80

"Printing in three dimensions"

If you want to make a simple object, you find the right material – clay for a bowl, wood for a chair, metal for a candlestick – and then you mould, carve or hammer it into the correct shape. But now there's another, much easier way. Developed during the second half of the twentieth century, 3D printers can produce solid objects of virtually any shape and size. Using plans created on computers, 3D printers stack ultra-thin layers of resin (a material made from either natural or synthetic compounds) called photopolymers on top of each other until the object is complete. Many scientists helped make this incredible technology possible. Japanese inventor Hideo Kodama created an experimental 3D printer in 1981, but it was not commercially successful. It was American Charles Hull who invented the first popular 3D printer in 1987: the SLA-1. 3D printing technology is much cheaper now and is used in an incredible range of applications. Toys, vehicle parts, electronic components, clothes, even bones, false teeth, works of art for people who are blind, boats and entire buildings have been printed.

Some 3D printing companies can take scans of people and create exact replicas of their bodies – clothes, pose, facial expression and all!

3D printer



Inventor Kodjo Afate Gnikou from Togo has invented a 3D printer that can be made cheaply using recycled electronic scraps and rubbish from junk yards.

Lifechanging 3D Limbs

3D printing technology is getting better all the time, and it's already being used to greatly improve people's lives. Of the around 30 million people in the world who are missing one or several limbs, only about 20 per cent have a prosthetic replacement. This is because they are difficult, expensive and time-consuming to make, and must be individually tailored to the person who needs it. However, a 3D scan can quickly and accurately measure the person's stump, and a 3D printer can create the required limb – be it a hand, arm or a leg.

Glossary

ALCHEMIST
A person who tries to use a mixture of science and magic to change common metals into gold.

ALLIES
Countries that opposed the **Axis** powers during the **Second World War**, including the United Kingdom and the Commonwealth countries, the United States, the USSR, France, China and Poland.

ALTITUDE
The height of an object (e.g. an aeroplane) in relation to sea or ground level.

AMBERGRIS
A waxy substance produced in the intestines of sperm whales.

AMPHITHEATRE
An oval or round open-aired venue for sports and entertainment, with seating surrounding a central area.

AQUEDUCT
A bridge used to transport water across a valley.

ARCHAEOLOGIST
An expert in history, who often uncovers hidden artefacts and buried historic locations.

ARISTOCRAT
A member of the nobility.

ASSYRIA
Ancient Mesopotamian civilisation that existed from the 21st century BCE to the 7th century BCE, and was located in modern-day Iraq.

ASTRONOMER
A person who studies the stars and other heavenly bodies.

AXIS
Countries that opposed the **Allied** powers during the **Second World War**, including, Germany, Japan and Italy.

BACTERIA
Single cell microorganisms that can cause disease.

CARGO
Items and goods being transported by vehicles.

CARTOGRAPHER
A person who draws maps.

CENSUS
An official count or survey, often of a population.

COLD WAR
Period of hostility and espionage between the United States of America, and the USSR, that lasted from 1947-91.

COMBUSTIBLE
Something that is easily set alight.

CULTIVATE
Treating and preparing land for planting crops.

CUTTING
Human-made excavation through a hill or mountain for a road or railway to pass through.

DOMESTICATED
The act of taming and breeding animals so they can be used for useful purposes, such as ploughing fields or transportation.

FIRST WORLD WAR
An international conflict lasting from 1914-18, involving most of the European nations as well as Russia, the United States and the Middle East.

FULLING MILL
Fulling mills clean fabrics.

HEMISPHERE
One half of the Earth, either divided into northern and southern halves, or eastern and western halves.

HOLOGRAM
A 3-dimensional image created by light cast by lasers.

MACE
Type of weapon similar to a club, with a heavy metal head.

MALLEABLE
A substance that can be hammered or pressed into different shapes without breaking.

MASS PRODUCED
Items manufactured in large quantities, using automated machines.

MATZO FLATBREAD
Thin unleavened (without yeast) bread made with water and flour.

MEMBRANE
A thin layer of organic tissue or cells that creates a barrier or lining.

MINERALS
A solid, naturally occurring inorganic substance, such as rock or sand.

MINOTAUR
Beast from Greek mythology that had a man's body and a bull's head.

NEMEAN LION
Monster from Greek mythology – a giant lion with golden fur that was killed by the hero Heracles.

NOMADIC
People who move around and don't settle in one place for long.

NORSEMEN
Name of the people who lived in Scandinavia during the Middle Ages.

PATENT
Official licence recognising that a person has invented something, and has the sole right to use, manufacture and sell it.

PORTABLE
Something that is easy to carry or transport.

PREHISTORY
The historic period before humans began creating written records.

RECONNAISSANCE
Exploring or examining a place or region to gain useful information.

SECOND WORLD WAR
Global conflict that lasted from 1939-45, involving the **Allied** and **Axis** powers, which included virtually every country in the world.

THE USSR
The USSR (Union of Soviet Socialist Republic) was a country that occupied much of Eastern Europe and Northern Asia from 1922–1991. The USSR broke up into 15 separate countries including Russia, Belarus and Ukraine.

WROUGHT IRON
Type of iron that is tough, easy to shape, and resistant to corrosion and rust.